WP3| D3.3

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Work Package 3 | Deliverable 3

D3.3 Piloted, culturally adapted, teaching and learning IBSE units – Part III

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Name of Coordinator:	Dr. Eilish McLoughlin
Name of lead partner for this report:	DCU

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A. Background to this report

This report is a deliverable of Work Package 3 (WP3) of the European FP7-funded project "European Science and Technology in Action: Building Links with Industry, Schools and Home" (ESTABLISH; 244749, 2010-2013). It meets the requirements of the Deliverable 3.3 by presenting the final set of piloted, culturally adapted, teaching and learning IBSE units – Part III as developed by the beneficiaries of ESTABLISH are listed in the following table.

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B. The ESTABLISH consortium

Beneficiary short name	Beneficiary name	Country	Abbreviation
DCU	DUBLIN CITY UNIVERSITY	Ireland	IE
AGES	AG EDUCATION SERVICES	Ireland	IE
UCY	UNIVERSITY OF CYPRUS	Cyprus	CY
UmU	UMEA UNIVERSITET	Sweden	SE
JU	UNIWERSYTET JAGIELLONSKI	Poland	PL
CUNI	UNIVERZITA KARLOVA V PRAZE	Czech Republic	CZ
AL	ACROSSLIMITS LIMITED	Malta	MT
UPJS	UNIVERZITA PAVLA JOZEFA ŠAFÁRIKA V KOŠICIACH	Slovakia	SK
COUO	CARL VON OSSIETZKY UNIVERSITAET OLDENBURG	Germany	DE
UTARTU	TARTU ULIKOOL	Estonia	EE
UNIPA	UNIVERSITA DEGLI STUDI DI PALERMO	Italy	IT
MaH	MALMÖ UNIVERSITY	Sweden	SE
IPN	LEIBNIZ-INSTITUT FUER DIE PAEDAGOGIK DER NATURWISSENSCHAFTEN UND MATHEMATIK AN DER UNIVERSITAT KIEL	Germany	DE
CMA	CENTRE FOR MICROCOMPUTER APPLICATIONS	Netherlands	NL
MLU	MARTIN LUTHER UNIVERSITAET HALLE-WITTENBERG	Germany	DE
FU	MESOKELEAS LTD (FREDERICK UNIVERSITY)	Cyprus	CY

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WP3
Unit Cosmetics

European Science and Technology in Action Building Links with Industry, Schools and Home

Work Package 3

WHY MAKE HOME-MADE COSMETICS?

Teacher Information

European Science and Technology in Action: Building Links with Industry, Schools and Home

Lead partner for Unit: **University of Tartu (UTARTU)**

The initial version of this learning module has been generated through the collaborative action research by the group of following teachers: Liivi Kuusma, Mare Murs, Marika Toom, Tiina Rannar, Katrin Vaino.

The further development of the package was made by Katrin Vaino, Miia Rannikmäe, and Jack Holbrook.

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A. Teacher Information

I. Unit description

In this module, the students will explore the science behind cosmetic products (mainly that of emulsion creams): what are the main ingredients of cosmetic products, what is their effect on skin or role in the product, and how cosmetical products are developed. Furthermore, the students themselves will develop a cosmetic product. Through this unit students develop their understanding of how the structure of matter is related to the properties of matter which is needed for understanding the technology of making cosmetic products. Moreover, students develop their understanding of possible advantages and disadvantages of industrial and home-made cosmetics.

Student level: Students aged 16-19
Discipline(s) involved: Chemistry, biology
Estimated duration: 8 lessons

The cosmetics unit can be taught as an advanced course deepening the knowledge on organic chemistry, but also as part of the compulsory chemistry course under the topics of polymers and fats or, structure and properties of matter.

II. IBSE character

In this unit students are given an opportunity to develop a variety of scientific process skills including aspects related to higher order learning:

- planning an investigation, discussing procedures, search for relevant information,
- developing argumentation skills and/or making justified decisions, besides conceptual science acquisition,
- designing the product and developing tests in order to make a decision on the on the suitability of the product,
- discussing with peers.

III. Science Content Knowledge

Introduction

In order to develop a good cosmetical product, there is a number of different factors to consider: the purpose (is it meant for absorbing unpleasant smell, moisturise the skin, clean the skin from grease, nourish the skin, etc.); whether the product is meant for men or women, what is the target age group, etc.

If the purpose and target group are already defined, then a number of other consideratins must be taken into account: e. g. when the purpose is to moisturise the skin, then how to make it really moisturising, how can skin be moisturised for hours if we know that in normal conditions, water just dries off skin in less than half an hour. In additon, if the purpose is to nurture the skin, how can we garantee that all active ingredients really penetrate the skin and reach to dermis. Therefore, it becomes highly important to study the properties of skin and skin structure in order to develop a good product that would really „work" as intended. The another important question is how to mix oils with water, common consituents of almost every cosmetic cream, if they are mutually insoluble, and even if shaked well, two layers will separate soon: oil and water?

As every cosmetical product consists of tens of ingredients which must be dissolved beforehand whether in oil or water, the knowledge about principles of solubility of inorganic and organic substances is needed. There are a number of ingredients that are responsible of the „right" thichness, certain durability, pleasant odor, needed effect, etc.
Different cosmetics brands in worldwide contribute to the development of their products using the latest scientific achievements in order to improve the existing prodcuts and create totally new products to meet growing consumer demands. At the same time, probably, many of us have asked ourselves, whether these high-tech products are really better than those made by our ancestors from quite simple ingredients. Therefore, in this unit, students are invited to learn about the world of cosmetics and later given the oppotunity to develope their own products.

General principles of solubility

When a solid, liquid or gaseous solute is mixed with a solvent and it seems to disappear or become part of the solvent, we say that it has dissolved. The forces of attraction between the solute and solvent are the key to understanding their solubility. The general rule is "like dissolves like". In other words, a polar or charged solute will dissolve in another polar or charged solvent and a non polar solute will be insoluble in a polar or charged solvent. This means that ionic substances generally dissolve in polar solvents (like water) and non-polar molecules are generally soluble in non-polar solvents (like hexane).

Solubility of covalent molecules

To understand why "like dissolves like" the balance between the forces holding the solute and solvent particles together needs to be considered.

Consider a) water (solvent) and b) ethanol (solute):

Figure 1. Intermolecular forces between a) water and b) ethanol molecules

Both molecules are polar which means that some part(s) of a molecule have positive and other part(s) negative charges. Molecular polarity itself is dependent on the difference in electronegativity between atoms in a compound. In the current case (Figure 1), in both, the water and the ethanol molecul, the oxygen is charged positively and the hydrogen next to the oxygen, positively. Polar molecules interact through dipole–dipole intermolecular forces and hydrogen bonds. A **hydrogen bond** is the electromagnetic attractive interaction between polar molecules in which the hydrogen (H) is bound to a highly electronegative atom, such as nitrogen (N), oxygen (O) or fluorine (F). In the current example, the hydrogen bond exists between the positively charged hydrogen and the negatively charged oxygen and is marked by a dotted line in Figure 1. The hydrogen bond is not a true bond but an especially strong dipole-dipole force.
The force of attraction between water molecules and between ethanol molecules is weaker than the force of attraction between the combined water and ethanol molecules making ethanol soluble in water. For the dissolution process to take place, it isthe hydrogen bonds between water molecules and the hydrogen bonds between ethanol molecules that are first broken. New hydrogen bonds are then formed between water and ethanol molecules.

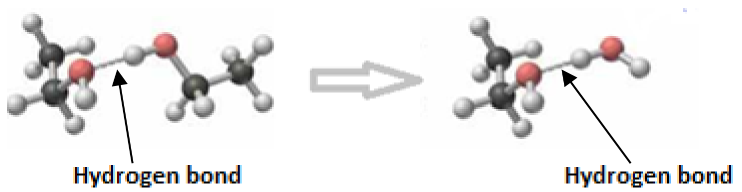


Figure 2. Hydrogen bond between ethanol molecules (left side and afterwards between ethanol and water molecules (right side)

Short chained organic molecules with a polar head tend to be soluble in polar solvents like water. However, as the length of the non polar hydrocarbon increases, the non-polar chain will eventually outweigh in size the polar „head“ and the molecule will become insoluble in polar solvents. The molecule will now dissolve in non-polar solvents. Actually, small attractive forces, called van der Waals forces, exist even between non-polar molecules as a result of temporary internal shifts in the distribution of electrons within a molecule (Figure 3). The longer the chains the stronger the force between molecules.

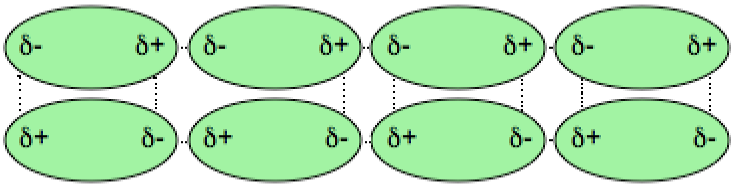
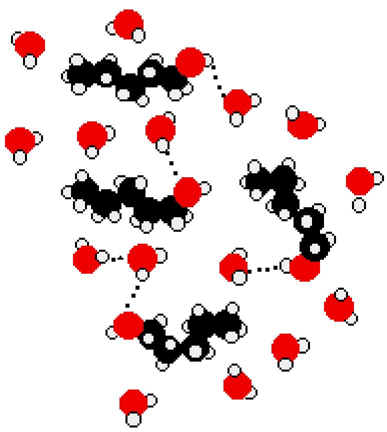


Figure 3. van der Waals forces between molecules

The longer the chains the stronger the force between molecules.
Consider the table below which shows the solubility of alcohol in a polar (water) and nonpolar (hexane) solvent. All alcohols have a characteristic polar –OH functional group attached to the hydrocarbon chain.

Table 1. Solubility of alcohols in polar and nonpolar solvents

Alcohol	Formula	Solubility in polar solvent (water) H_2O	Solubility in nonpolar solvent (hexane) C_6H_{14}
methanol	CH_3OH	soluble	
ethanol	CH_3CH_2OH	soluble	
propanol	$CH_3CH_2CH_2OH$	soluble	
butanol	$CH_3CH_2CH_2CH_2OH$	insoluble	
pentanol	$CH_3CH_2CH_2CH_2CH_2OH$	insoluble	
....	...		
octanol	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2OH$	insoluble	



Consider what happens when alcohol pentanol is mixed with water. The hydrophilic OH-end of alcohol molecules can form new hydrogen bonds with water molecules, but the non polar hydrocarbon "tail" does not form hydrogen bonds. This means that quite a lot of the original hydrogen bonds being broken are not replaced with new ones. These attractions are much weaker meaning that pentanol will not mix with water and instead forms an insoluble layer on top of the water.

Figure 4. Hydrogen bond between molecules of pentanol and water

Therefore, when a polar solute dissolves in a polar solvent, the intermolecular bonds between the solute and solvent are broken and new intermolecular bonds are formed between the solute and solvent molecules. Nonpolar solutes at the same time, dissolve in nonpolar solvents. For example, relatively nonpolar oils and fats, while insoluble in water, are very soluble in nonpolar solvents (e.g. alkanes).

Solubility of ionic compounds

If an ionic substance dissolves in water, it means that the force of attraction that polar water molecules have towards ions is greater than the force of attraction that positive and negative ions in the lattice have towards one another. The partial negative charge of the oxygen atom of water is attracted to the positive metal ions of the giant ionic lattice and the partial positive charge of the hydrogen atoms of water are attracted to the negative non-metal ions.

Not all ionic compounds are soluble in water and most can be classified as either soluble, insoluble or sparingly soluble. As a general rule, a soluble substance is one where ≥ 1g of the substance dissolves in 100g of a solvent. In the case of an insoluble solute ≤ 0.1g of a solute dissolves in 100g of a solvent. In the case of a sparingly soluble solvent, approximately 0.1-1g of a solute dissolves in 100g of a solvent.

In a chemical equation the process of NaCl dissolving in water is represented in the following way:

$$NaCl(s) + H_2O(l) = Na^+(aq) + Cl^- (aq)$$

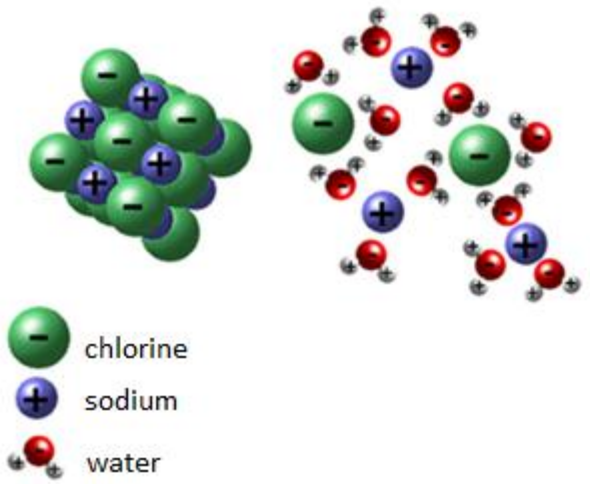


Figure 5. Process of NaCl dissolving in water

Table 2. The type and explanation of interations between solute and solvent

Solvent	Intermolecular forces between solvent molecules	Solute	Forces of attraction in solute	Solubility	Rationale
H_2O	Hydrogen bonds between solvent molecules	NaCl	Electrostatic attraction between Na^+ and Cl^- ions	Soluble	Soluble, because the force of attraction between Na+ and Cl- is weaker than the electrostatic force formed between polar water molecules and ions
H_2O	Hydrogen bonds between solvent molecules	C_6H_{14} (hexane)	van der Waals forces[1] between non-polar molecules	Insoluble	Insoluble because water molecules attract each other and hexane molecules attract each other more strongly than hexane molecules attract water molecules.
C_6H_{14} (hexane)	van der Waals forces* between non-polar molecules	C_6H_6 (benzene)	van der Waals forces between non-polar molecules	Soluble	Soluble because the attraction between non polar hexane and non polar benzene is stronger than the attraction between hexane molecules and benzene molecules.

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http://en.wikipedia.org/wiki/Solubility
http://chemicalparadigms.wikispaces.com/file/view/4.5+Solubility.pdf

The main ingredients of cosmetic creams

Cosmetic creams (lotions) are emulsions. Emulsions are dispersions where liquid substance(s) are dispersed or mixed with another liquid substance while the liquids actually do not mix microscopically. In cosmetic emulsions these are oils-fats as one part and water as the other part. This kind of a dispersion is not very persistent. Since oil drops are lighter than water, they accumulate quite quickly to the surface after shaking and form

[1] **van der Waals forces** are relatively weak electric forces that attract neutral molecules to one another in gases, in liquefied and solidified gases, and in almost all organic liquids and solids.

two separate phases: an oil phase and an aqueous phase. Therefore, emulsifiers are used to make the emulsion more persistent.

Oils and fats

Oils and fats are composed of basically non-polar molecules (prevailingly C-C and C-H bonds) and are thus hydrophobic. Fats and oils are used to add to the lipid[2] layer on the skin. The lipid layer on the skin functions mainly as a barrier to protect the skin from the outside influences. It reduces the fluid loss from epidermis by forming a thin film on the skin. It also fills the microscopic unevennesses and by that it makes the skin smoother and softer and reduces smaller wrinkles. Oils and fats with a low melting point are easily smeared onto the skin, whereas substances like wax that have a higher melting point can be quite solid; this, however, is useful in the case of lipsticks.

(a) Natural oils and fats

Herbal and animal oils and fats are triglycerides (esters[3]) that are formed of three fatty acid (usually composed of 16 or 18 carbon atoms) and one glycerine (alcohol) molecule. They are almost non-polar and hydrophobic substances. Natural oils and fats are never pure substances, rather they are a complex mixture of triglycerides and various additives.

When fatty acid residues in the fat molecule consist of double-bonded carbon atoms, they are called unsaturated fatty acids; when there is a single bond between carbon atoms then they are called saturated fatty acids. Fats composed of unsaturated fatty acid residues are more liquid-like than these composed of saturated fatty acid residues and are thus more appropriate to be used in a cream; at the same time it makes the fats more open to being oxidised by oxygen from the air. The latter process is called rancidification. As a result of rancidification, the smell, taste and/or the appearance of fats changes. In figure 2, one can see that the molecule is composed of two saturated and one unsaturated fatty acid residues.

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[2] **Lipids** are biolmolecules with an ester-like structure. They are composed of at least two components: an alcohol and a fatty acid. Fats, oils, waxes, steroids and other water-insoluble compounds are lipids.

[3] **Esters** are formed as a result of a reaction between a carboxylicacid and an alcohol. The general formula is R-COO-R'

$$R\text{-}COOH + R'OH \rightleftharpoons RCOOR' + H_2O$$

Glycerol Residue

Fatty acid residues

Figure 6. The structure of fats

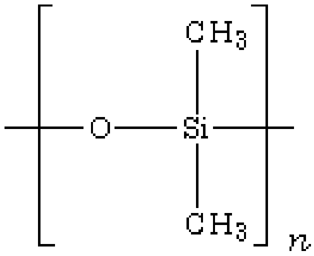
(b) Synthetic fats and oils

Synthetic fats and oils are much more tolerant to oxygen from the air since they do not contain multiple bonds like herbal fats/oils. However they do not break into essential fatty acids like natural fats. Hydrocarbons (paraffin, vaseline and other petroleum products) and silicones form an impermeable film on the skin and reduce the skin`s natural resilience when used for a long time.

- **Vaseline and mineral oils** (*paraffinum liquidum, petrolatum, petroleum jelly)* – petroleum products; mixture of hydrocarbons, mainly that of alkanes, where the number of carbon atoms in the molecule is usually > 25. Vaseline and mineral oils soften the skin and dissolve other hydrophobic substances. They are often used in hand creams, but mainly still in cheaper products.

  $H(-CH_2-)_nH$

- **Silicones** are polymers consisting of silicon. Dimethicone is one example of a silicone. It forms an extremely efficient water-repellent film on the surface of skin or hair. Silicones are used a lot in hair care products.



Polydimethylsiloxane (PDMS) or dimethicone.

Emulsifiers

Emulsifiers are used in creams and other emulsions in order to mix two phases that do not mix: the oil phase and the aqueous phase. This makes the system more persistent.
The typical emulsifier molecule is rather bulky and mostly non-polar making it hydrophobic and dissolvable in fat (directed towards the oil phase). The polar and hydrophilic end is directed towards the aquous phase.

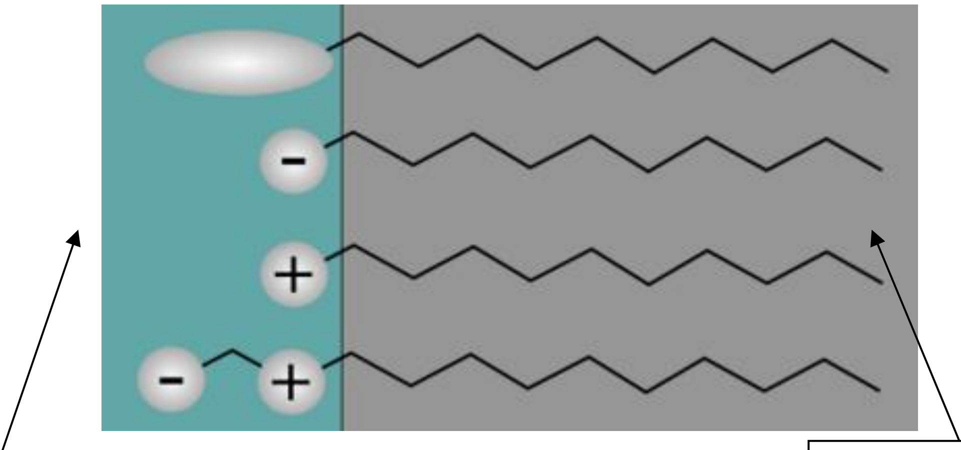


Figure 3: Comparison of different types of emulsifiers

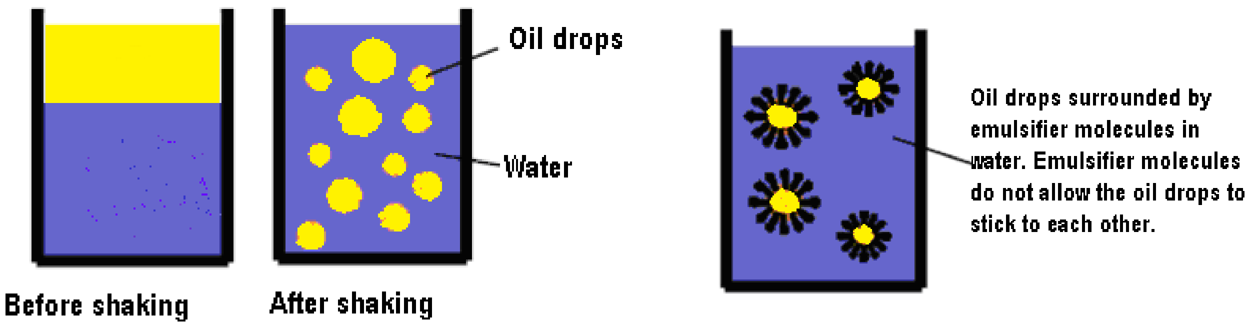
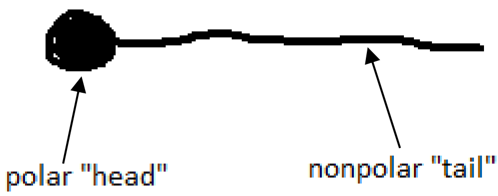


Figure 4. Emulsion without emulsifier (left) and emulsion with emulsifier (right)
(Source: http://www.makingcosmetics.com/articles/02-making-emulsions-for-cosmetics.pdf)

There are 2 types of emulsifiers (Figure 5): oil in water (o/w) and water in oil (w/o). Night creams and sunscreens are often w/o- type of emulsions that are quite greasy. Body lotions and day creams are o/w-type of emulsions that are lighter and moisturise better.



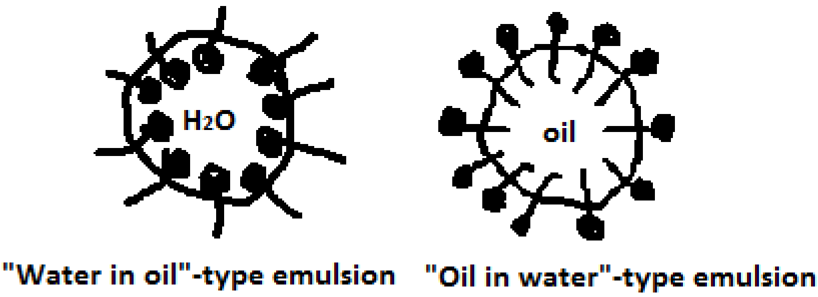


Figure 5. A comparison between water in oil and oil in water type of emulsions

Skin

Skin is very important as it covers and protects everything inside your body. Skin holds everything together. It also protects our body, helps keep it at just the right temperature and, through nerve endings close to the surface of the skin, allows us to have the sense of touch.

However skin can become infected with bacteria, viruses and fungi, and can be irritated by chemicals or other substances it is in contact with. Skin is also exposed to sunlight, and can suffer as a result.

Skin is composed of two parts (see Figure 6) – dermis and epidermis. The upper most layer of epidermis is called *stratum corneum*. Stratum corneum is made up of keratinuous dead cells. This is the part of skin and body that is peeled off daily. New skin cells are formed in the lower, e.g. basal layer, which is always forming new cells through cell division. The new cells gradually move towards the surface, which takes 1-2 months. As they move up they gradually die, become flattened and develop keratin and the outermost layer of flat dead cells is being continually worn away by friction. The keratin and oil from the sebaceous glands help to make the skin waterproof. Keratin is the substance that hair, nails and horns are made of. The thickness of stratum corneum can easily be measured in cell layers — it is the thickest under the heels, some people have more than 100 cell layers. The thinnest stratum corneum covers the genital organs, for example the penis has only 6 cell layers.

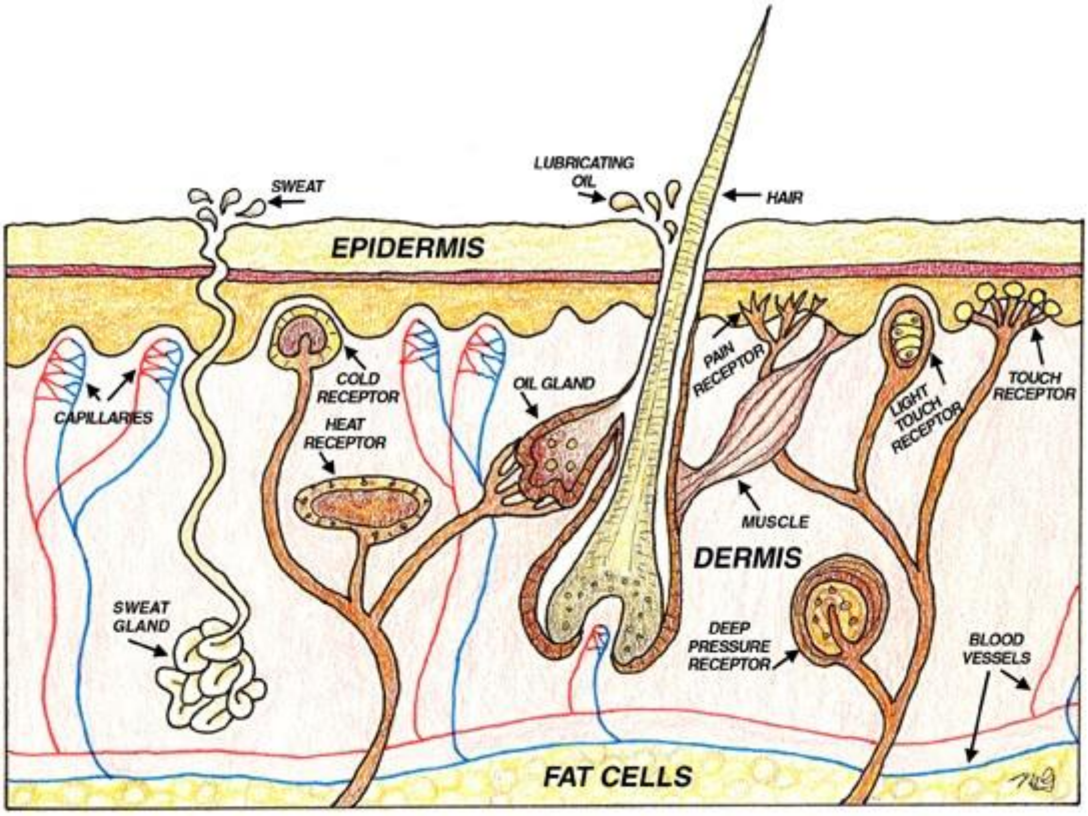


Figure 6: The cross-section of skin (Source: http://www.infovisual.info/03/036_en.html)

The **dermis** is the inner layer. The following tissues and structures can all be found in the dermis:

Connective tissue – packs and binds the other structures in the skin.
Elastic fibres – make the skin resilient.
Capillaries – tiny blood vessels.
Muscle fibres – to move the position of the hairs.
Sensory cells – to sense touch, pressure, heat, cold and pain.
Nerve fibres – to activate muscles and glands and relay messages from the sensory cells to the brain.
Pigment cells which produce melanin, a very dark pigment.
Sweat glands which open onto the surface as pores
Hair follicles – pits in the epidermis in which hairs grow.
Sebaceous glands – produce oil to keep hair follicle free from dust and bacteria, and to help the skin become more waterproof.

There is a layer of fat underneath and in the lower regions of the dermis. The thickness of this layer varies depending on the part of the body and from person to person. A store of fat is useful to the body as insulation and it can be used for energy when the intake of nutrients is insufficient.

Skin has many functions:

- Control of body temperature
- Stops infection
- Acts as a waterproof barrier
- Protects delicate tissues underneath
- Heals itself when damaged

Temperature control

Body temperature is normally 37ºC regardless of the temperature of the surroundings. It is controlled by a feedback system, that is, information about the temperature of the body, for example from the temperature sensitive receptors in the skin, is fed back to the hypothalamus, the temperature-regulating centre of the brain. The brain then sends messages to parts of the body, including the skin, to keep heat in or to lose excess heat.

Other feedback systems are used in controlling the amount of glucose and water in the blood.

Keeping temperature, glucose and water at the right levels is known as homeostasis and is important for the chemical processes of the body to work properly.

A waterproof coat

Keratin in the epidermis and oil produced by the sebaceous glands help to make our skin waterproof. This means we do not go soggy in the bath or dry up in the sun.

Stopping infection

Millions of microorganisms live harmlessly on the skin and in the air around us. The skin forms a very effective barrier to stop them entering the body unless damaged, when infections can occur.

Skin colour

Melanin is a pigment that gives skin a colour from pink through brown to black. People are different colours because their skin contains different amounts of melanin. Melanin protects skin from ultra-violet (UV) radiation. When skin is exposed to the sun, more melanin is produced and the skin darkens. An albino person has skin which contains no melanin. Therefore they have no natural protection from UV rays. Their skin must be covered up in sunlight.

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http://courses.washington.edu/bioen327/Labs/Lit_SkinStruct_Bensouillah_Ch01.pdf
http://www.abpischools.org.uk/page/modules/skin/.cfm?coSiteNavigation_allTopic=1

IV. Pedagogical Content Knowledge

The most difficult part for students will probably be the understanding the relationship between the structure of matter and the properties of matter: what makes a molecule hydrophobic or hydrophilic; how to choose the right solvent for a particular substance, etc. The task for a teacher is to develop students' understanding that (1) there is a quite sophisticated science behind cosmetics, (2) science knowledge can contribute to the production of better products, and (3) there are always a number of pros and cons of industrial as well as home-made cosmetics.

Overall aims/competencies: The students are expected to be able to:

1. Propose ideas as to why we should make cosmetic products ourselves and what are related pros and cons.
2. Search for relevant information from the Internet and library resources.
3. Critically analyse the ingredients of cosmetic products and make decisions about their quality.
4. Understand the general principles behind the ingredients of cosmetic (emulsion) creams; based on his/her scientific knowledge be able to explain what role the ingredients play in the cream and explain their effect on the skin.
5. Make an emulsion cream from simple ingredients on their own
6. Work as a team in looking for information, analysing, planning the experiment and presenting the product
7. Present the product to others in a persuasive manner
8. Use the correct terminology related to the topic both orally as well as in written format.
9. Use creative thinking in designing the product, the commercial, and making up tests in order to be able to answer whether a self-made product is usable
10. Be aware of the careers related to cosmetics industry

The learning content as defined by the syllabus: Hydrophobic and hydrophilic substances, chemical bond, polar and non-polar substances, principles of solubility, emulsion, emulsifier, fats, the structure and functions of skin.

The types of activities: Searching for information from various sources, analysing the ingredients of cosmetic products, designing the product (from idea to implementation and marketing), producing a commercial and presenting it to the class, testing the properties of a product against determined criteria, making a decision on the suitability of the self-made product in place of analogous commercial products.

V. Industrial Content Knowledge

Cosmetic industry

The cosmetic industry is currently dominated by a small number of multinational corporations that originated in the early 20th century, but the distribution and sale of cosmetics is spread among a wide range of different businesses. The world's largest cosmetic companies are The L'Oréal Group, The Procter & Gamble Company, Unilever, Shiseido Company, Limited and Estée Lauder Companies, Inc.

The cosmetic industry worldwide seems to be continuously developing, now more than ever with the advent of the Internet companies. Many famous companies sell their cosmetic products online also in countries in which they do not have representatives.

Besides well-known international companies, there is a growing trend in the World, to produce almost hand-made cosmetics with limited production using natural or almost natural raw materials and cosmetics manufactured in a way that is environmental-friendly. For consumers of this type of production it is important that they can buy good, unique and well-produced products, not available from mass market retailers. Each manufacturer brings their own design and creativity to their products. Sometimes, hand-made goods of a company become so popular that they outgrow from a small enterprise and become a well known brand.

One such example is the UK's company "Lush", which was established in 1994 by Mark and Mo Constantine[4]. There are now 830 stores in 51 countries. Lush produces and sells a variety of handmade products, including soaps, shower gels, shampoos and hair conditioners, bath bombs, bubble bars, hand and body lotions and face masks.

Lush products are made in factories around the world (including Poole, Dorset and Vancouver, Canada), and are made in small batches based on orders from individual stores to ensure the freshness of the product. Stores do not sell products older than four months and most products have a total shelf life of approximately 14 months.

Lush products are 100% vegetarian, 83% vegan, and 60% preservative-free and feature grapefruit juice, vanilla beans, avocado butter, rosemary oil, and fresh papaya and coconut, etc. Typically, these products are free from packaging. Lush does not buy from companies that carry out, fund, or commission any animal testing. Lush tests its products on human volunteers before they are sold. Their aim is to have 100% of their packaging easily recyclable, compostable or biodegradable. Although there exist many opponents because of their radical political actions related to animal rights, etc., their products are continually popular among consumers.

The other, Estonian success story about a small factory the hand-made products of which quickly became popular amongst consumers, is about JOIK. Their[5] story of success began in 2005, when company founder Eva-Maria Õunapuu was searching for high-quality scented candles that she could burn during dark and cold autumn and winter evenings. However, finding suitable candles turned out to be harder than expected.

She did not want to burn petroleum-based paraffin candles and was constantly disappointed in the aromas of scented candles. The solution was to get into the exciting

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[4] The following text is adapted from http://en.wikipedia.org/wiki/Lush_%28company%29
[5] The following text is adapted from http://www.joik.eu/our-story/the-company/

world of scented candles herself and thereby learn to make high-quality, clean-burning candles that are true to the promised aroma.

She discovered that a suitable alternative to paraffin was natural soy wax. The next step then was to find the desired aromas. The process of getting the candles exactly right was long and full of nuances. However, it was worth the effort and eventually the candels turned out so good that other peole also developed an interst for them. Therefore, the idea to start selling candles was born.

Step by step the hobby turned into a business and a successful company grew out of it. Over the years natural cosmetics products were added to the line, starting with soaps, body oils and bodycreams, bath products. Later a hand and foot care as well as a facial range were added. The most important aspect of JOIK products has always been the high-quality ingredients that are as natural as possible. A long process of research and testing precedes the launch of all new JOIK products – all for the satisfaction of their clients.

Thanks to hard work JOIK is now the most successful Estonian natural cosmetics brand. JOIK products are sold in stores all over the country, but also in Europe and in Asia.

Careers related to cosmetic industry

Different types of jobs in the cosmetics industry include production, research, testing, sales and application. Like any industry, there are also a number of management positions. Various career paths in the cosmetics industry more related to science, are introduced below.

Scientists in the cosmetic industry[6]

There are literally thousands of scientists working in the cosmetics industry and the number of jobs continues to grow. This is an industry that continues to sell products even in uncertain economic times. There are various types of companies that employ cosmetic scientists and chemists. These include manufacturers of finished goods, contract manufactures, raw material suppliers, and testing laboratories. The most common degree required of a cosmetic scientist is a bachelors' degree in Chemistry, Chemical Engineering, Biology or Microbiology, and to a lesser extent a degree in Physics; bigger companies like Procter & Gamble or L'Oreal tend to favour students who have a Masters or a PhD degree in cosmetic science.

A person looking to work as a scientist in the cosmetic industry, has a wide range of jobs to choose from:

a. **Cosmetic Formulator** – If one likes inventing and creating (e.g. the newest lipstick formula, or a biodegradable nail polish), the position of a formulator is probably the best

[6] Adapted from http://chemistscorner.com/how-to-become-a-cosmetic-chemist/

choice. Most of these jobs are with finished goods and contract manufacturers[7]. Some raw material suppliers employ formulators in their technical services departments.

b. **Quality Control Chemist –** This position is ideal for someone who likes gas chromatography, infra-red spectroscopy, and mass spectrometry. Every company in the industry hires this type of scientists.

c. **Analytical Services** – This area of work is closest in the industry to scientific research. Most raw material suppliers and finished goods manufacturers have analytical departments.

d. **Process Engineering -** This profession involves work very similar to building things and engineering. Almost any cosmetics company with manufacturing facilities will hire PE scientists.

e. **Synthesis Chemist** – For those who love organic chemistry, raw material synthesis is an appropriate career choice. Most of these jobs will be with raw material suppliers.

f. **Regulatory Scientists** – For people who like science but do not like to be in the lab, working as a regulatory scientist is a suitable alternative. Nearly all companies hire regulatory scientists and even more jobs are being added, because more governmental regulations make it more complicated to create innovative cosmetics.

g. **Marketing (sales)** – A career in marketing is suitable for somebody who likes communicating to peole and at the same time wants to work with cosmetics in the cosmetics industry. Professionals in cosmetics marketing manage research focus groups, promote the desired brand image, and provide other marketing services (sales forecasting, allocation to different retailers, etc.).

References

http://en.wikipedia.org/wiki/Cosmetics#Cosmetic_careers
http://en.wikipedia.org/wiki/Prosthetic_makeup
http://chemistscorner.com/how-to-become-a-cosmetic-chemist/

The main ingredients of cosmetic creams

As manufacturers have to present the ingredients of a cosmetic product according to the requirements of INCI (International Nomenclature for Cosmetic Ingredients), the ingredients' names below are given according to INCI (in latin). This will also be helpful in looking for information from the internet. The list of ingredients on the package of the product must be presented in the order of decreasing content percentage.

[7] A contract manufacturer is a type of manufacturing business that specializes in producing goods for a client, based on specific criteria that is provided by that client.

Most often used natural fats and oils in cosmetic products

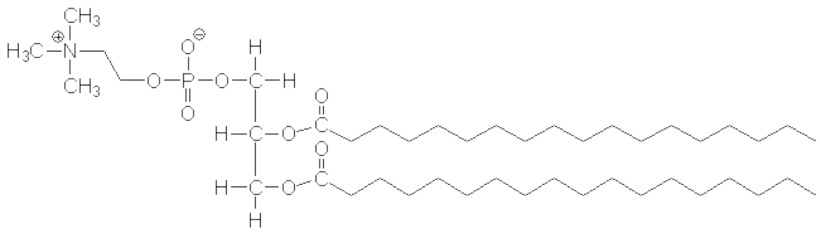
- **Cocoa butter** – a liniment with a balmy chocolate smell, heals, moistens and softens (rough, dry) skin and is thus recommended to be used for smoothing scars, spots and other skin defects and treat sunburn. It has an anti-wrinkle effect and makes the skin more elastic. Cocoa butter is a natural cream thickner that stabilizes an emulsion. Creams usually contain 3-6% and balsams 6-60% of cocoa butter.
- **Grapefruit seed oil** – it is known as a natural preservative and is sometimes added to the soap mixture in cold process soap making. Since it contains antioxidants, it is an antibacterial oil and is suitable for problematic and sensitive skin. Because it contains a lot of vitamine C, it is good for making creams (inc. anti-acne), lotions and serums.
- **Coconut oil** – coconut oil is one of the basic ingredients of soap and cream. It adds firmness (strenght) to soap and makes it foam nicely as well as softens and smoothens skin. It is used in making creams, emulsions, soaps and shampoos, and in ointments, baby care products, protection creams and bath oils.
- **Shea butter** – shea butter is good for skincare; it is moisturizing, smoothening, anti-ageing and anti-inflammatory; it has a calming effect, treats microwounds; to some extentprotects against UV-radiation. It is added to emulsions, creams, sunscreens and after-sun lotions, moisturizing creams, body liniments and to ointments in the range of 3 to 100%.
- **Sweet almond oil** – it is one of the most popular oils for making cosmetics. It is squeezed from the fruit cores of the almond tree. It is suitable for dry and sensitive skin, has a wonderful skin moisturizing and smoothening effect, vitalizes and absorbs well into the skin, treats well chapped skin. It is added to creams, emulsions, ointments, bath oils and baby care products.
- **Rasberry seed oil** – cold-pressed rasberry seed oil contains a lot of E- and A-vitamins that make the oil a wonderful skin care product. It protects the skin from free radicals and offers protection from sun radiation. Because of this, the oil is used in eye creams, lip balms and face creams.
- **Castor oil –** castor oil has a diverse skin softening and smoothening effect. It is used in creams, emulisons, hair care products, bath oils, sunscreens, lip balms and lip balsams.
- **Avocado oil –** this oil contains A, B_1, B_2, D ja E vitamins. It has a healing effect on skin diseases such as psoriasis and eczema. It is a natural sunscreen and contains natural antioxidants. It is used in creams, emulsions, body liniments inc. lip liniments (lip balm), products usually contain 4-20% of avocado oil.
- **Olive oil** – olive oil moisturizes the skin, increases its elasticity, reduces signs of aging and rejuvenates skin. It can be used by itself or in mixture with other luxury oils to make a perfect face serum.
- **Grape seed oil –** this oil absorbs well and is slightly astringent; it is a non-greasy softener with a tonic effect. Because of these characteristics the oil works best for problematic and impure skin. It can be added in the amount of 1-100% to creams tonics, massage oils and bath oils.
- **Rose hip seed oil –** it is a wonderful softener and moisturizer, helps treat surgical wounds, burns, eczema, reduces wrinkles and is ideal for stressed skin. In an undiluted

form it is used as a massage oil. In creams, emulsions, bath oils, tanning and baby care products it is used in the range of 1-100%

Emulsifiers

(a) Water/in oil type of emulsifiers

- **Lecitine** – it is added to the oil phase before mixing. Used in creams, ointments, body gels, shampoos, sunscreens, body liniments and decorative cosmetics.

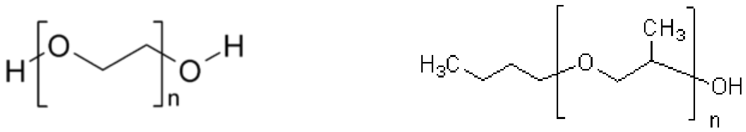


- **Egg yolk**
- **Sorbitan monostearate**
- **Triglyceryl monooleate**

(b) **Oil/ in water type of emulsifiers**

- **Stearic acid –** emulsifies and thickens, gives the skin a slightly waxy feel and a shiny and cooling effect. It is usually added in the range of 2-10%. Extensively used in soaps, creams, emulsions, in protection and shaving creams and other skincare products.

- **Polyethylene glycols (PEG) and polypropyleneglycols (PPG)**



They can act both as emulsifiers and as fat-like substances. The number behind the abbreviation represents the number of elementary links in the molecule. For example, PEG-40.

- **Polysorbate**
- **Cetearyl alcohol –** contains molecules consisting of 8-22 carbon atoms. Makes up 1-5 % of the total mass of a cream. It is added to both w/o as well as to o/w type of emulsions

Octane-1-ol

Waxes

Waxes are complex mixtures of alcohols, fatty acids and esters[2]. They are harder, less greasy and highly resistant to humidity, oxidation and microbiotic degradation. Waxes are very useful ingredients in cosmetic products due to their protective, softening and thickening properties as well as for the fact that they form a film. They increase the persistence and viscosity of cosmetic products and make them more even.

- **Bee wax** – non-congealing thickener, emulsifier, forms a film, slightly anti-bacterial, softens the skin. Melted by heating to a temperature of 61-68 ^{o}C. Products can contain 2-40% of bee wax. Used in creams, emulsions, pomades, liniments, lipsticks, mascaras, eye shadows, ointments, protective creams.
- **Carnauba wax**
- **Candelilla wax etc.**

Thickeners and constituents of the base

Fats and fat-like substances as well as emulsifiers already act as thickeners. Nevertheless, special thickeners can be added—usually polymers, eg. carbomers, corn starch, modified starch, xanthan gum, cellulose gum etc. Some salts such as calcium chloride, sodium chloride and magnesium sulphate also have a thickening effect.

Sunscreens

UV- light is essential for humans since it creates vitamin D that helps develop bones. Melamine in the skin might not protect the skin enough from harmful UV-radiation. Sunscreens either reflect or absorb UV-radiation. Substances that reflect radiation are for example (powdered):

- TiO_2 – titanium dioxide
- ZnO – zinc oxide

Humectants

Humectants are important ingredients of cosmetic products that help avoid and maintain the moisture loss of the skin. Strateum corneum can protect the skin efficiently only when it contains enough water. Skin becomes dry and develops cracks when the water level decreases. Microbes can enter via the cracks and the dryness of skin causes itching. The moisture content of skin can decrease when a person is smoking or due to dry air and of course when the skin ages. The natural humectants between two skin cells are amino acids and sugars. The main characteristic of a humectant is the ability to strongly bind water (via hydrogen bonds). Humectants are not only added to skin care products but also to hair care products, to add volume to hair. This group includes a number of proteins, acids, polysaccharides and some smaller molecules: polyhydroxyl alcohols such as glycerin, hexane-1,2,3,4,5,6-hexaol (sorbitol), propylene clycol, but also urea and amino acids such as aloe vera juice.

Preservatives

Cosmetics are a good surface for bacteria, viruses and fungi since the products contain water, oils, peptides and sugars. Because of this, various cosmetic products require preservatives or have a short life span.

- **Grapefruit seed oil** – (look at previous pages). This can be added to warm or cold mixtures before adding the odour. Products usuallycontain 0.5-1% of the oil (2-3% in the case of more complex mixtures). It is not enough for long term preservation and is thus combined with different parabens.

- **Potassium sorbate, sodium sorbate**

- **Sodium bensoate**

- **Parabens –** commonly found in cosmetic products from stores. They are absorbed easily and fast through the skin and get into the blood circulation within tens of minutes after use. Studies have shown that they mimic the body`s own hormones and can thus interfere with the endocrine systems. The best known parabens are methylparaben and ethylparaben.

Antioxidants

Antioxidants are active components of cosmetic products. Generally they help stop oxidation reactions and bind free radicals (eg. peroxides). Both of these processes ruin the functions and integrity of natural substances. Antioxidants are useful in two ways: they prevent the degradation of natural ingredients (proteins, carbohydrates, fats) in a cosmetic product; and at the same time they protect the skin cells and slow down aging-related processes. Antioxidants have become useful substances that help make the skin more shiny and decrease signs of aging.

- **Vitamin E** (tocopherol) and its derivatives – besides having an antioxidant effect they also moisturize, are anti-aging, repair the skin relief, soften and are anti-inflammatory. They also stimulate the growth of skin cells and the activeness of enzymes. They are added in the range of 0.5-2.5% to have an effect on the skin and in the range of 0.1-0.5% to stabilize the fat- and oil-containing product. Used in various skin and hair care products. Added to the oil phase.
- **Vitamin C** (L-ascorbic acid) and its derivatives – besides having an antioxidant effect it is also anti-aging: it repairs skin elasticity and stimulates the formation of collagen, avoids over-pigmentation, is anti-inflammatory. Added to the aquous phase, usual content of 0.2- 4%. Used in emulsions, creams, post-tanning products etc.
- **Vitamin A** – promotes skin regeneration. Promotes epithelium and keratin formation, anti-wrinkle properties. It is useful to freeze it in order to preserve it. Should be put into a warm-water bath to melt and add to the product as the final

ingredient. Average amount of 10 drops per 100g of cream. Used in all sorts of skin care products, especially in nutritive and sunburn creams.

Skin peeling agents

Skin peeling agents work in two ways: via mechanically and chemically removing dead skin cells. Various herbal flours, but also sugar and salt crystals are mechanical peelers. Weak acids such as lactic acid, citric acid and malic acid are chemical peelers and they dissolve the space between two cells—this causes the release of the cells on top. As a result of the peeling, the skin becomes more shiny and the effect of other cosmetic products increases as they can get deeper into the skin. The top layer of skin recovers very quickly.

Alpha hydroxy acids (AHA's)
AHA's most commonly used in cosmetic applications are typically derived from food products including glycolic acid (from sugar cane), lactic acid (from sour milk), malic acid (from apples), citric acid (from citrus fruits) and tartaric acid (from grape wine). For any topical compound to be effective, including AHA, it must penetrate into the skin where it can act on living cells. Bioavailability (influenced primarily by small molecular size) is an important factor in a compound's ability to penetrate the top layer of the skin. Glycolic acid, having the smallest molecular size, is the AHA with greatest bioavailability and penetrates the skin most easily; this largely accounts for the popularity of this product in cosmetic applications.They have a peeling effect, keratolytic effect, added in the range of 5-15% to the aqueous phase.

Odours

Nowadays most loitions contain odours. The purpose of those added odours is to make the product more attractive, while at the same time they might also be used to conceal the smell of the original components, which might not be so pleasant. Odours can be natural as well as synthetic. The best known natural odours are essential oils, which constitute complex mixtures of compounds. The best known synthetic odours are geraniol, citronellol, citral and others, which simulate natural odours.

Other components

- **Citric acid** – acidity regulator, gelatine formation, neutralizes certain minerals in order to increase the efficacy of antioxidants and preservatives, has buffer capacity (helps maintain a pH between 2.5 to 6.5), higher concentration has exfoliating properties (like with AHA acids), moisturizes, exfoliates, softens, has an anti-wrinkle effect. The safe use of citric acid should not exceed 10% and not be at a lower pH value than 3.5. Citric acid is added to creams, shampoos, shower gels, bath perls (along with sodium carbonate).
- **Salicylic acid** – proven anti-acne effect due to its anti-septic properties, very effective keratolytic effect (exfoliating effect extends to the pores of the skin). Used

in exfoliators, anti-dandruff products, anti-psoriasis products and in products meant for problematic skin: for acne – 0.5-3%; for dandruff – 1-3%, for warts – 5-25%. Products containing salicylic acid may smell on the skin. When salicylic acid is attempted to be used together with other exfoliators such as benzoyl peroxide, recorcinol or soaps and other cometics products that dry your skin one must be aware of an excessive exfoliating effect.

- **Aloe Vera** juice (extract, gel) – moisturizes, rejuvenates, heels, penetrates easily through the skin while stimulating the blood circulation and the immune system, increases the elasticity of the skin and stimulates collagen synthesis, found in various products.
- **Allantoin** – heels (sun) burns, abrasions, works well for chapped skin, leaves a soft and dry feeling (for example in the case of an incubated diaper), usually added to an aqueous base in the amount of 0.2 - 2%. Added to a great variety of products.

Resources

- http://www.makeyourcosmetics.com

a comprohensive page where a lot of different information can be found: recipes, components, the content of the components, effect etc.

- http://www.naturalnews.com/022113.html

the effect of parabens

- http://lifestyle.blogtells.com/2009/03/17/home-made-skin-creams-and-ointments recipes/

home-made creams

- http://www.vitaminstuff.com

a lot of information about vitamins

- http://www.essentialwholesale.com

here one can buy substances, but it also gives information about the ingredients and their effect

- http://www.makingcosmetics.com

articles about cosmetics and a whole book about the ingredients of cosmetic products, the effect and how much and where to add something

- http://www.joik.ee/?section=et/2033&class=shop_order_center&action=show_items &id=203

ideas to experiment with different mixtures

- http://allnaturalbeauty.us/emulsions.htm

a lot of information about emulsifiers

The list of labels that may or may not be taken into account before buying a product or ingredients to make ones own cosmetics

- **No animal ingredients (100% vegetarian ingredients or Vegan)**
- **No animal testing (also known as Cruelty free products)**
- **No artificial colors, sweeteners or flavours**
- **Containers are recyclable**

- **Fair trade**

Fair trade is an organised social movement that aims to help producers in developing countries to make better trading conditions and promote sustainability. The movement known as fairtrade indicating the certification advocates the payment of a higher price to exporters as well as higher social and environmental standards.

- **Certified organic ingredients**

Organic certification is a certification process for producers of organic food and other organic agricultural products. In general, any business directly involved in food production can be certified, including seed suppliers, farmers, [food] processors, retailers and restaurants.

Requirements vary from country to country, and generally involve a set of production standards for growing, storage, processing, packaging and shipping that include:

- no human sewage sludge fertilizer used in cultivation of plants or feed of animals
- avoidance of synthetic chemical inputs (e.g. fertilizer, pesticides, antibiotics, food additives, etc.), genetically modified organisms, irradiation, and the use of sewage sludge;
- use of farmland that has been free from prohibited synthetic chemicals for a number of years (often, three or more);
- keeping detailed written production and sales records (audit trail);
- maintaining strict physical separation of organic products from non-certified products;
- undergoing periodic on-site inspections.

- **Biodegradable**

Biodegradation or biotic degradation or biotic decomposition is the chemical dissolution of materials by bacteria or other biological means. Biodegradable simply means to be consumed by microorganisms and return to compounds found in nature. The term is often used in relation to ecology, waste management, biomedicine, and the natural environment (bioremediation) and is now commonly associated with environmentally friendly products that are capable of decomposing back into natural elements. Organic material can be degraded aerobically with oxygen, or anaerobically, without oxygen. Biosurfactant, an extracellular surfactant secreted by microorganisms, enhances the biodegradation process.Biodegradable matter is generally organic material such as plant and animal matter and other substances originating from living organisms, or artificial materials that are similar enough to plant and animal matter to be put to use by microorganisms.

References

Diaz, E. (editor). (2008). *Microbial Biodegradation: Genomics and Molecular Biology* (1st ed.). Caister Academic Press. ISBN 1-904455-17-4.

Measuring Biodegradability", *The University of Waikato*, June 19, 2008

Agamuthu, P. Biodegradability and Degradability of Plastic Waste, *International Solid Waste Association*, November 9, 2004.

- **Paraben free**

Parabens are a class of chemicals widely used as preservatives by cosmetic and pharmaceutical industries. Parabens are effective preservatives in many types of formulas.

These compounds, and their salts, are used primarily for their bactericidal and fungicidal properties. They can be found in shampoos, commercial moisturizers, shaving gels, personal lubricants, topical/parenteral pharmaceuticals, spray tanning solution, makeup, and toothpaste. They are also used as food additives. They are becoming increasingly controversial, however, because they have been found in breast cancer tumors (an average of 20 nanograms/g of tissue).[3] Parabens have also displayed the ability to slightly mimic estrogen (a hormone known to play a role in the development of breast cancer). No effective direct links between parabens and cancer have been established, however. Another concern is that the estrogen-mimic aspect of parabens may be a factor in the increasing prevalence of early puberty in girls. Most known parabens are methylparaben and ethylparaben.

- **Mineral oil free (Petroleum free)**

A mineral oil is any of various colourless, odorless, light mixtures of alkanes in the C15 to C40 range from a non-vegetable (mineral) source, particularly a distillate of petroleum.The name *mineral oil* by itself is imprecise, having been used to label many specific oils over the past few centuries. Other names, similarly imprecise, include white oil, liquid paraffin, and liquid petroleum. Most often, mineral oil is a liquid by-product of the distillation of petroleum to produce gasoline and other petroleum-based products from crude oil. A mineral oil in this sense is a transparent, colorless oil composed mainly of alkanes [2] and cyclic paraffins, related to petroleum jelly (also known as "white petrolatum").

One of the common concerns regarding the use of mineral oil is its presence on several lists of comedogenic substances. These lists of comedogenic substances were developed many years ago and are frequently quoted in the dermatological literature. At the same time it is reported that highly refined and purified mineral oil found in cosmetic and skincare products is noncomedogenic (does not clog pores).

Ressources

DiNardo, J. C. (2005), Is mineral oil comedogenic? Journal of Cosmetic Dermatology, 4, 2–3.

- **Free of chemical preservatives**

The meaning of such a label is that the product is made without synthetic preservatives. Due to controversy surrounding the use of synthetic preservatives in food and cosmetics, some companies are turning to other options to help extend products' shelf life. Some are switching from synthetic to natural. Unfortunately all natural preservatives may not be as good as they sound, especially if taken in excess. But on a positive note they are not as toxic as synthetic preservatives. The best option would be no preservatives at all, but products would not be able to stay fresh for too long.

The issue with manufacturing products entirely without the use of preservatives is that, besides taking a lot of time to be made, they are very expensive. Products manufactured without preservatives need to be fabricated in a sterilized environment using a flow hood similar to that found in hospitals and laboratories. They should also be refrigerated immediately after their first use. Because of this some companies are considering making products using natural preservatives.

There are ways of reducing microbial activity (such as using essential oils) in a more natural way. Antioxidants can help in this task as well. They will protect the oils, which become rancid when hit by light or air, from spoiling and becoming susceptible to contaminants. This is a process that cannot be stopped 100%, but antioxidants have the ability of slowing down this process.

Antioxidants and essential oils are completely natural ingredients. Antioxidants, as the word implies, are substance such as Vitamin E, Vitamin C or beta carotene that protect cells from the damaging effects of oxidation. In the case of essential oils, these are powerful antiseptics that kill most of the harmful bacteria and fungi without causing any damaging effects to the human body. Essential oils are derived form plants, flowers, leaves and grasses. The discovery of the aniseptic properties of these oilswas made in France during the cholera epidemic when it was observed that workers in perfume factories seemed to be almost fully immune to the disease while the rest of the population perished.

References

http://www.chemicallyspeaking.com/archive/2011/04/15/preservatives-in-cosmetics.aspx

VI. Learning path

This unit consists of 10 activities. The exemplary sequence of activities, in which all activities are used, is given in the table below.

Activity	***Inquiry Type***	***E-emphasis***
1. Capturing students' interests	Interactive discussion	Engagement
2. Exploring the science behind cosmetic creams	Structured inquiry	Exploration
3. Exploring the ingredients of and their role in cosmetic creams	Structured inquiry	Exploration/Explanation
4. Analysis of the cosmetic cream	Interactive demonstration/ Guided inquiry	Exploration /Explanation
5. Preparations for making an emulsion cream	Guided/structured inquiry	Elaboration/Extension
6. Experiment: making the product	Guided inquiry	Exploration
7**.** Estimating the suitability of the self-made product	Version A: structured inquiry Version B: open inquiry	Evaluation
8. Presenting the product	Interactive demonstration/discussion	Evaluation
9. Decision-making	Argumentation and reasoning	Evaluation/Extension
10. Exploring careers related to the cosmetics industry	Guided inquiry	Exploration

VII. Assessment

Students will be assessed in many different ways throughout the course, including both science process skills, general competences, and topic-related content knowledge. Types of assessments will include formative assessments including observation, participation and and summative assessments such as a final project.

Assessments that could be done throughout the project:

Formative	**Summative**
Formats and objects	
• Oral/written feedback from teacher (based on obseravtions, questions asked, etc.) throughout the unit, during the experiments and other formats of group work • Peer assessment (during the final presentation) • Individual worksheets	• Product presentation (measured through performance, questions asked) • Group portfolio on the product development (extended recipe, results of tests) • Individual worksheets

VIII. *Student Learning Activities*

Activity 1. Capturing students' interests

Learning aims:

Students are expected to

- Express their previous knowledge regarding the topic;
- Generate and share ideas for further exploration with their group members.

Materials:

http://www.youtube.com/watch?v=mYt0v0v19eM (an example of a large scale enterprise)
http://www.youtube.com/watch?v=PvaeTb38TJc (an example of a small factory)
http://www.youtube.com/watch?v=bj0XooeMFcs (an example of a home-made production)

Suggestions for use:

After presenting given video excerpts, group discussion is carried out where students are asked to think about reasons why one would want to make cosmetics while supermarkets are full of all imaginable cosmetic products. In addition, students are asked to think about the possible benefits and risks of (a) industrial, (b) home-made cosmetic products.
We propose 7 possible reasons that can be used to help guide the students if needed:

- **Cheaper -** cheapness is of course relative, but if one is skilled enough (knows how to get the ingredients, how to mix and preserve the product) then the outcome can really be much cheaper compared to similar products from the store.The beginner often has the problem of not knowing exactly what needs to be used in the product and thus many constituents will go to waste.

- **To use more natural raw materials** – especially in the cheaper cosmetic products, petroleum-derived materials are very often used. These are not very skin-friendly, eg. vaseline leaves a very greasy feeling, but it does not actually absorb through the skin, it is hydrophobic; at the same time, a longer usage of vaseline can cause the skin to dry; this is a problem with hygenic lip balms. The advantage of vaseline and silicone is that they do not have multiple bonds making them more chemically stable. At the same time, the last property speaks in favor of natural cosmetics, as natural oils are more easily biodegradable.

- **Design products according to one`s own taste**
We would be able to choose the odour we like or have no odour at all. Still, since compounds from the nature have their natural odour then a cream with no specific flavouring could still have an odour.

- **To make products that are more effective**
Commercial products often do not include enough of the beneficial substances that have an effect on the skin. Rather the additives written on the package have a psychological effect, e.g. " Vitamine E helps reduce the signs of ageing on the skin".

- **To make especially natural products for children**

There is no need to add substances that add odour, colour or increase preservation time. The cream does not have to be kept on the shop shelves for months; it can be mixed together and be used straight away.

- **To make products for one's own company**
  And why not? – the so called hand-made products with a short preservation time are becoming a growing trend in cosmetics. Many spas and beauty salons offer skin care using products made on the spot (eg. coffee grounds mixed with honey as a body scrub etc.)

- **To make cosmetic gifts for close friends**
  It is often said that the best gift is one that is made by yourself. Adding a bit of heart to it makes the gift better than any other, often a more expensive gift.

People who choose to make their own cosmetics, however, should be aware that whatever recipes they dream up at home will most likely not resemble the highly processed and largely synthetic products that they are used to buying in stores. Additionally, people who venture to make homemade cosmetics should take into consideration the effects that natural products might have on the skin and always be careful not to let products expire or spoil.
Commercial products often contain significant amounts of synthetic ingredients that can be irritating or damaging to skin. The positive side is that these synthetics, as well as the ample preservatives in commercial cosmetics, extend the shelf lives of these products and prevent them from spoiling or harboring bacteria. Homemade cosmetics, although they are free of synthetics such as parabens, are much more quick to go rancid. As a result, homemade cosmetics can be made only in very small batches, and they need to be stored properly and used quickly to prevent contamination. Failing to do so can cause spoiling or the growth of bacteria that can cause infections.

Possible questions:

- What do you think, why would anybody want to make their own beauty products?
- What could be the advantages and disadvantages of home-made cosmetic products?
- What should you know before starting to make a beauty product on your own?

Activity 2. Exploring the science behind cosmetic creams

Learning aims:

It is expected that students:

- Develop further an understanding of the general principles of solubility of nonpolar and polar substances; emulsions and emulsifiers.
- Predict solubility of known and unknown substances in different solvents.

Supporting materials:

Ressources

- Appendix 4
- http://www.elmhurst.edu/~chm/vchembook/170solutions.html
- http://www.elmhurst.edu/~chm/vchembook/

Suggestions for use:

As in the following lessons students are invited to make a cosmetic product on their own and moreover, deal with product development (why, to whom, how, the probable price, the scientific explanation of the effect etc.), students will investigate the science behind cosmetic creams.

At the very beginning teacher should recall or, when not learned before, introduce students to the key concepts and principles related to polar and non-polar substances, general solubility rule concerning the polarities of a solute and solvent ("like dissolves like"), and emulsions and emulsifiers. Students may also read through Appendix 4.
After that students fill the worksheet on solubility (Table 1).

Possible questions:

- What are the general principles in predicting the solubility of a particular solute in a particular solvent?

Activity 3. Exploring the ingredients of and their role in cosmetic creams

Learning aims:

Student are expected to

- Search for information from different sources.
- Cooperate within groups where each member will explain the role and structure of skin or the role of different ingredients in cosmetic creams, to their group members, ask questions when needed from group members.
- Understand the composition of cosmetic creams and the role of different ingredients in the mixture.

Supporting materials:

- Appendix 1.
- http://www.makingcosmetics.com

The ingredients of cosmetics, the purpose of the ingredients and their function; you can also download the whole catalogue, where the classification of the ingredients, the most famous representatives and their effect can be found.

- http://www.davidsuzuki.org/publications/downloads/2010/homemade-cosmetic-ingredients.pdf

The list of most common ingredients of home-made cosmetics, their purpose, properties, where to get them and where they are used, is given on this web-site.

Suggestions for use:

In this activity, students will investigate the composition of cosmetic creams and the role of different ingredients in the mixture.
Within the group, topics are divided so that each group member will look for information about the topic from the Internet, recommended literature and/or from the materials given by the teacher (e.g. Appendix 1). Afterwards, each group member should be able to present their topic to the others.

Topics:

I. The structure and functions of skin.

The main ingredients of cream (role and/or effect on skin):

II. Oils and fats (natural and synthetic), waxes
III. Emulsifiers, humectants
IV. Preservatives, antioxidants
V. Other substances (nutritive, exfoliative, bleaching, anti-inflammatory, anti-wrinkle etc. ingredients, odours (essential oils)

Possible questions:

What are the main functions of skin?

What is the role of different ingredients in a cosmetic cream?

Activity 4. Analysis of the cosmetic cream

Students are expected to

- Analyse the consistence of a given cosmetic product using the science knowledge gained from the previous activities.

Supporting materials:

- **Appendix 1 and 2.**
- http://www.makingcosmetics.com/articles/07-essential-role-vitamins-in-cosmetics.pdf about the role of vitamins in cosmetic products
- http://www.makingcosmetics.com/articles/01-how-to-use-preservatives-in-cosmetics.pdf suggestions related to preservatives
- http://www.makingcosmetics.com/articles/13-humectants-moisturizing-agents-in-cosmetics.pdf suggestions related to humectants and moisturisers

Suggestions for use:

In the next lesson, based on the knowledge gained about skin and creams, students will be able to analyse and assess the consistence of one cosmetic cream.

Each group will receive a description of the ingredients of one cosmetic cream. For example, a daily cream "Intensive Care" that promises to moisturise and provide nutrients to the skin.

Ingredients: *Aqua, paraffinum liquidum, PEG-6, sweet almond oil, cetyl alcohol, glycine, glycerine, citric acid, calcium chloride, vitamin A, vitamin E, linalool, propyl parabene*

Cruelty free product.

Students classify the substances in the recipe according to their function:

- oils and fats;
- emulgators;
- waxes;
- humectants;
- preservatives;
- antioxidants;
- special agents (nutritive, exfoliative, bleaching, anti-inflammatory, anti-wrinkle etc. ingredients);
- odours (essential oils).

The use of each ingredient in the product should be explained: why is it added to the product, what kind of properties does it give to the product. The analysis does not have to be in a tabular format, but the same issues should be still addressed. Based on the analysis, students make a poster or fill the table as given in student work sheet (Table 2).

In order to be more knowledgeable in different markings related to cosmetic products (e.g. “cruelty free” or “paraben free” product), students should introduce themselves with the Appendix 2 where the meaning of such kind of labels is provided.

Activity 5. Preparations for making an emulsion cream

Learning aims:

Students are expected to

- Work as a team in looking for, and critically analysing, relevant information;
- Plan the experiment;
- Use creative thinking in designing the product.

Materials:

Sources

- http://www.makingcosmetics.com/How-to-Market-Your-Own-Cosmetics-149.html
- http://www.makeyourcosmetics.com
- http://lifestyle.blogtells.com/2009/03/17/home-made-skin-creams-and-ointments-recipes/
- http://www.makingcosmetics.com
- http://www.davidsuzuki.org/publications/downloads/2010/homemade-cosmetic-ingredients.pdf
  The list of most common ingredients of home-made cosmetics, their purpose, properties, where to obtain them from, where they are used.

Materials and equipment

We offer the following list of the ingredients easily found from trade:
Oils and fats: Cocoa butter/cocoa oleum, coconut oil, olive oil, almond oil, ricinus oil (castor oil), shea butter, grape seed oil, liquid parafine, avocado oil, apricot kernel oil,
Vitamines: E-vitamine, A-vitamine.
Emulsifiers: stearic acid, bees wax.
Essential oils, rose water.

Some essential ingredients can also be found from home, eg. honey, vitamins, essential oils to add the odour, herbs that can be used to make water-based extracts and be used in the recipes instead of (rose) water etc.

Supplies that are needed include electronic weights, (wand) mixer or hand whisk, a cooker or at least hot water that can be used as a waterbath to melt the ingredients. It is convenient to use small bowls made of stain (stainless/enamel-coated). These small bowls can be put into a pot or into a bigger stain bowl to be used in the waterbath to melt the ingredients together and mix them. Empty jars for the cream are also needed.

Suggestions for use:

In this part, students will choose, based on their Internet searches, the recipe of a favourite cream (preferrably it should be an emulsion cream), and start to develop their own product. Before the next activity it would be useful four groups to read through the Internet article „How to Market Your Own Cosmetics” (http://www.makingcosmetics.com/How-to-Market-Your-Own-Cosmetics-149.html) getting the necessary knowledge for the following activities.

As a result of this activity, students have to present the list of necessary ingredients and the plan and rationale of the following activities to the teacher.

Possible questions:

- What are the main steps of making an emulsion cream?
- What ingredients are the most essential for making an emulsion cream ?

Activity 6. Experiment: making the product

Learning aims:

Students are expected to:

- Make an emulsion cream from simple ingredients on their own.
- Cooperate as a member of the team.

Supporting materials:

Equipment:
Given by the activity 5.

Resources:
http://www.makingcosmetics.com/articles/02-making-emulsions-for-cosmetics.pdf

Suggestions for use:

The amounts suggested in recipes are often quite large. Since all the groups (optimal group size would be 4-5) need to be able to use the materials available, it should be noted that the amount of the product that is to be made should not exceed 50ml (50g). The amounts of the ingredients should be proportionally reduced if needed.
Students attention should be brought to the safety issues: Using a water bath for melting waxes and fats may be related to the risk of getting burned by hot water or oil.
Students will be able to mix emulsion cream together within one lesson if all necessary ingredients and tools are provided beforehand and students have a clear understanding of what should be done.

Water-soluble substances should first be mixed with an aqueous phase; oil-soluble substances with an oil phase. Both of these mixtures should be heated simultaneously to 75-80°C while stirring constantly. To heat the fat basis of the cream**,** the dish containing it should be placed in a water bath (a larger tin bowl half filled with water, into which a smaller tin bowl can be fitted). When both cream bases reach the required temperature, remove the container with the water basis from the heating plate, the bowl with the fat basis along with the water (in the bath) should be kept warm (in the case of an electrical stove, keep it at the lowest temperature level).

Next pour the fat basis into the water basis in a thin stream, at the same time stirring the mix constantly. For mixing purposes a mixer or a whisk is ideal. The mixer should be working at a medium speed. Keep on stirring and place the cream mixture back into the water bath, to avoid its rapid cooling. Continue stirring for the next 5 minutes. The mixture should be evenly creamy.

Next remove the cream basis from the water bath and cool it down to 40°C while stirring at the same time. The mixer should now be working at the lowest possible speed. The less the cream comes into contact with air, the better the end result. The thickness of the cream depends on the length and intensity with which the mixture was stirred. If necessary, remove the thicker mass of the cream from the walls of the dish. At 40ºC preservatives, E-vitamins, moisturisers, etc. can be added one by one without stopping the stirring. If the additives are of different thickness, start with the thickest one.

Possible questions:

- *What are the main risks when making a cosmetic cream?*
- *How to decide, which ingredients should be dissolved in water and which in oil phase?*

Activity 7. Estimating the suitability of the self-made product

Learning aims:

Students are expected to:

- Establish the criteria in order to assess the suitability of the self-made product in place of analogous commercial products (only by activity 7b).
- Carry out a number of tests.
- Draw conclusions based on the results of the tests.

Supporting materials:

Equipment:
pH-sensor or universal indicator paper
the self-made product (from the previous activity)

Ressources:
http://www.makingcosmetics.com/Stability-Testing-of-Cosmetics-148.html

Suggestions for use:

After making the product, students are expected to establish their criteria in order to assess the "goodness" of the product. Students will carry out the experiments where self-made product is tested against the pre-determined criteria while presenting gathered data in a tabular format. Some tests, actually quite important, cannot be conducted within limited classroom time (e.g. determing shelf life of a product). Still, some tests may be applicable like measuring pH, estimating qualitatively the feeling on the skin left by the product, the odour, appearance and viscosity. Based on the findings, students draw conclusions about the product. This learning activity may be organised in a way using more open or more structured formats of student inquiry. Based on Bianchi and Bell (2008)[8] students' inquiry may be conducted as:

- **Confirmation inquiry:** Students are given a question, the procedure, and the results are known in advance.Teachers use activities at this level to introduce a tool or practice a procedure such as observation, measurement, or data collection.
- **Structured inquiry:** questions and procedures are provided, but students develop their explanation supported by their collected evidence
- **Guided inquiry:** Students are provided with the question, but students design the procedures and develop explanations of the results (with teacher guidance and feedback).
- **Open inquiry**: Students develop their research question, design procedures, carry

[8] Bianchi, H. & Bell, R. (2008). The many levels of inquiry. Science and Children, 46 (2), 26-29.

out experiments and communicate the results.

It would be probably reasonable to implement an open inquiry with students who already have sufficient experience with other formats of inquiry. More or less, it depends on a teacher's decision which format to use taking into consideration his/her students and their previous experiences. Compared to more structured formats, more open formats certainly take more time to carry out this activity.

Therefore, the two different ways suggested to carry out this activity are: (1) using a structured inquiry, and (2) using an open inquiry.

Activity 7a. Structured inquiry

Using this format, students are provided with the research question and criteria to assess the self-made product plus, the description of procedures to follow.

They are asked to find answers to the following question:

Does the self-made product meet the predetermined criteria regarding its: (a) pH, (b) viscosity, (c) outlook, (d) smell, (e) feeling on skin? Is the self-made product comparable with analogous commercial products?

Probable tests:

1) pH

The usual pH of a cosmetic cream may vary between 5 – 8. Normal skin has a pH level of about 5.5. Skin or at least the outermost layer of it is slightly acidic. The acidic layer helps your skin retain moisture and keeps germs out. To help maintain the skin's fatty protective layer cosmetics should be a pH level similar to that of the skin itself. For example, soap that is too alkaline pH≥ 8, will break up the acid in skin, causing dryness.

However, the cosmetics that contain alpha hydroxy acids (AHA's) may be more acidic than other. Alpha hydroxy acids found in skin-care products work best in a concentration of 5% to 8% and at a pH of 3 to 4. Beta hydroxy acid, salicylic acid, is a topical exfoliant that can reverse some of the effects of photoaging such as fine wrinkles and discolored skin. Currently, salicylic acid is the only beta hydroxy acid used as an exfoliant.

2) Feeling on skin

The product can be tested on skin, too. Volunteers should be warned to apply cream only on a very small area on skin. They should also be aware of the ingredients in order to minimise possible allergic reactions. Does it leave the skin soft, smoothe, and not very greasy? The last may be even OK when the product is meant for rough hands and/or frosty whether.

3) Odor and appearance

Odor and appearance may also be very important factors when buying a product. At the same time, the sense of smell may be quite subjective, therefore, it is suggested to use a number of „expert noses" to estimate the attractiveness of the smell. The same issue is related to the appearance of the product.

4) Viscosity

Viscosity of different products may broadly vary depending on its purpose, still it cannot be too runny and therefore inconveniet to use, and the other way around – if it is too thick, it will be difficult to spread on skin. Students probably are not expected to measure quantitatively the viscosity, rather, they give their qualitative estimation on viscosity.

5) Shelf life
This may be a case for individual inquiry as it takes time to become rancid even for a product made without preservatives.

How long may be the shelf-life[9] of homemade cosmetics? Products can be preserved for a couple of weeks or for three to four years depending on three factors: 1) how clean one works (disinfection is very important); 2) what kind of container one uses (dispensers are preferable because contamination is minimised); 3) the concentration of anti-microbial agents (essential oils, vitamins, and preservatives).

How do you know that the product is spoiled?
Besides a gray-green layer of mold on the surface of a product, there are several other factors indicating that a cosmetic product is severly contaminated with microbes:

- Loss of viscosity (product becomes thinner)
- Emulsion break (separation of water and oil)
- Cloudiness of previously clear products
- Loss or change of color or bad smell
- Drop in pH (product becomes more acid)

Activity 7b. Open inquiry

This is an alternative to Activity 7a following the open inquiry format where students are expected to develop their own research question(s) and criteria for deciding whether the product is applicable in place of analogous commercial products. Although it is expected that students make up tests on their own, they may need the teacher's help to decide whether the criterion is met (e.g. what is actually the normal pH of cosmetic creams).

Possible questions:

- What are the control variables when carrying out the tests in order to assess the suitability of self-made product?
- What is the usual pH of cosmetic creams? What may be the consequences when the normal ranges of pH in cosmetic products are exceeded?

[9] **Shelf life** is the length of time that foods, beverages, pharmaceutical drugs, chemicals, and many other perishable items are given before they are considered unsuitable for sale, use, or consumption. In some regions, a *best before*, *use by* or *freshness date* is required on packaged perishable foods.

Activity 8. Presenting the product

Learning aims:

Students are expected to:

- Use creative and critical thinking when producing a commercial.
- Present the produced commercial to the other groups.
- Analyse critically and put forward suggestions for improving the commercials made by the groups.

Supporting materials:

Sources

http://en.wikipedia.org/wiki/Advertising

Overview of different types of advertising; effects; criticism and ethical issues related to advertising.

The equipment needed for this activity depends on the chosen format of commercial: from paper and pencils to video cameras and digital media.

Suggestions for use:

In this activity, students will develop an advertisement: a booklet or an advertisement in the style of "TV Shop": the product is introduced by a specialist (cosmetician, dermatologist, scientist), or a consumer; the scientific content is strongly emphasised.

The advertisement should include the description of both the target audience as well as the effect of the product, its ingredients and their function. Furthermore, it would be good to think about what kind of advantages to emphasise in the given cosmetic product (see Appendix 2). For example:

- Are the ingredients natural (from so called clean nature)
- Bring forth the advantages of the product compared to other products that might include preservatives such as parabens, triclosan or sodium lauryl sulfate e. SLS.

After producing the advertisement (this may take 1-2 lessons or more, depending on the format), the rest of the class could be the judges, giving their opinions about how convincing the presentation of the product was: what was done well, but also giving suggestions for any improvements that could be done.

Moreover, the ethical issue (were the ways, in which a possible consumer was influenced, ethical?) could be posed and discussed after watching a presentation.

Possible questions:

What may be the causes why labels indicated below have been used in marketing cosmetics (see Appendix 2):

- No animal ingredients (vegetarian ingredients or Vegan)
- No animal testing (also known as Cruelty free products)
- No artificial colors, sweeteners or flavours
- Containers are recyclable

- Fair trade
- Certified organic ingredients
- Biodegradable
- Paraben free
- Mineral oil free (Petroleum free)
- Free of chemical preservatives

In your opinion, which of these qualities are important for you? Explain!

Activity 9. Making the final decision on the suitability of self-made cosmetic products (emulsion creams)

Learning aims:

Students are expected to:

- Analyse critically the possible pros and cons of self-made cosmetic products (emulsion creams) based on the knowledge and experiences gained from this learning unit .
- Make a (individual) decision on the suitability of self-made products in place of analogous commercial products

Supporting materials:

-

Suggestions for use:

Based on the information gathered (inc. the experiments carried out), each student will fill in a table where they should write down the advantages and disadvanatges of home-made creams. Having regard to the table the student should make an individual decision about the viability of home-made creams.

Possible questions:

- What are the advantages and disadvantages of self-made cosmetic products, and more specifically, of emulsion creams?

Activity 10. Careers related to cosmetics industry

Learning aims:

Students are expected to:

- Find relevant information related to the careers in cosmetics industry.
- Make a summary of one of the jobs related to the cosmetics industry and share the findings within a group or class.

Supporting materials:

Sources
References
http://en.wikipedia.org/wiki/Cosmetics#Cosmetic_careers
http://en.wikipedia.org/wiki/Prosthetic_makeup
http://chemistscorner.com/how-to-become-a-cosmetic-chemist/

Suggestions for use:

After introducing themselves to the text given in Appendix 3, students will search for information from the Internet about (at least) one job related to the cosmetics industry.They then write a summary based on what they have found. Students' share their findings within a group or class.

WP3
Unit Cosmetics

European Science and Technology in Action Building Links with Industry, Schools and Home

Work Package 3

WHY MAKE HOME-MADE COSMETICS?

Classroom Materials

European Science and Technology in Action: Building Links with Industry, Schools and Home

Lead partner for Unit: **University of Tartu (UTARTU)**

The initial version of this learning module has been generated through the collaborative action research by the group of following teachers: Liivi Kuusma, Mare Murs, Marika Toom, Tiina Rannar, Katrin Vaino.
The further development of the package was made by Katrin Vaino, Miia Rannikmäe, and Jack Holbrook.

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Classroom materials

Why make home-made cosmetics?

Introduction

For already thousands of years, people have been putting a lot of effort and also money into different cosmetic products in order to look more beautiful, younger and healthier. Our foremothers used to make cometic products themselves and their secrets were passed on from generation to generation. In the 20th century, most of the people started to use cosmetic products that were commercially manufactured. However, there are increasing number of those who have become frustrated and are now looking for some modern alternatives like making cosmetic products on their own or preferring hand-made and certified organic cosmetics from small factories. Watch the following video excerpts and try to answer to the following questions (see Activity 1. Discussion in groups).

Activity 1. Discussion in groups

- Why do you think anybody would want to make their own beauty products?
- What could be the advantages but also the disadvantages of (a) industrial, b) home-made cosmetic products?
- What should you know before starting to make a beauty product on your own?
- Put forward as many questions as you can related to the topic!

Be prepared to present your groupwork to the others in the class.

Activity 2. Exploring the science behind cosmetic creams

In the following lessons, you are invited to make a cosmetic cream on your own and also deal with the so called product development issue (why, to whom, how, the probable price, why should it „work“ - the scientific explanation of the effect etc.). In order to do that, it is important to familiarise yourself in advance to the science behind the cosmetic creams.

After reading individually and discussing in groups about the learning material “Solubility”, try to predict the solubility of a particular substance in the given solvent (Table 1).

NB! Keep in mind that polar and ionic solutes tend to be soluble in polar solvents whereas nonpolar ones tend to be soluble in nonpolar solvents. Thus the first step toward answering the question is to label each solute as being ionic or molecular and those that are molecular as polar or nonpolar.

Example: Because C_7H_{16} is a hydrocarbon, we recognise it as nonpolar.

Na_2SO_4, a compound containing a metal and nonmetals, is ionic;

We would therefore predict that C_7H_{16} would be more soluble in the nonpolar CCl_4 than in polar H_2O. In contrast, water would be the better solvent for Na_2SO_4.

Table 1. Predicting solubility

Solvent	Solute	Soluble/insoluble
H_2O	HCl	
H_2O	CCl_4	
H_2O	NaCl	
H_2O	CH_3CH_2OH	
CCl_4	I_2	
CCl_4	$CH_3CH_2CH_3$	
CCl_4	NaCl	
H_2O	Vegetable oil	
CCl_4	Vegetable oil	

Activity 3. Researching cosmetic creams in terms of the ingredients and their role

Divide the different topics within a group so that each group member will search for information about the topic from the Internet, recommended literature and/or from the help material given by the teacher. Afterwards each group member should be able to present their topic to the others. In the next lesson, based on the knowledge gained about skin and creams, you will have to be able to analyse and assess the content of one cream.

Topics:

I. Skin structure and functions

The main ingredients of cream (role and/or effect on skin):

II. Oils and fats (natural and synthetic), waxes
III. Emulsifiers, humectants
IV. Preservatives, antioxidants
V. Other substances (nutritive, exfoliative, bleaching, anti-inflammatory, anti-wrinkle etc. ingredients, odours (essential oils))

Once the preparation time is up, each group member introduces their topic to the other group members within 5-7 minutes using drawings or other methods in order to illustrate and facilitate the explanations. Make brief notes when listening to the others!

Activity 4. Analysis of the cosmetic cream

Each group gets an ingredient description of one cream. For example, a daily cream “Intensive Care“ that promises to moisturise and provide nutrients to the skin.

Students have to classify the substances in the recipe according to their function:
- oils and fats;
- emulgators;
- waxes;
- humectants;
- preservatives;
- antioxidants;
- special agents (nutritive, exfoliative, bleaching, anti-inflammatory, anti-wrinkle etc. ingredients);
- odours (essential oils).

Ingredients: *Aqua, paraffinum liquidum, PEG-6, sweet almond oil, cetyl alcohol, glycine, glycerine, citric acid, calcium chloride, vitamin A, vitamin E, linalool, propyl parabene*

Cruelty free product.

Try to classify the substances in the recipe according to their function.

The use of each ingredient in the product should be explained: why is it added to the product, what kind of properties does it give to the product.

Regarding the other information on the label, see Appendix 2.

NB! The analysis does not have to be in a tabel format, but the following questions should be addressed.

NOTE! In a complex molecule there can be several different types of chemical bonds in one molecule. The best source to find the formula of a substance is Wikipedia. Information about the function of different ingredients can also be found at http://www.makingcosmetics.com/.

Table 2. Analysis of a product

Ingredient	Classification according to function (effect on skin or on the properties of the cream)	Structural formula (if possible)	The type(s) of chemical bond(s) in the ingredients, in the case of possible hydrogen-bond please make a drawing picturing hydrogen bond between this substance and water Is the substance hydrophobic/hydrophilic? Indicate the hydrophobic/hydrophilic part of the molecule	Is the substance soluble in water or in oil/fat or in both?

Other remarks:____

____

____

Based on the analysis, would you suggest this product to your friends? Why/why not?

____

____

Activity 5. Preparations for making an emulsion cream

In this part, you will choose, based on the Internet searches, the recipe of a favourite cream (preferrably it should be an emulsion cream), and start to develop your own product.

Read through the Internet article „How to market your own cosmetics" (http://www.makingcosmetics.com/How-to-Market-Your-Own-Cosmetics-149.html) getting the necessary knowledge for the following activities.

At the end of this activity, your group has to present the list of necessary ingredients, the plan of activities and consult with your teacher.

Sources

- http://www.makeyourcosmetics.com
- http://lifestyle.blogtells.com/2009/03/17/home-made-skin-creams-and-ointments-recipes/
- http://www.makingcosmetics.com

The ingredients of cosmetics, the purpose of the ingredients and their function; you can also download the whole catalogue, where the classification of the ingredients, the most famous representatives and their effect can be found.

- http://www.davidsuzuki.org/publications/downloads/2010/homemade-cosmetic-ingredients.pdf

The list of most common ingredients of home-made cosmetics, their purpose, properties, where to get them, where they are used in, can be found on this web-site.

- http://www.vitaminstuff.com/supplements-shea-butter.html

Materials and supplies:
Oils and fats: Cocoa butter/cocoa oleum, coconut oil, olive oil, almond oil, ricinus oil (castor oil), shea butter, grape seed oil, liquid parafine, avocado oil, apricot kernel oil
Vitamines: E-vitamine, A-vitamine
Emulsifiers: stearic acid, bees wax
Other: essential oils, rose water

Some essential ingredients can also be found from home, eg. honey, vitamins, essential oils to add the odour, herbs that can be used to make water-based extracts and be used in the recipes instead of (rose) water etc.

Equipment: Electronic weights, (wand) mixer or hand whisk, cooker, waterbath to melt the ingredients, small stainless/enamel-coated bowls, empty jars for the cream (already used jars may be used, in this case, a jar must be washed very carefully with hot water and dish soap and rinsed afterwards with water.

Activity 6. Experiment: making the product

The amounts included in the recipe are often quite large. Since all the groups (optimal group size would be 4-5) need to be able to use the materials available, it should be noted that the amount of the product that is to be made should not exceed 50ml (50g). The amounts of the ingredients can be proportionally reduced if needed.

NOTE!

In order to successfully make a product, it is not enough to mix the ingredients given in the recipe. You have to have an idea of how to make it as well. Some ingredients can be replaced by others, for example oils and fats with each other, also you can add some ingredients (herb extracts, vitamins etc.). Nevertheless, exchanging ingredients or leaving them out can greately change the final outcome. Thus it should be discussed with the teacher when the content of the recipe is wanted to be changed. The water and fat (oil) phase amount ratio should be kept the same and also the emulsifier should not be left out if the product is an emulsion.

Pay attention to the cleanliness of the product as it is a very important factor ensuring shelf life, long enough!

Procedure:

- Water-soluble substances should be first mixed with an aqueous phase; oil-soluble substances with an oil phase. Both of these mixtures should be heated simultaneously to 75-80°C while stirring constantly. To heat the fat basis of the cream**,** the dish containing it should be placed in a water bath (a larger tin bowl half filled with water, into which a smaller tin bowl can be fitted).
- When both cream bases reach the required temperature, remove the container with the water basis from the heating plate, the bowl with the fat basis along with the water (in the bath) should be kept warm (in the case of an electrical stove, keep it at the lowest temperature level).
- Pour the fat basis into the water basis in a thin stream, at the same time stirring the mix constantly. For mixing purposes a mixer or a whisk is ideal. The mixer should be working at a medium speed. Keep on stirring and place the cream mixture back into the water bath, to avoid its rapid cooling. Continue stirring for the next 5 minutes. The mixture should be evenly creamy.
- Remove the cream basis from the water bath and cool it down to 40°C while stirring at the same time. The mixer should now be working at the lowest possible speed. The less the cream comes into contact with air, the better the end result. The thickness of the cream depends on the length and intensity with which the mixture was stirred. If necessary, remove the thicker mass of the cream from the walls of the dish.
- At 40ºC, preservatives, E-vitamins, moisturizers and the others can be added one by one without stopping the stirring. If the additives are of different thickness, start with the thickest one.
- Place the cream into the clean jar and close with a lead.

Activity 7a. Estimating the suitability of the self-made product

After making a product, you are expected to answer to the following questions:

Does the self-made product meet the predetermined criteria regarding its: (a) pH, (b) viscosity, (c) appearance, (d) smell, (e) sensation on skin? Based on the tests, is the self-made product comparable with the analogous commercial products?

In order to answer these questions, you are expected to carry out a range of tests:

1) pH

This simple test can be carried out by a universal indicator paper or digital pH sensor. Insert the results to Table 3 and based on the information given by every criterion, give your estimation regarding the suitability of the self-made product. Pay attention to the variables that are not actually tested (control variables).

Notice

The usual pH of a cosmetic cream may vary between 5 – 8. Normal skin has a pH level of about 5.5. Skin or at least the outermost layer of it is slightly acidic. The acidic layer helps your skin retain moisture and keeps away germs. To help maintain the skin's fatty protective layer cosmetics should be a pH level similar to that of the skin itself. For example, soap that is too alkaline pH≥ 8, will break up the acid in skin, causing dryness.
However, the cosmetics that contain alpha hydroxy acids (AHA's) may be more acidic than others. Alpha hydroxy acids found in skin-care products work best in a concentration of 5% to 8% and at a pH of 3 to 4. Beta hydroxy acid, salicylic acid, is a topical exfoliant that can reverse some of the effects of photoaging such as fine wrinkles and discolored skin. Currently, salicylic acid is the only beta hydroxy acid used as an exfoliant.

2) Sensation on skin

The product can be tested on skin, too. Volunteers schould be warned to apply cream only on a very small area on skin. They should also be aware of the ingredients in order to minimise possible allergic reactions. The volunteer gives his/her estimation: What is the sensation on skin: a) after a minute; b) after 10 minutes? Does it leave the skin soft, smoothe, moisturised and not very greasy? The last may be even OK when the product is meant for rough hands and/or frosty whether. Insert the results to Table 3.

3) Odour and appearance

Odor and appearance may also be very important factors when buying a product. The sense of smell may be quite subjective, therefore, it is suggested to use a number of „expert noses“ to estimate the attractiveness of the smell. The same issue is related to the appearance of the product.

4) Viscosity

Viscosity of different products may broadly vary depending on its purpose, still, it cannot be too liquidy and therefore inconveniet to use, and vice versa – if it is too thick, it will be difficult to spread it on the skin.
Based on your observations (these may come even from the previous tests), give your qualitative estimation on the viscosity of the product (Table 3).

Table 3. Results of the tests

	Results	**Give your estimation: does the product meet the criterion?**
pH		
Sensationon on skin		
Odour		
Appearance		
Viscosity		

Explain your results:____

____

____

Conclusions:____

____

____

5) Shelf life

This may be a case for individual inquiry as it takes time to start smelling badly even for a product made without preservatives.

How long may the shelf-life[1] of homemade cosmetics be?

Products can be preserved for a couple of weeks or for three to four years depending on three factors: 1) how cleanly one works (disinfection is very important); 2) what kind of container one uses (dispensers are preferable because contamination is minimised); 3) the concentration of anti-microbial agents (essential oils, vitamins, and preservatives).

[1] Shelf life is the length of time that foods, beverages, pharmaceutical drugs, chemicals, and many other perishable items are given before they are considered unsuitable for sale, use, or consumption. In some regions, a *best before*, *use by* or *freshness date* is required on packaged perishable foods.

How do you recognise that the product has gone bad?
Besides a gray-green layer of mold on the surface of a product, there are several other factors indicating that a cosmetic product is greatly contaminated with microbes:

- Loss of viscosity (product becomes thinner)
- Emulsion break (separation of water and oil)
- Cloudiness of previously clear products
- Loss or change of color or bad smell
- Drop in pH (product becomes more acidic)

Activity 7b. Estimating the suitability of the self-made product

After making the product, you are expected to formulate your research question(s) and develop tests regarding the suitability of the self-made product based on commercial products.
Establish your criteria in order to assess the "goodness" of the product. Design and carry out experiments presenting gathered data in a tabular form. The following source may help you when making up criteria:
http://www.makingcosmetics.com/Stability-Testing-of-Cosmetics-148.html

Your report must include the following sections:

1. Research question(s) including established criteria for deciding whether the product is suitable for use.
2. The list of required materials/equipment.
3. Plan of activities.
4. Procedure: Write a detailed account of how you will set up your experiment.
5. Data: Construct a table that contains your results.
6. Based on the findings, will be able to draw conclusions about the product.

Activity 8. Presenting the product

After producing the cream, your group is challenged to make an advertisement: a booklet or poster or an advertisement in the style of “TV Shop“: the product can be presented by a specialist (cosmetician, dermatologist, scientist), or a consumer. It is advised that the possible audience would be convinced about the scientific content of the product..

The advertisement should include the description of both the target audience as well as the effect of the product, its ingredients and their function. Furthermore, it would be good to think about what kind of advantages should be emphasized in the given cosmetic product (see Appendix 2). For example:

- Are the ingredients natural (from the so called pure nature).
- Bring forth the advantages of the product compared to the others that might include preservatives such as parabens, triclosan or sodium lauryl sulfate e. SLS.

When groups are presenting their products, the rest of the class could be the judges, giving their opinions about how convincing the presentation of the product was: what was done well, but also giving suggestions for any improvements that could be done. Moreover, ethical issues could be posed after watching the presentation: were the methods to influence the possible consumer ethical?

Activity 9. Making the final decision about the suitability of the self-made cosmetic product

Individually: Based on the information gathered, including the experiments carried out, think about the advantages and disadvanatges of home-made creams (Table 4). Based on the table, you should make your individual decision about the suitability of home-made creams:

Table 4.

Home-made cosmetic creams	
Advantages	**Disadvantages**

Decision: I my opinion, self-made cosmetic products are suitable/are not suitable, because...

Activity 10. Careers related to cosmetics industry

Read through the text given in Appendix 3 and start to search for information about (at least) one job related to cosmetics industry. Based on your searches, write a short summary.

Be prepared to share your findings with your group (in 5-10 minutes).

Appendix 1

I. Skin structure and functions

Skin is very important as it covers and protects everything inside your body. Skin holds everything together. It also protects our body, helps keep it at just the right temperature and, through nerve endings close to the surface of the skin, allows us to have the sense of touch.

However skin can become infected with bacteria, viruses and fungi, and can be irritated by chemicals or other substances that it is in contact with. Skin is also exposed to sunlight, and can suffer as a result.

Skin is composed of two parts (see Figure 6) – dermis and epidermis. The upper most layer of **epidermis** is called *stratum corneum*. Stratum corneum is made up of keratinuous dead cells. This is the part of skin and body that is peeled off daily. New skin cells are formed in the lower, e.g. basal layer, which is always forming new cells through cell division. The new cells gradually move towards the surface, which takes 1-2 months. As they move up they gradually die, become flattened and develop keratin and the outermost layer of flat dead cells is being continually worn away by friction. The keratin and oil from the sebaceous glands help to make the skin waterproof. Keratin is the substance that hair, nails and horns are made of. The thickness of stratum corneum can easily be measured in cell layers — it is the thickest under the heels, some people have more than 100 cell layers. The thinnest stratum corneum covers the genital organs, for example the penis has only 6 cell layers.

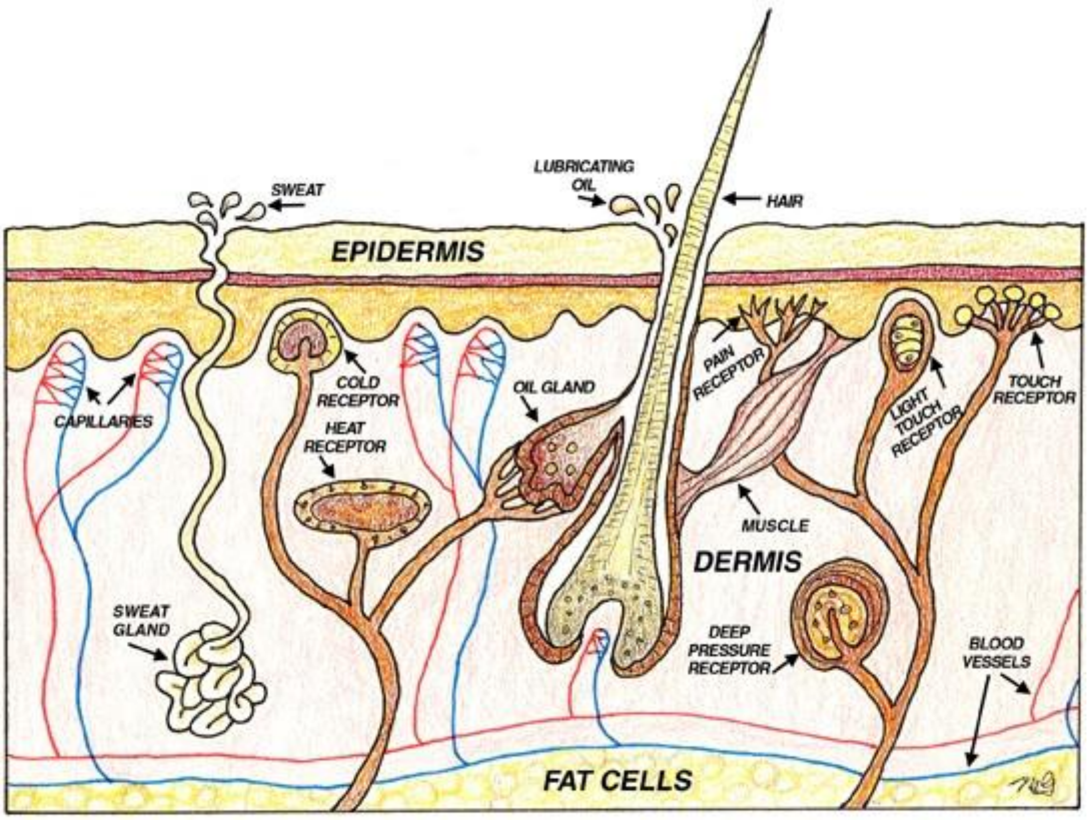

Figure 6: The cross-section of skin (Source: http://www.infovisual.info/03/036_en.html)

The **dermis** is the inner layer. The following tissues and structures can all be found in the dermis:

Connective tissue – packs and binds the other structures in the skin.

Elastic fibres – makes the skin resilient.
Capillaries – tiny blood vessels.
Muscle fibres – to move the position of the hairs.
Sensory cells – to sense touch, pressure, heat, cold and pain.
Nerve fibres – to activate muscles and glands and relay messages from the sensory cells to the brain.
Pigment cells which produce melanin, a very dark pigment.
Sweat glands which open onto the surface as pores
Hair follicles – pits in the epidermis in which hairs grow.
Sebaceous glands – produce oil to keep hair follicle free from dust and bacteria, and to help waterproof the skin.

There is a layer of fat underneath and in the lower regions of the dermis. The thickness of this layer varies depending on the place in the body and from person to person. A store of fat is useful to the body as insulation and it can be used for energy when the intake of nutrients is insufficient.

Skin has many functions:

- Controls of body temperature
- Keeps away infection
- Makes a waterproof barrier
- Protects delicate tissues underneath
- Mends itself when damaged

Temperature control

Body temperature is normally 37ºC no matter what the temperature of the surroundings is. It is controlled by a feedback system, that is, information about the temperature of the body, for example from the temperature-sensitive receptors in the skin, is fed back to the hypothalamus, the temperature-regulating centre of the brain. The brain then sends messages to parts of the body, including the skin, to keep heat in or to lose excess heat.

Other feedback systems are used in controlling the amount of glucose and water in the blood.

Keeping temperature, glucose and water at the right levels is known as homeostasis and is important for the chemical processes of the body to work properly.

A waterproof coat

Keratin in the epidermis and oil produced by the sebaceous glands help to make our skin waterproof. This means that we do not go soggy in the bath or dry up in the sun.

Keeping away infection

Millions of microorganisms live harmlessly on the skin and in the air around us. The skin forms a very effective barrier to stop them entering the body unless damaged; infections can occur when skin is damaged.

Skin colour

Melanin is a pigment that gives skin a colour from pink to brown to black. People have different skin colours because their skin contains different amounts of melanin. Melanin protects skin from ultra-violet (UV) radiation. When skin is exposed to the sun, more melanin is produced and the skin darkens. The skin of an albino person contains no melanin. Therefore they have no natural protection from UV rays. Their skin must be covered up in sunlight.

Resources

http://courses.washington.edu/bioen327/Labs/Lit_SkinStruct_Bensouillah_Ch01.pdf
http://www.abpischools.org.uk/page/modules/skin/.cfm?coSiteNavigation_allTopic=1

II. The main ingredients of cosmetic creams

Because the manufacturers have to present the ingredients of the cosmetic product according to the requirements of INCI (International Nomenclature for Cosmetic Ingredients), the substances' names below are given according to INCI (in latin). This will also be helpful when looking for information from the internet. The list of ingredients on the package of the product must be presented in the order of decreasing content percentage.

Oils, fats and waxes

Oils and fats are composed of basically non-polar molecules (prevailingly C-C and C-H bonds) and they are thus hydrophobic. Fats and oils are used to strengthen the lipid[2] layer on the skin. The lipid layer on the skin functions mainly as a barrier to protect the skin from the outside influences. It reduces the fluid loss from epidermis by forming a thin film on the skin. It also fills the microscopic unevennesses and by that it makes the skin smoother and softer and reduces smaller wrinkles. Oils and fats with a low melting point are easily appliable onto the skin, whereas substances like wax that have a higher melting point can be quite solid; this however is useful in the case of lipsticks.

(a) Natural oils and fats

Herbal and animal oils and fats are triglycerides (esters[3]) that are formed of three fatty acid (usually composed of 16 or 18 carbon atoms) and one glycerine (alcohol) molecule. They are basically non-polar and hydrophobic substances. Natural oils and fats are never pure substances, rather they are a complex mixture of triglycerides and various additives.

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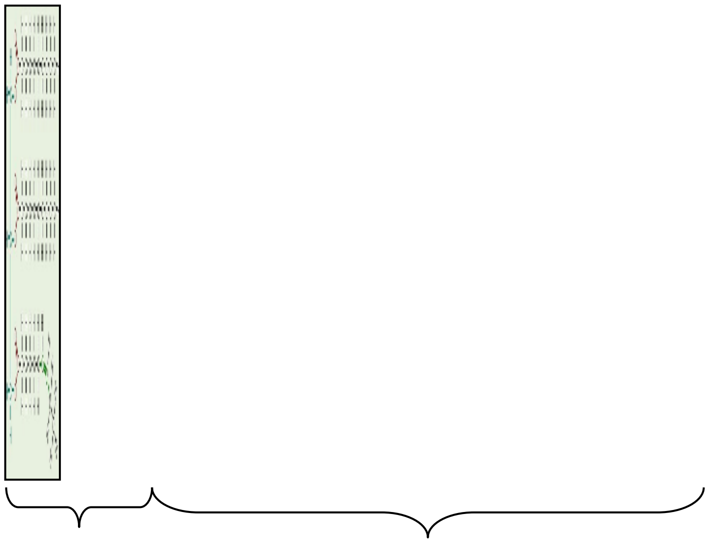
[2] **Lipids** are biolmolecules with an ester-like structure. They are composed of at least two components: an alcohol and a fatty acid. Fats, oils, waxes, steroids and other water-insoluble compounds are lipids.

[3] **Esters** are formed as a result of a reaction between a carboxylicacid and an alcohol. The general formula is R-COO-R'

$$R\text{-}COOH + R'OH \rightleftharpoons RCOOR' + H_2O$$

When the fatty acid residues in the fat molecule consist of double-bonded carbon atoms, then they are called unsaturated fatty acids; when there is a single bond between carbon atoms then they are called saturated fatty acids. Fats composed of unsaturated fatty acid residues are more liquid-like than these composed of saturated fatty acid residues and are thus more convenient to be used in a cream; at the same time it makes the fats more open to being oxidised by oxygen from the air. The latter process is called rancidification. As a result of rancidification, the smell, taste and/or the appearance of fats changes. In figure 2, one can see that the molecule in composed of two saturated and one unsaturated fatty acid residues.



Glycerol residue

Fatty acid residues

Figure 6. The structure of fats

Most often used natural fats and oils in cosmetic products:

- **Cocoa butter** – a liniment with a balmy chocolate smell, heals, moistens and softens (rough, dry) skin and is thus recommended to be used for smoothing scars, spots and other skin defects, to treat sunburn. It has an anti-wrinkle effect and makes the skin more elastic. Cocoa butter is a natural cream thickner that stabilizes an emulsion. Creams usually contain 3-6%, balsams 6-60% of cocoa butter.
- **Greipfruit seed oil** – it is known as a natural preservative and in some recipes it is added to the soap mixture in a cold process of up to 5% of the liquid oil volume. Since it contains antioxidants, it is an antibacterial oil and thus it is good to use it on problematic and sensitive skin. Because it contains a lot of C-vitamine, it is good to be used for making creams (inc. anti-acne), lotions and serums.
- **Coconut oil** – one of the basic ingredients of soap and cream. It nicely adds strength to soaps and foams, softens and smoothens skin. It is used in making creams, emulsions, soaps and shampoos, also in ointments, baby care products, protection creams and bath oils.
- **Shea butter** – offers a maximal care for the skin; it is moisturizing, smoothening, anti-ageing and anti-inflammatory; it has a calming effect, treats microwounds; to some extent protects against UV-radiation. It is added to emulsions, creams, pre- and after-suntanning creams, moisturizing creams, body liniments, to ointments in the range of 3 to 100%.

- **Sweet almond oil** – one of the most popular oils for making cosmetics. It is squeezed from the fruit cores of the almond tree. It is suitable for dry and sensitive skin, has a wonderful skin moisturizing and smoothening effect, vitalizes and absorbs well into the skin, treats well chapped skin. It is added to creams, emulsions, ointments, bath oils and baby care products.
- **Rasberry seed oil** – cold-pressed rasberry seed oil contains a lot of E- and A-vitamins that make the oil a wonderful skin care product. It protects the skin from free radicals and offers protection from the sun radiation. Because of this, the oil is used in creams meant for putting around one`s eyes, in lip balms and also in face creams.
- **Castor oil –** it has a diverse skin softening and smoothening effect. It is used in creams, emulisons, hair care products, bath oils, sunscreens, lip balms and lip balsams.
- **Avocado oil –** this oil contains A, B_1, B_2, D ja E vitamins. It has a healing effect on skin diseases such as psoriasis and eczema. It is a natural sunscreen, contains natural antioxidants. It is used in creams, emulsions, body liniments inc. lip liniments (lip balm), products usually contain 4-20% of avocado oil.
- **Olive oil** – moisturizes the skin, increases its elasticity, reduces the signs of aging and rejuvenates skin. It can be used on its own or in a mixture with other luxury oils to make a perfect face serum.
- **Grape seed oil –** it absorbs well, slightly astringent; it is a non-greasy softener with a tonic effect. Because of this the oil works best for problematic and impure skin. It can be added in the amount of 1-100% to creams tonics, massage oils and bath oils.
- **Rose hip seed oil –** it is a wonderful softener and moisturizer, helps treat surgical wounds, burns, eczema, reduces wrinkles, ideal for stressed skin. In an undiluted form used as a massage oil. In creams, emulsions, bath oils, tanning and baby care products used in the range of 1-100%

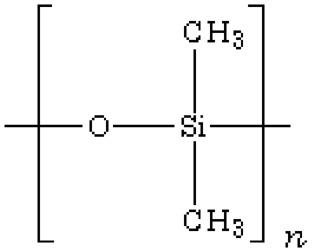
(b) Synthetic oils and fats

Synthetic fats and oils are much more tolerant to oxygen from the air since they do not contain multiple bonds like herbal fats/oils. However they do not break into essential fatty acids like natural fats. Hydrocarbons (paraffin, vaseline and other petroleum products) and silicones form an impermeable film on the skin and reduce the skin`s natural resilience when used for a long time.

- **Vaseline and mineral oils** (*paraffinum liquidum, petrolatum, petroleum jelly)* – petroleum products; mixture of hydrocarbons, mainly that of alkanes, where the number of carbon atoms in the molecule is usually > 25. Vaseline and mineral oils soften the skin and dissolve other hydrophobic substances. They are often used in hand creams, but mainly still in cheaper products.

  $$H(-CH_2-)_nH$$

- **Silicones** are polymers consisting of silicon. Dimethicone is one example of a silicone. It forms an extremely efficient water-repellent film on the surface of skin or hair. Silicones are used a lot in hair care products.



Polydimethylsiloxane (PDMS) or dimethicone.

(c) Waxes

Waxes are complex mixtures of alcohols, fatty acids and esters[2]. They are harder, less greasy and highly resistant to humidity, oxidation and microbiotic degradation. Waxes are very useful ingredients in cosmetic products due to protective, softening and thickening properties as well as for the fact that they form a film. They increase the persistence and viscosity of cosmetic products and make them more even.

- **Bee wax** – non-congealing thickener, emulsifier, forms a film, slightly anti-bacterial, softens the skin. Melted by heating to a temperature of 61-68 ^{o}C. Usual content of 2-40%. Used in creams, emulsions, pomades, liniments, lipsticks, mascaras, eye shadows, ointments, protective creams.
- **Carnauba wax**
- **Candelilla wax etc.**

III. Emulsifiers and humectants

Cosmetic creams (lotions) are emulsions. Emulsions are dispersion systems where liquid substance(s) are dispersed or mixed with another liquid substance while the liquids actually do not mix microscopically. In cosmetic emulsions these are oils-fats as one part and water as the other part. Everyone knows that this kind of spray is not very persistent. Since oil drops are lighter than water, they accumulate quite quickly to the surface after shaking and form two separate phases: an oil phase and an aqueous phase. Emulsifiers are used to make the emulsion more persistent.

Emulsifiers

Emulsifiers are used in creams and other emulsions in order to mix two phases that do not mix: the oil phase and the aqueous phase. This makes the system more persistent.
The typical emulsifier molecule is rather bulky and mostly basically non-polar making it hydrophobic and dissolvable in fat (directed towards the oil phase). The polar and hydrophilic end is directed towards the aquous phase.

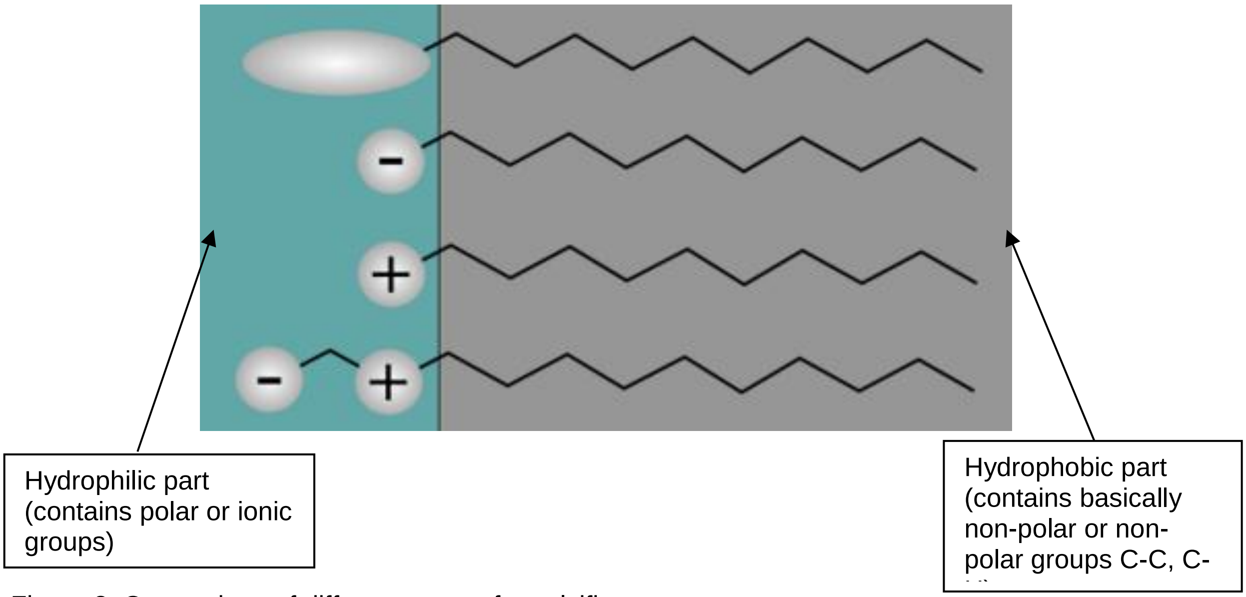


Figure 3: Comparison of different types of emulsifiers

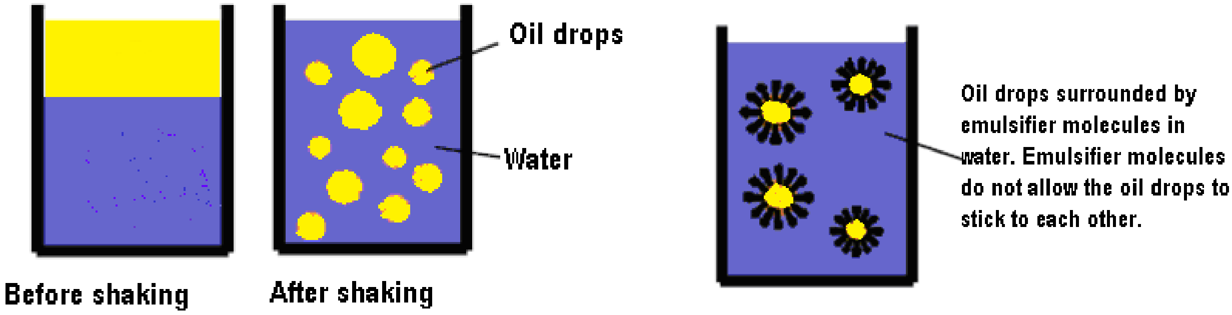


Figure 4. Emulsion without emulsifier (left) and emulsion with emulsifier (right)
(Source: http://www.makingcosmetics.com/articles/02-making-emulsions-for-cosmetics.pdf)

There are 2 types of emulsifiers (Figure 5): oil in water (o/w) and water in oil (w/o). Night creams and sunscreens are often w/o- type of emulsions that are quite greasy. Body lotions and day creams are o/w-type of emulsions that are lighter and moisturise better.

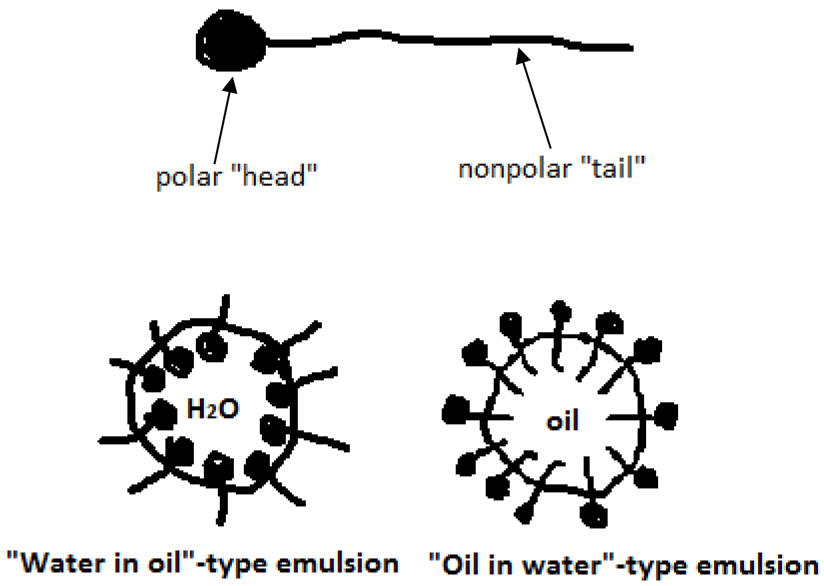
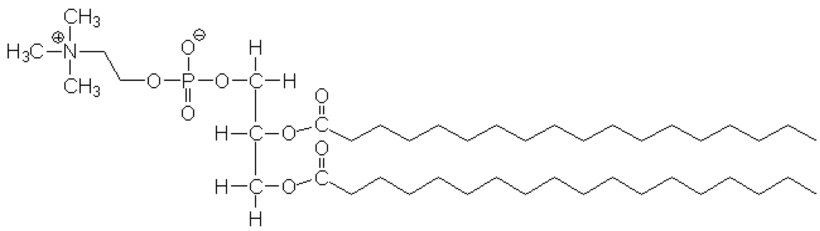


Figure 5. A comparison between water in oil and oil in water type of emulsions

(a) Water/in oil type of emulsifiers

- **Lecitine** – it is added to the oil phase before mixing. Used in creams, ointments, body gels, shampoos, sunscreens, body liniments and decorative cosmetics.

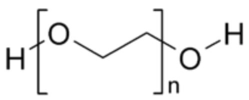


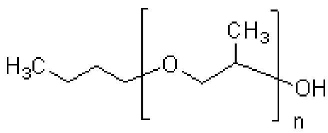
- **Egg yolk**
- **Sorbitan monostearate**
- **Triglyceryl monooleate**

(b) **Oil/ in water type of emulsifiers**

- **Stearic acid –** emulsifies and thickens, gives the skin a slightly waxy feel, shiny and a cooling effect. Content is usually 2-10%. Extensively used in soaps, creams, emulsions, in protection and shaving creams and other care products.

- **Polyethylene glycols (PEG) and polypropyleneglycols (PPG)**





They can act both as emulsifiers as well as fat-like substances. The number behind the abbreviation represents the number of elementary links in the molecule. For example, PEG-40.

- **Polysorbate**
- **Cetearyl alcohol –** contains molecules consisting of 8-22 carbon atoms. Makes up 1-5 % of the total mass of a cream. It is added to both w/o as well as to o/w type of emulsions

Octane-1-ol

Humectants

Humectants are important ingredients of cosmetics allowing to avoid and maintain the moisture loss of the skin. Strateum corneum can protect the skin efficiently only when it contains enough water. Skin becomes dry and develops cracks when the water level decreases. Microbes can enter via the cracks and the dryness of skin causes itching. The moisture content of skin can decrease when a person is smoking or due to dry air and of course when the skin ages. The natural humectants between two skin cells are amino acids and sugars. The main characteristic of a humectant is the ability to strongly bond water (via hydrogen bonds). Humectants are not only added to skin care products but also to hair care products to add volume to the hair. This group includes a number of proteins, acids, polysaccharides and some smaller molecules: polyhydroxyl alcohols such as glycerin, hexane-1,2,3,4,5,6-hexaol (sorbitol), propylene clycol, but also urea and amino acids such as aloe vera juice.

IV. Preservatives and antioxidants

Preservatives

Cosmetics are a good surface for bacteria, viruses and fungi since the products contain water, oils, peptides and sugars. Because of this, the various cosmetic products require preservatives or their life-span is very short.

- **Grapefruit seed oil** – (look at previous pages). This can be added to warm or cold mixtures before adding the odour. Usual content of 0.5-1% (for more complex mixtures it is 2-3%). It is not enough for long term preservation and is thus combined with different parabens.
- **Potassium sorbate, sodium sorbate**
- **Sodium bensoate**
- **Parabens –** disputable, but bound to be found in cosmetic products from stores. Is absorbed easily and fast into skin and gets into the blood circulation within tens of minutes after use. Studies done have shown that they mimic the body`s own hormones and can thus interfere with the endocrine systems. Most known parabens are methylparaben and ethylparaben.

Antioxidants

Antioxidants are active components of cosmetic products. Generally they help stop oxidation reactions and bind free radicals (eg. peroxides). Both of these processes ruin the functions and integrity of natural substances. Antioxidants are useful in two ways: they prevent the degradation of natural ingredients (proteins, carbohydrates, fats) in a cosmetic product; and at the same time they protect the skin cells and slow down aging-related processes. Antioxidants have become useful substances that help make the skin more shiny and decrease the signs of aging.

- **Vitamin E** (tocopherol) and its derivatives – besides having an antioxidant effect they also moisturize, are anti-aging, repair the skin relief, soften and are anti-inflammatory. They also stimulate the growth of skin cells and the activeness of enzymes. They are added in the range of 0.5-2.5% to have an effect on the skin and in the range of 0.1-0.5% to stabilize the fat- and oil-containing product. Used in various skin and hair care products. Added to the oil phase.
- **Vitamin C** (L-ascorbic acid) and its derivatives – besides having an antioxidant effect it is also anti-aging: it repairs skin elasticity and stimulates the formation of collagen, avoids over-pigmentation, is anti-inflammatory. Added to the aquous phase, usual content of 0.2- 4%. Used in emulsions, creams, after-tanning products etc.
- **Vitamin A** – promotes skin regeneration. Promotes epithelium and keratin formation, anti-wrinkle properties. It is useful to freeze it in order to preserve it. Should be put into a warm-water bath to melt and add to the product as the final ingredient. Average amount of 10 drops per 100g of cream. Used in all sorts of skin care products, especially in nutritive and sunburn creams.
- **Green tea extract -** Green tea contains a simple form of flavonoid known as catechins (flavan-3-ols) plus gallic acid, both known as good antioxidants. It also contains carotenoids, tocopherols, ascorbic acid (vitamin C) and minerals such as chromium, manganese, selenium, zinc and certain phytochemical compounds strenghtening even more the antioxidant potential of green tea**.**

V. Other components

Skin peeling agents

Skin peeling agents work in two ways: via mechanically and chemically removing dead skin cells. Various herbal flours, but also sugar and salt crystals are mechanical peelers. Weak acids such as lactic acid, citric acid and malic acid are chemical peelers and they dissolve the space between two cells—this causes the release of the cells on top. As a result of peeling, the skin becomes more shiny and the effect of other cosmetic products increases as they can get deeper into the skin. The top layer of the skin recovers very quickly.

Alpha hydroxy acids (AHA's) most commonly used in cosmetic applications are typically derived from food products including glycolic acid (from sugar cane), lactic acid (from sour milk), malic acid (from apples), citric acid (from citrus fruits) and tartaric acid (from grape wine). For any topical compound to be effective, including AHA, it must penetrate into the skin where it can act on living cells. Bioavailability (influenced primarily by small molecular size) is an important factor in a compound's ability to penetrate the top layer of the skin. Glycolic acid, having the smallest molecular size, is the AHA with greatest bioavailability and penetrates the skin most easily; this largely accounts for the popularity of this product in cosmetic applications.They have a peeling effect, keratolytic effect, added in the range of 5-15% to the aqueous phase.

Odours

Nowadays most loitions contain odours. The purpose of those added odours is to make the product more attractive, while at the same time they might also be used to conceal the smell of the original components, which might not be so pleasant. Odours can be natural as well as synthetic. The best known natural odours are essential oils, which constitute complex mixtures of compounds. The best known synthetic odours are geraniol, citronellol, citral and others, which simulate natural odours.

Other components

- **Citric acid** – acidity regulator, gelatine formation, neutralizes certain minerals in order to increase the efficacy of antioxidants and preservatives, has buffer capacity (helps maintain a pH between 2.5 to 6.5), higher concentration has exfoliating properties (like with AHA acids), moisturizes, exfoliates, softens, has an anti-wrinkle effect. The safe use of citric acid should not exceed 10% and not be at a lower pH value than 3.5. Citric acid is added creams, shampoos, shower gels, bath pearls (along with sodium carbonate).
- **Salicylic acid** – proven anti-acne effect due to its anti-septic properties, very effective keratolytic effect (exfoliating effect extends to the pores of the skin). Used in exfoliators, anti-dandruff products, anti-psoriasis products and in products meant for problematic skin: for acne – 0.5-3%; for dandruff – 1-3%, for warts – 5-25%. Products containing salicylic acid may smell on the skin. When salicylic acid is attempted to be used together with other exfoliators such as benzoyl peroxide, recorcinol or soaps and other cometics products that dry your skin one must be aware of an excessive exfoliating effect.
- **Aloe Vera** juice (extract, gel) – moisturizes, rejuvenates, heels, penetrates easily through the skin while stimulating the blood circulation and the immune system, increases the elasticity of the skin and stimulates collagen synthesis, found in various products.
- **Allantoin** – heels (sun) burns, abrasions, works well for chapped skin, leaves a soft and dry feeling (for example in the case of an incubated diaper), usually added to an aqueous base in the amount of 0.2 - 2%. Added to a great variety of products.

Resources

- http://www.makeyourcosmetics.com

a comprohensive page where a lot of different information can be found: recipes, components, the content of the components, effect etc.

- http://www.naturalnews.com/022113.html

the effect of parabens

- http://lifestyle.blogtells.com/2009/03/17/home-made-skin-creams-and-ointments recipes/

home-made creams

- http://www.vitaminstuff.com

a lot of information about vitamins

- http://www.essentialwholesale.com

here one can buy substances, but it also gives information about the ingredients and their effect

- http://www.makingcosmetics.com

articles about cosmetics and a whole book about the ingredients of cosmetic products, the effect and how much and where to add something

- http://www.joik.ee/?section=et/2033&class=shop_order_center&action=show_items&id=203

ideas to experiment with different mixtures

- http://allnaturalbeauty.us/emulsions.htm

a lot of information about emulsifiers

Appendix 2

The list of labels that may or may not be taken into account before buying a product or ingredients to make ones own cosmetics

- **No animal ingredients (100% vegetarian ingredients or Vegan)**

- **No animal testing (also known as Cruelty free products)**
- **No artificial colors, sweeteners or flavours**
- **Containers are recyclable**
- **Fair trade**

Fair trade is an organised social movement that aims to help producers in developing countries to make better trading conditions and promote sustainability. The movement known as fair trade indicating the certification advocates the payment of a higher price to exporters as well as higher social and environmental standards.

- **Certified organic ingredients**

Organic certification is a certification process for producers of organic food and other organic agricultural products. In general, any business directly involved in food production can be certified, including seed suppliers, farmers, [food] processors, retailers and restaurants.

Requirements vary from country to country, and generally involve a set of production standards for growing, storage, processing, packaging and shipping that include:

- no human sewage sludge fertilizer used in cultivation of plants or feeding of animals
- avoidance of synthetic chemical inputs (e.g. fertilizer, pesticides, antibiotics, food additives, etc.), genetically modified organisms, irradiation, and the use of sewage sludge;
- use of farmland that has been free from prohibited synthetic chemicals for a number of years (often, three or more);
- keeping detailed written production and sales records (audit trail);
- maintaining strict physical separation of organic products from non-certified products;
- undergoing periodic on-site inspections.

- **Biodegradable**

Biodegradation or biotic degradation or biotic decomposition is the chemical dissolution of materials by bacteria or by other biological means. Biodegradable simply means to be consumed by microorganisms and returned to compounds found in nature. The term is often used in relation to ecology, waste management, biomedicine, and the natural environment (bioremediation) and is now commonly associated with environmentally friendly products that are capable of decomposing back into natural elements. Organic material can be degraded aerobically with oxygen, or anaerobically, without oxygen. Biosurfactant, an extracellular surfactant secreted by microorganisms, enhances the biodegradation process. Biodegradable matter is generally organic material such as plant and animal matter and other substances originating from living organisms, or artificial materials that are similar enough to plant and animal matter to be put to use by microorganisms.

Resources

Diaz, E. (editor). (2008). *Microbial Biodegradation: Genomics and Molecular Biology* (1st ed.). Caister Academic Press. ISBN 1-904455-17-4.
Measuring Biodegradability", *The University of Waikato*, June 19, 2008
Agamuthu, P. Biodegradability and Degradability of Plastic Waste, *International Solid Waste Association*, November 9, 2004.

- **Paraben free**

Parabens are a class of chemicals widely used as preservatives by cosmetic and pharmaceutical industries. Parabens are effective preservatives in many types of formulas. These compounds, and their salts, are used primarily for their bactericidal and fungicidal properties. They can be found in shampoos, commercial moisturisers, shaving gels, personal lubricants, topical/parenteral pharmaceuticals, spray tanning solution, makeup, and toothpaste. They are also used as food additives. They are becoming increasingly controversial, however, because they have been found in breast cancer tumors (an average of 20 nanograms/g of tissue). Parabens have also displayed the ability to slightly mimic estrogen (a hormone known to play a role in the development of breast cancer). No effective direct links between parabens and cancer have been established, however. Another concern is that the estrogen-mimicing aspect of parabens may be a factor in the increasing prevalence of early puberty in girls. Most known parabens are methylparaben and ethylparaben.

- **Mineral oil free (Petroleum free)**

A mineral oil is any of various colourless, odorless, light mixtures of alkanes in the C15 to C40 range from a non-vegetable (mineral) source, particularly a distillate of petroleum.The name *mineral oil* by itself is imprecise, having been used to label many specific oils over the past few centuries. Other names, similarly imprecise, include white oil, liquid paraffin, and liquid petroleum. Most often, mineral oil is a liquid by-product of the distillation of petroleum to produce gasoline and other petroleum-based products from crude oil. A mineral oil in this sense is a transparent, colorless oil composed mainly of alkanes [2] and cyclic paraffins, related to petroleum jelly (also known as "white petrolatum").

One of the common concerns regarding the use of mineral oil is its presence on several lists of comedogenic substances. These lists of comedogenic substances were developed many years ago and are frequently quoted in the dermatological literature. At the same time it is reported that highly refined and purified mineral oil found in cosmetic and skincare products is noncomedogenic (does not clog pores).

Resources

DiNardo, J. C. (2005), Is mineral oil comedogenic? Journal of Cosmetic Dermatology, 4, 2–3.

- **Free of chemical preservatives**

The meaning of such label is that the product is made without synthetic preservatives. Due to controversy surrounding the use of synthetic preservatives in food and cosmetics, some companies are turning to other options to help extend products' shelf life. Some are switching from synthetic to natural. Unfortunately all natural preservatives may not be as good as they sound, especially if taken in excess. But on a positive note they aren't as toxic as synthetic preservatives. The best option would be no preservatives at all, but then products would not be able to stay fresh that long.

The issue with manufacturing products entirely without the use of preservatives is that, besides taking a lot of time to make they are very expensive. Products manufactured without preservatives need to be fabricated in a sterilized environment using a flow hood similar to that found in hospitals and laboratories. They should also be refrigerated immediately after their first use. Because of this some companies are considering making products using natural preservatives.

There are ways of reducing microbial activity (such as using essential oils) in a more natural way. Antioxidants can help in this task as well. They will protect the oils, which start smelling bad when hit by light or air, from going bad and becoming susceptible to contaminants. This is a process that cannot be stopped 100%, but antioxidants have the ability of to slow down this process.

Antioxidants and essential oils are completely natural ingredients. Antioxidants, as the word implies, is a substance such as Vitamin E, Vitamin C or beta carotene that protects cells from the damaging effects of oxidation. Essential oils are powerful antiseptics that kill most of the harmful bacteria and fungi without causing any damaging effects to the human system. Essential oils are derived form plants, flowers, leaves and grasses. The discovery of these oils antiseptic properties was made in France during the cholera epidemic when it was observed that workers in perfume factories seemed to be almost fully immune to the disease while the rest of the population died.

Ressources

http://www.chemicallyspeaking.com/archive/2011/04/15/preservatives-in-cosmetics.aspx

Appendix 3

Cosmetic scientists[4]

There are literally thousands of scientists working in the cosmetic industry and the number of jobs continues to grow. This is an industry that continues to sell products even in uncertain economic times. There are various types of companies that employ cosmetic scientists and chemists. These include finished goods manufacturers, contract manufactures, raw material suppliers, and testing laboratories. The most common degree

[4] Adapted from http://chemistscorner.com/how-to-become-a-cosmetic-chemist/

required from cosmetic scientists is a bachelor degree in Chemistry, Chemical Engineering, Biology, and Microbiology, less in Physics; bigger companies like Procter & Gamble or L'Oreal tend to favour students who have a master or PhD degrees in cosmetic science.

If one is looking to work as a scientist in the cosmetic industry then there are a wide variety of jobs to choose from:

a. **Cosmetic Formulator** – If one likes inventing and creating (e.g. the newest lipstick formula, or a biodegradable nail polish), the formulator is probably the best choice. Most of these jobs are with Finished Goods & Contract manufacturers[5]. A few raw material suppliers employ formulators in their technical service departments.

b. **Quality Control Chemist -** If one likes Gas Chromatography, Infa-Red spectroscopy, and Mass Spectrometry. Every company in the industry hires these scientists.

c. **Analytical Services** – Closest thing in the industry to scientific research. Most raw material suppliers and finished goods manufacturers have analytical departments.

d. **Process Engineering -** This job involves work very similar building things and engineering. Almost any cosmetic company with manufacturing facilities will hire PE scientists.

e. **Synthesis Chemist** – If one loves organic chemistry, then raw material synthesis is the place to develop your career. Most of these jobs will be with raw material suppliers.

f. **Regulatory Scientists** – For the people who like science but do not like to be in the lab, this is a good place to go to. Nearly all companies hire regulatory scientists and even more jobs are being added, because more governmental regulations make it tougher to create innovative cosmetics.

g. **Marketing (sales)**– If one likes talking to people, but also cosmetics and cosmetics industry. Professionals in cosmetics marketing careers manage research focus groups, promote the desired brand image, and provide other marketing services (sales forecasting, allocation to different retailers, etc.).

References

http://en.wikipedia.org/wiki/Cosmetics#Cosmetic_careers
http://en.wikipedia.org/wiki/Prosthetic_makeup
http://chemistscorner.com/how-to-become-a-cosmetic-chemist/

[5] A contract manufacturer is a type of manufacturing business that specializes in producing goods for a client, based on specific criteria that is provided by that client.

WP3
PHOTOCHEMISTRY

European Science and Technology in Action Building Links with Industry, Schools and Home

Work Package 3

Photochemistry
Teacher Information

European Science and Technology in Action: Building Links with Industry, Schools and Home

Lead partner for deliverable: **CMA**

Lead partner for Unit: **JU**

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I. Unit description

The unit photochemistry[1] is an interdisciplinary unit built on the chemistry, biology, physics and issues. The whole unit is based on the properties of light and electromagnetic waves. It consists of 4 subunits:

Subunit	Level	Number of hours
I. The magic of colours	lower secondary school	2
II. In the rainbow-hued land	lower/upper secondary school	5
III. How to measure the colour?	upper secondary school	12
IV. In the world of energy		8

Each of the subunits contains engaging questions and research Activity s for students.
In the whole unit, a great emphasis was placed not only on students' hands-on Activity s, but also the preparation of the research tools, and so the students:

- in subunit II – construct a simple spectroscope,
- in subunit III – construct a colorimeter,
- in subunit IV – construct light source chambers and a solar cell.

In the case of limited time for the unit completion, devices recommended for independent preparation can be replaced with their commercial equivalents.

[1] Photochemistry is defined as a discipline of natural science, that deals with chemical processes occurring under the influence of the electromagnetic radiation. For the purpose of this study, the word 'photochemistry' is used in relation to the thematic unit based on the chemistry, biology, physics and interdisciplinary issues.

Structure of the unit:

Subunits	Laboratory exercises for students	Type of inquiry	Topics
I. The magic of colours	• Where does colour of an object come from?	Guided discovery	• The concept of colour • Mono- and polychromatic light • UV-VIS spectroscopy
	• Mixing colours	Guided discovery	
II. In the rainbow-hued land	• Are the rainbow colours always the same?	Guided discovery	• Structure of the atom • Excited state of electrons • Diffraction and scattering of light • Continuous and band spectrum of light • Types of radiation • Absorption and emission of light • Mechanism of colour vision • Structure of the eye • UV-VIS spectroscopy
	• What is the spectrum of white light after passing through the coloured objects?		
	• The visible light and what's next?	Guided discovery	
	• What is the difference between the light from the fluorescent lamp and the light of bulb?	Guided discovery	
III. How to measure the colour?	• Construction of a colorimeter	Guided discovery	• Colorimetry • Lambert Beer's law • Methods of measurement of the concentration of coloured solutions • Properties of d-block elements • Structure and properties of complex compounds
	• Determination of the Lambert Beer's law	Guided inquiry	
	• Determination of $CuSO_4$ concentration in unknown samples.	Guided inquiry	
	• Estimation of the iron(III) ions amount in water.	Bounded inquiry	
	• The equilibrium between cobalt complexes	Guided inquiry	
	• Cyanotype.	Guided inquiry	
IV. In the world of energy	• Photos from the starch. How do plants get their energy?	Guided inquiry	• Nutrition of plants – photosynthesis process • Anatomy and physiology of plants • Reserve substances of plants • The flow of energy in nature • Extraction of dyes • Performance of solar cells • Determination of device capacity
	• The photosynthesis performance	Bounded inquiry	
	• How can we use the solar energy?	Bounded inquiry/ Open inquiry	

II. IBSE Character

Each of the Activity s presented in the unit is based on the so-called engaging questions. A teacher should guide a discussion in such a way, that students will define the research problem, which forms the basis of presented Activity s, by themselves. Activity s III.3, IV.2, IV.3b are open inquiry kind. Exemplary approaches for solving these problems as well as exemplary results are included. Due to the fact, that students should design the procedure for the Activity by themselves, the outcome may strongly depend on the chosen method.

III. Pedagogical Content Knowledge and learning paths

The 'Photochemistry' unit is mainly based on the chemical issues and can be carried out during chemistry lessons. The interdisciplinary character of discussed problems also predisposes it to be realized during nature lessons at the upper-secondary level. Some of the proposed Activity s can also be used independently during biology and physics classes. The unit can therefore be carried out:

- As an interdisciplinary path – recommended when all the students attend chemistry, biology and physics lessons.
- As an interdisciplinary project - in cases where students attend only selected lessons from the natural science path. In that case, it is essential to ensure cooperation and information exchange between the subject teams.
- As a topic of the nature lesson in the upper-secondary school:

  Section 11Light and vision[2]

  - 11.1. Colours and their submission (not sure what this means); the RBG and CMYK colour notation; light-sensitive elements in camcorders and digital cameras.
  - 11.2. Photosensitive substances; formation of an image on the photosensitive material.
  - 11.3. Photoreceptors and eyes of the animals; formation of an image on the retina and in the brain; a photographic print on a leaf; bioluminescence.
  - 11.4 A picture civilization – picture as the transfer of information, its social and cultural conditioning.
- As a topic for extracurricular activities for interested students.

An example of division of problems discussed in the unit for different subjects is presented in the following chart.

---

[2] The core curriculum with comments, the 5th volume. Natural science education in primary school, secondary school and high school. The annex to the Regulation of the Minister of National Education of the 23rd December 2008 on the core curriculum of the kindergarten education and general education in particular types of schools with comments.

Photochemistry

Chemistry

- structure of the atom
- excited state of electrons
- structure and properties of coordination compounds
- properties of d-block elements
- methods of measurement of the concentration of coloured solution
- chemical equilibrium
- extraction of dyes
- alternative sources of energy
- nanostructures

Biology

- mechanism of color vision
- structure of the eye
- nutrition of plants – photosynthesis process
- anatomy and physiology of plants
- plants' reserve material
- the flow of energy in nature

Physics

- diffraction and scattering of light
- the concept of colour
- mono- and polychromatic light
- continuous and band spectrum of light
- types of radiation
- Lambert Beer's law
- absorption and emission of light
- colorymetry
- UV-VIS spectroscopy
- determination of device capacity

During following issues from the „Photochemistry" unit, student:

- explores how colours are formed,
- becomes familiar with the RGB scale,
- gets to know with the mechanism of the human eye action,
- gets to know with the mechanism of colour vision,
- gets to know with the concept of the primary and complementary colours, can explain their meaning,
- gets to know with the phenomenon of splitting the light and is able to give its example in everyday life,
- discovers the continuous and linear spectrum,
- discovers the existence of UV and IR radiation,
- learns to associate light with the wave of a certain energy,

- learns about methods of invisible light detection,
- becomes familiar with the structure and working of colorimeter,
- becomes familiar with elements of the environmental analytics on the example of the contamination with the iron compounds,
- becomes familiar with elements of the instrumental analysis and its application in measuring the concentration of given substances in solution,
- gets to know with the chemistry of the photographic process and its chemical origin,
- becomes familiar with the properties of complexes a discussion of their properties on the example of the cobalt compounds,
- becomes familiar with the alternative energy sources on the example of the solar cell
- consolidates knowledge from the field of structure and nutrition of autotrophic organisms,
- learns about redox systems and their application in getting energy.

Realisation of the above educational purposes also influences on the student's skills in the range of:

- planning the course of Activity s,
- setting up the research hypotheses,
- verification of hypotheses and making conclusions,
- evaluation of the performed Activity s,
- an independent design and construction of research equipment.

IV. Industrial Content Knowledge

Topics discussed in this unit on the borderline of chemistry, physics and biology are used in many areas of life. For example, the RGB scale is used e.g. in the case of monitors, computer and television. The composition of colours, the colour mixing is applied in painting (also in the room one). It is the practical knowledge, that may be useful in the life of each student. Interactive websites that show demonstrate the mixing the colours are also worth visiting:

- http://meyerweb.com/eric/tools/colour-blend/,
- http://www.colourschemer.com/online.html,
- http://www.colourblender.com/

Optical phenomena are widely used in technology: the reflection of light – in the pier glasses, mirrors, reflectors; the refraction of light – in lenses and devices containing lenses; the total internal reflection – in optical fibres; polarization in displays. Prisms are used in sights and rangefinders.

The UV lamps are applied for instance in:

- polygraphy – drying and curing of paints and varnishes (digital printing, pad printing and offset printing, and also the furniture industry), exposures of templates for screen printing, production of packaging for foods (the UV flexo),
- curing of adhesives and nail tips,
- dealing with harmful microorganisms and disinfection of:
  - transporters and conveyor belts (the food, chemical and cosmetic industry)

- air (laboratories, the so-called “cleanrooms” e.g. in the pharmaceuticals industry, offices, hospitals)
- water – in the water supply systems, swimming pools and aquariums

The infrared lamp (Sollux) in used for the treatment of such disorders as ear, nose and throat diseases, it is also used in case of bruises, as well as in the treatment of rheumatic diseases. It is also widely applied in dermatology and cosmetology e.g. in the treatment of acne. Infrared lamps irradiation helps in the muscle diseases, rheumatism, arthritis and back pain. Moreover, suchirradiation will strengthen the immune system and may suppress the development of the disease when the first symptoms of colds occur. Infrared rays have also relaxing and calming effects. Heat emitted by the infrared lamps penetrates deep into the skin, stimulates the metabolism and the blood circulation, and thus may be useful in the fight against cellulite. The lamps are being increasingly used for hair drying in hairdressing salons and beauty salons, as well as for heating churches and cafes in the fall-winter season.

Knowledge about the light and its effects on the skin is used in the production of sunscreen means (creams / foams / sunbathing oils).

Photosensitive materials are used in photography, production of films, and some fax machines. Mid-infrared spectroscopy is used for: identification of substances of known structure, determination of molecular structure on the basis of group frequency table, determination of the compounds purity, control of the course of the reaction, quantitative analysis, the study of intermolecular interactions.

The near-infrared spectroscopy is used in the study of the moisture content in flour, starch, milk powder, instant coffee, crisps, and also in the analysis of the spectrum of light reflected or emitted by the planets.

Colorimetry is an analytical technique for determining of the concentration of colour solutions through visual comparison of the colour intensity of the test solution with the intensity of the colour of the reference solution. The method is regarded as simple, fast and accurate. Miniature handheld colorimetric kits with colour tables are used in medicine, food testing (beer, alcoholic drinks of a whisky type, and the caramel dye, oils and fats present in them):

- http://www.donserv.pl/index.php?option=com_content&view=article&id=137&Itemid=131,

measurements of the water parameters in the power industry and the production of industrial water, drinking water and in the wastewater treatment plants:

- http://www.metrohm.pl/Applikon/Alert_Colorimeter.html,
- http://www.mera-sp.com.pl/przyrzpom.php?go=kolorymetry,

as well as in the agricultural measurements and the environmental contamination studies:

- http://www.envag.com.pl/aparatura-terenowa-rzeki-jeziora-cieki-wodne/kolorymetry/564-kolorymetr-dr800-firmy-hach.

Colorimetry is widely used for quick estimation of solution pH by means of the calibrated indicator papers. It is one of the methods widely used in the water studies in the laboratories of the National Sanitary Inspection.

V. Science Content Knowledge

Light is a form of energy whose properties can be explained either on the basis of wave and particle instead theory. We talk about the so-called particle-wave dualism. The wave nature of light is indicated in the Planck relation $E = hv$, which relates the energy of the particle to one of the wave properties by one of the wave properties – frequency. In the following work, we will focus on light as an electromagnetic wave. Electromagnetic wave is characterized by two main parameters: A – the amplitude, and frequency (ν) and wavelength ((λ).) that determines the colour of the light[3] ν(λ). Frequency and wavelength are related to each by a constant, the speed of light. The spectrum of the daylight VIS (Figure 1) illustrates the link between the energy and wavelength and the change of the colours of light. Each of the colours is associated with the appropriate wave parameters. Directly adjacent to the VIS spectrum is the IR (infrared) (lower energy) spectrum and UV (ultraviolet) (higher energy) spectrum.

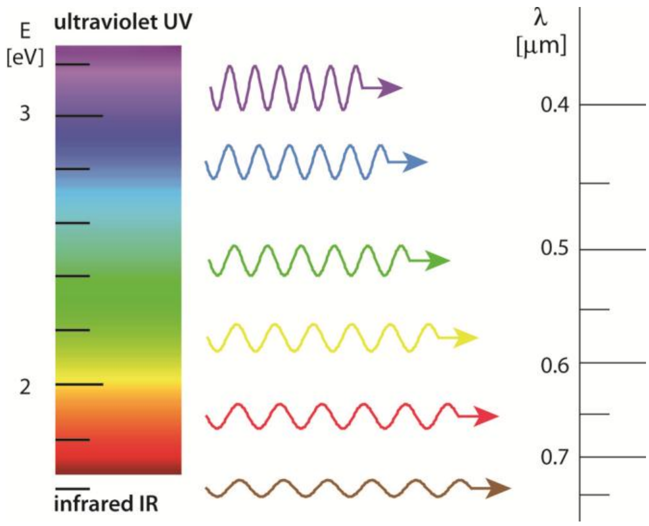

Figure 1. The white light spectrum with the wave parameters corresponding to particular colours. (Derived from: *Krzysztof Korona, Materiały do wykładu Fizyka w doświadczeniach, Uniwersytet Warszawski 2010)*

The colours of items that are perceived by the human are images resulting from the interpretation of light waves reaching the eye. The human eye is sensitive to waves responsible for the following

[3] Frequency and wavelength are treated as one parameter as they are related to each other by a constant according to the formula: $\nu \cdot \lambda = c$

colours: blue, red and green. Other colours are perceived thanks to the analysis of the differences in the intensity of those three waves.
The colour parameters of light-emitting elements could be encoded thanks to the RGB colour scale (from the English words: R – red, G – green, B – blue). The scale gives the intensity of the primary colours in the range of 0-255, for example: white (255,255,255), black (0, 0, 0).
The human eye perceives colour thanks to the presence of three types of so-called cones. Each type of the cones is sensitive to 1 colour so that it responds to light of a different wavelength. Colour blindness (daltonism) is a result of the impairment of one or more of the three types of cones.

Camcorders and digital cameras record the electromagnetic waves through silicon detectors. These detectors are sensitive to light with wavelengths shorter than 1.1 µm (of an energy of over 1.1 eV). LED diodes, commonly used in remote controls for operating various devices, emit light of wavelength of 0.9 µm (having an energy of over 1.4 eV). Silicon detectors can thus be used for recording light not visible to the human eye. It is interesting, that bees have the ability to see the ultraviolet light – I think.

Matter may:

- produce the light (emission),
- consume (absorption),
- change the direction of propagation (scattering).
- Transmit the light

Mechanism of the colour creation is a combination of above-mentioned processes.

A continuous spectrum of light is a characteristic of objects that are luminous because of their high temperature, such as light bulbs and the sun. Coloured substances absorb certain wavelengths, and reflect the remaining. Absorption is connected for example with the excitation of electrons, which are moved from their ground states to the excited states. Below, in the Figure 2.a the absorption spectrum of hydrogen is presented. In the spectrum of white light, colours that correspond to the energy absorbed by the excited electrons in hydrogen atoms are missing. In Figure 2.b the emission spectrum of hydrogen is shown. This spectrum arises, when the excited electrons in hydrogen atoms go back to the state of a lower energy and emit the excess energy.

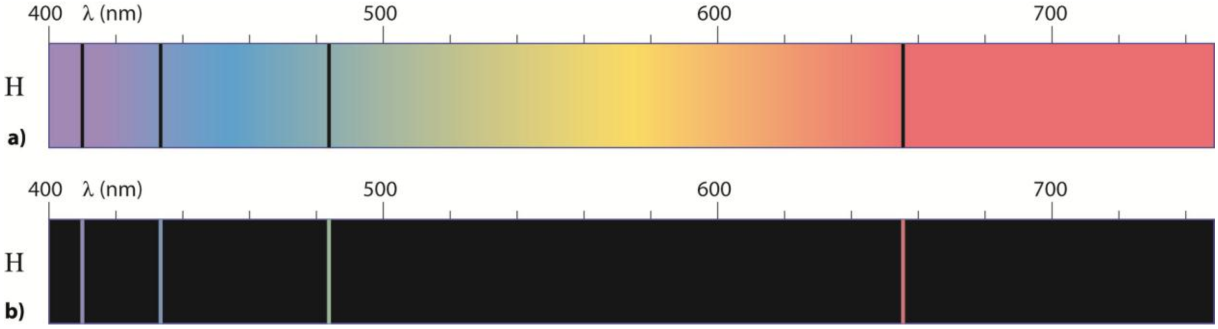

Figure 2. Hydrogen spectrum a) absorption spectrum, b) emission spectrum. *(Derived from: Physics for Scientists and Engineers (6th ed.) by Serway and Jewett,Thomson Brooks/Cole, 2004).*

Only some of the electron transitions in the hydrogen atom are associated with the visible light. Emission spectrum of hydrogen and the possible electronic transitions are presented in Figure 3.

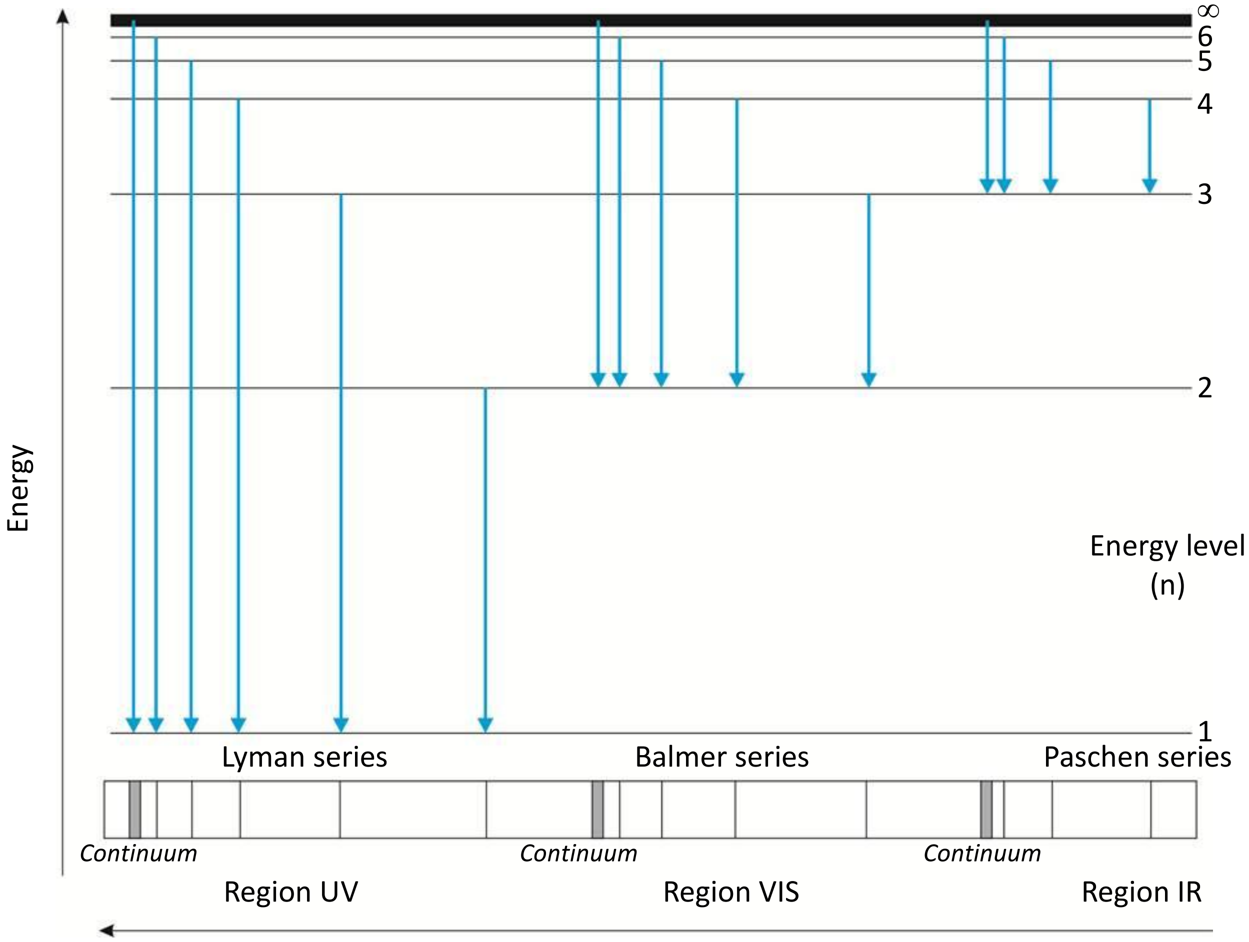

Figure 3. Possible electron transitions and series of the hydrogen emission spectrum. *(Derived from: John Green, Sadru Damji, Chemistry (3rd ed.), IBID Press, 2007)*

Hydrogen and other elements are able to emit electromagnetic waves not only in case of heating them to high temperature. After excitation (need to apply a current), the light creates a band spectrum, characteristic for each element. Fluorescent lamps are examples of the „cold" light source.

The ability to absorb (and therefore emit) light from the visible spectrum is a characteristic of the coordination compounds of transition metals. The d-type atomic orbitals of the isolated atoms of a given element are of the same energy. In the surroundings of ligands, the energy levels are split into sublevels. For the compounds that have an octahedral structure (coordination number 6), the characteristic splitting is that, when three energetic sublevels are of the lower energy, and two – of the higher energy. (Figure 4).

Difference in energy of the levels corresponds to the energy of the visible light and depends on the geometry of the coordination compound[4], coordination number and the type of ligands. However, it

[4] Current recommendations say that 'coordination compound' is related to compound with inorganic ligands, when ligands are organic, we say about 'complex compound'. In this work, those terms are used alternatively.

should be remembered, that according to the quantum chemistry theories, the d-d transitions in octahedral complexes with a centre of symmetry are forbidden.
This is the main problem that occurs during the interpretation of the spectra of complex compounds. The Laporte selection rule states: the only transitions allowed are those, which are accompanied by the parity change. Nevertheless, as a result of asymmetric vibrations, the complex centrosymmetry is disturbed. Therefore, due to the lack of the centre of symmetry, d-d transitions are no longer forbidden and gain slight intensity. In such cases, when thanks to asymmetric vibrations in the molecule, the transition gains in intensity, it is called the vibronic transition.

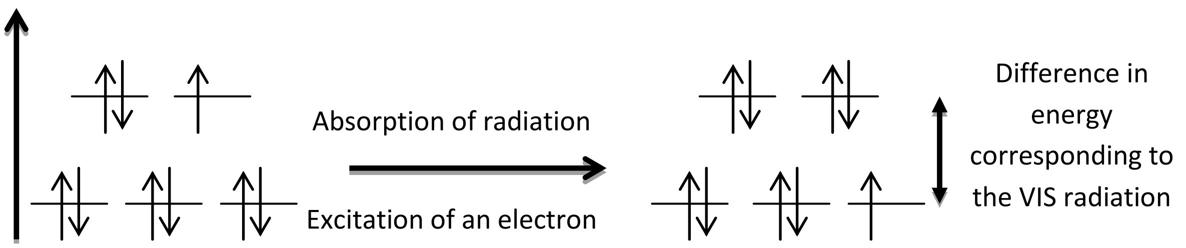

Figure 4. Diagram of d-type orbitals splitting and the electronic excitation for the octahedral coordination compounds.

Spectroscopy is a set of techniques involved in studying the interactions of electromagnetic radiation with matter; it is also a broad area of various techniques of chemical analysis. Depending on the energy of the analysed waves, different types of spectroscopy are distinguished e.g, infrared, visible, uv.

Another method based on the interaction of radiation with matter is colorimetry. It allows the determination of the solution concentration on the basis of its colour intensity. In the measurements, a device called a colorimeter is used, and it was invented by a Polish researcher Jan Szczepanik. The colorimeter measures the amount of light that passes through the sample. The dependence of light intensity on the concentration is described by the second absorption law, called the law of Lambert-Beer. It is expressed by the equation $A = \frac{\log I_0}{I} = \varepsilon bc$; where: A represents absorbance, I_0 – the radiation intensity before passing through the sample, I – the intensity of radiation that passed through the sample, c – the concentration of the solution, b – the cuvette thickness, ε – the molar absorption coefficient. As follows from the above-presented equation, the absorbance (A) – which describes the ability of the absorption of radiation - is directly proportional to the concentration of substance in the solution and that proportionality is used in the colorimetric measurements.

The absorbed energy of electromagnetic waves may be emitted, as it is case of simple chemical compounds. However, plants possessed the ability of storing and processing the solar energy – in the process called photosynthesis. Photosynthesis can be defined as an anabolic biochemical process, as a result of which, with the use of solar radiation and with the participation of assimilatory pigments and enzymes, monosaccharides (in the form of hexoses) are produced from the carbon dioxide. Before the solar energy will take part in this complicated biochemical process, it has to be "captured" – in order to do this, the plants need chlorophyll. Thanks to this dye, plants are capable of absorbing light and using it in photosynthesis. Chlorophyll is green, because it absorbs blue and red light, whereas green light is passed through it without being absorbed. The energy of light is absorbed by chlorophyll for wavelengths corresponding to the red and blue colour of light and then it is used for the conversion of carbon dioxide into the glucose. If the amount of the glucose produced in this process in greater than a demand for it, the sugar is converted into starch by linking many glucose molecules together to form a long chain (polymer). At night, it is the starch that is transformed back to the grape sugar (glucose) to provide energy for plants, until the sun rises again and the chlorophyll is able to absorb the appropriate amount of light to renew the starch reserve.

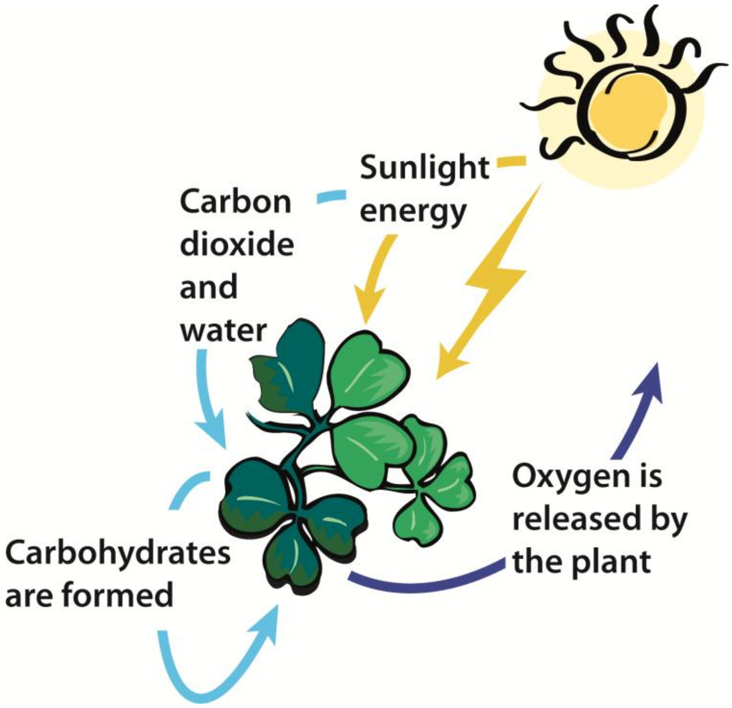

Figure 5. A graphic scheme of photosynthesis

The possibility of using solar energy and transforming it into electricity is extremely important for the future of humanity. The solar cells are semiconductor devices, in which occurs the conversion of solar energy into electricity as a result of the photovoltaic phenomena. Solar cells are used e.g. for the artificial satellites, space probes, calculators and watches. However, their disadvantage is that they absorb mainly the ultraviolet light, whereas the highest amount of solar energy that reaches the Earth is from the region of visible light. Hence, the idea of sensitization of semiconductor by organic dyes, which efficiently absorb the visible light was brought up. Such a cell was first built in the Swiss Federal Institute of Technology in Lausanne, Switzerland in 1991 and now attracts considerable attention of researchers - although it is not yet used commercially.

Literature:

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- John Green, Sadru Damji, *Chemistry (3rd ed.)*, IBID Press, 2007
- Peter Atkins, *Physical Chemistry*, sixth edition Oxford University Press, Oxford Melbourne Tokyo 1998.
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VI. Assessment

Assessment is very much dependent on the really taught way and the elaborated content. This will differ in each school, each class and each country. Assessment tasks have to be constructed together with the teacher in charge.

WP3
PHOTOCHEMISTRY

European Science and Technology in Action Building Links with Industry, Schools and Home

Work Package 3

Photochemistry

Student Activities & Classroom Materials

European Science and Technology in Action: Building Links with Industry, Schools and Home

Lead partner for deliverable: **CMA**

Lead partner for Unit: **JU**

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VII. Student Activities

Subunit I – The magic of colours

Activity I-1: Where does colour of an object come from?

Engaging questions:

- Why do objects have different colours?
- What is the mechanism of the colour creation?
- What is the colour of light emitted by green jelly bear that is highlighted with a flashlight?
- What is the colour of light emitted by a finger that is highlighted with a torch?
- What is the colour of light emitted by green jelly bear that is highlighted with a red laser pointer?
- What is the colour of light emitted by black jelly bear that is highlighted with a flashlight?

Chemicals: Jelly bears of different colours. Instead of the bears, cuvettes filled with the coloured solutions can be used, they may be the solutions of food dyes (recommended for younger children) or for example:

- green solution: $FeCl_2$ at the concentration of 1 mol/dm^3
- red solution: HCl at the concentration of 1 mol/dm^3 + methyl orange,
- violet solution: $KMnO_4$, 1 mol/dm^3 (or blue solution: $CuSO_4$, 1 mol/dm^3)

Equipment: flashlights, various colours laser pointers.

Caution! Do not stare into pointer beam!

Description of the Activity :

Students:

1. Highlight jelly bears (cuvettes) by a flashlight.
2. Highlight a finger by a torch.
3. Highlight jelly bears (cuvette) by lasers.
4. Highlight a finger with green and red pointer.

Discussion:

- Why finger highlighted with flashlight is red?
- What is the difference in illumination of objects with laser and flashlight?

Activity I-2: Mixing colours.

Engaging questions:

- How are colours on the TV set created?
- What are the base colours?

- How are complementary colours formed?
- What is the mechanism of the human eye action?
- What colours can the human eye perceive?
- What is the RGB scale?

Equipment: flashlights, filters: green, blue, red (they can be made of tinted film).

Description of the Activity :

Students put filters on the torches, and then watch the colour of light on a white sheet of paper. Then, they illuminate the same spot using two torches.

Discussion:

- What is the colour of light that will be formed as a result of superposition of light from all 3 torches?
- What is the colour of light that will be a result of putting on a torch 2 different filters?

Subunit II – In the rainbow-hued land.

Activity II-1: Are the rainbow colours always the same?

Engaging questions:

- What do we see on the back of CD/DVD when we illuminate it with flashlight?
- When can we see a rainbow?
- What is the colour of the sunlight?
- How many colours are there in the rainbow?
- What is the colour of the sky?
- Why sky is blue during a day and yellow or red in the evening?
- Why stars are invisible during a day?
- Why is the sky blue during a day, the evening?

Equipment:

- a cardboard or PCV tube of the length of about 50 cm,
- carton – for aperture preparation,
- plasticine – as a sealant,
- a lamp with bulb or a flashlight,
- splitting element e.g. diffraction grating, prism or CD/DVD (from the recorded disc, the layer of an aluminium foil should be removed, e.g. by sticking and unsticking the adhesive tape),
- recorder – digital photo camera (the mobile phone camera may be used).

Description of the Activity :

The spectroscope diagram is presented at Figure II.1. One side of the tube should be shut off by the aperture (a cardboard disk with a slit as narrow as possible). The disk can be embedded and sealed with the use of plasticine. On the other side of the tube (about 3-4 cm from the end), a transverse incision should be made, being a place for the splitting element, which should be put there. The light source should be placed on the side with the slit. On the other side, at an angle of about 30 degrees, a light detector should be placed (Figure II.1). In order to prevent light entering the detector from the side, it can be covered with a cloth. The spectrum of the bulb and of the sun are recorded.

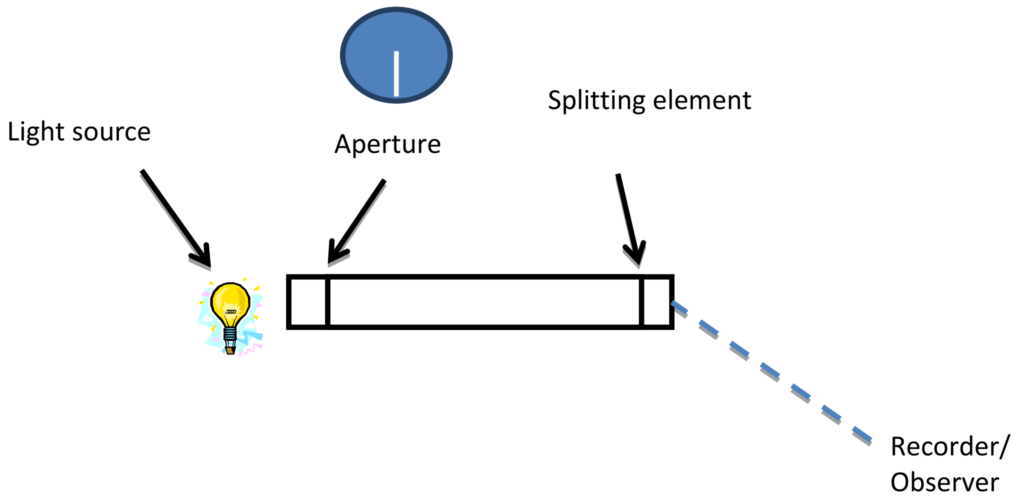


Figure II.1. A diagram of the spectrometer structure.

Discussion:

- Are the observed light colours similar to the rainbow?
- Are the colours of the rainbow arranged in the specific order?
- Are the observed light colours similar to the colours of the sky?
- Why is the light being split?
- What parameter influences the level of colour separation?

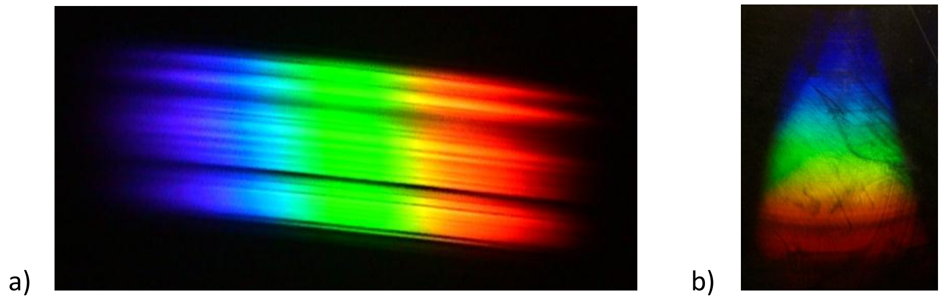


Figure II.2. An exemplary bulb light spectrum a) splitting element – a diffraction grating, b) splitting element – a CD

Activity II-2: What is the spectrum of white light after passing through the coloured objects?

Engaging questions:

- What will be the colours in the room illuminated by daylight if we shut the window pane with red foil?
- How does the spectrum of the light bulb change after passing through the red filter?
- What should the spectrum of the red light bulbs look like?

Reagents:

- green solution: $FeCl_2$ 1 mol/dm^3
- red solution: HCl + methyl orange,
- violet solution: $KMnO_4$ (or blue solution: $CuSO_4$ 1 mol/dm^3)

Equipment: Spectroscope from the Activity II.1, lamp with a bulb, cuvettes.

Description of the Activity :

Students fill the cuvette with the coloured solution. Cuvettes are placed in the spectroscope on the light path, in front of the shutter (Figure II.2). Students collect the spectra.

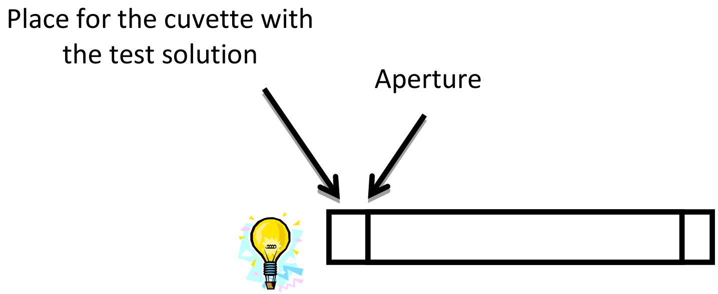


Figure II.3. A diagram of the spectrometer structure together with a place for the sample.

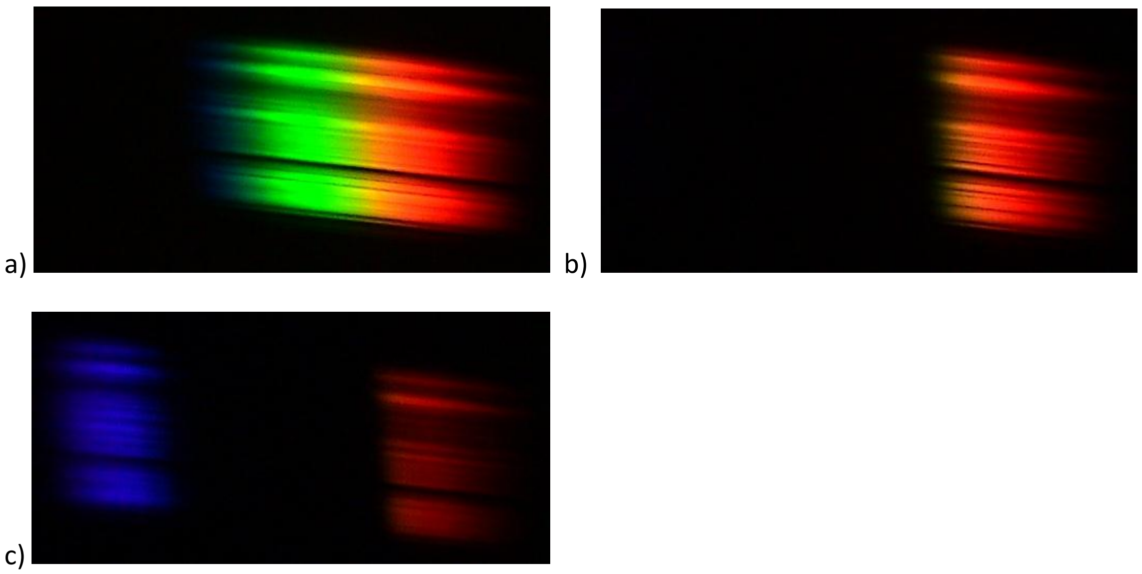


Figure II.4. The spectrum of white light after passing through the solutions: a) $FeCl_2$, b) red food dye, c) $KMnO_4$.

Discussion:

- Compare the colours from the spectra with the solution colours,
- What colours are „missing” in the observed spectra?
- Should the intensity of the solution colours influence the spectra appearance?
- Should the intensity of the bulb light used in the Activity influence the spectra appearance?

Activity II-3a: The visible light, and what's next? – IR radiation

Engaging questions:

- When a TV channel is changed, certain information is sent from the remote control to the television set. How does the remote control communicate with the TV set?
- How does the human eye work?
- Does every person perceive colours in the same way?
- Why are the dog whistles inaudible to people? more useful for sound unit

Equipment: TV remote control (VCR or DVD player), cell phone with a camera (or digital camera, camcorder).

Description of the Activity :

Students try to see the light from the remote control with the naked eye and through the camera. They may take photos or make a video

Discussion:

- Why cannot we see the light emitted by the TV remote control?
- Why does not every remote control works with each TV set?
- Are we able to switch the TV channel turning the remote control in the opposite direction than our TV set?
- Daltonism is a disorder of colours vision and recognition. With what may it be related? Compared to the camera, are we all daltonists?
- How does a thermal imaging camera work?
- Why do cats see well at night?

Activity II-3b Visible light, and what's next? – UV radiation

Engaging questions:

- Do you know what types of waves can you not see? How can you prove their existence?
- How do we know, that there is UV radiation?
- How do the sunglasses and sun creams work?

Equipment:

- box (e.g. shoe box),
- prism,
- light-sensitive blueprint paper, (a description of the paper preparation is the Activity III-5)
- Pencil.

Description of the Activity :

Students make an incision in the box and they place there the prism. Then, the box is placed in the sun. The sunlight should be split into different colours of light when it passes through the prism – on the bottom of the box, the white light spectrum should be seen (Figure II.5). In the place where the spectrum is visible, students place the blueprint paper and copy the spectra contour plot (marking the red and blue colour) as soon as possible. The Activity is left for the light exposure for about 20 minutes.

NOTE: The Activity should be performed during a sunny day. In case of poor insolation, the effect may be difficult to observe or may occur after a long time.

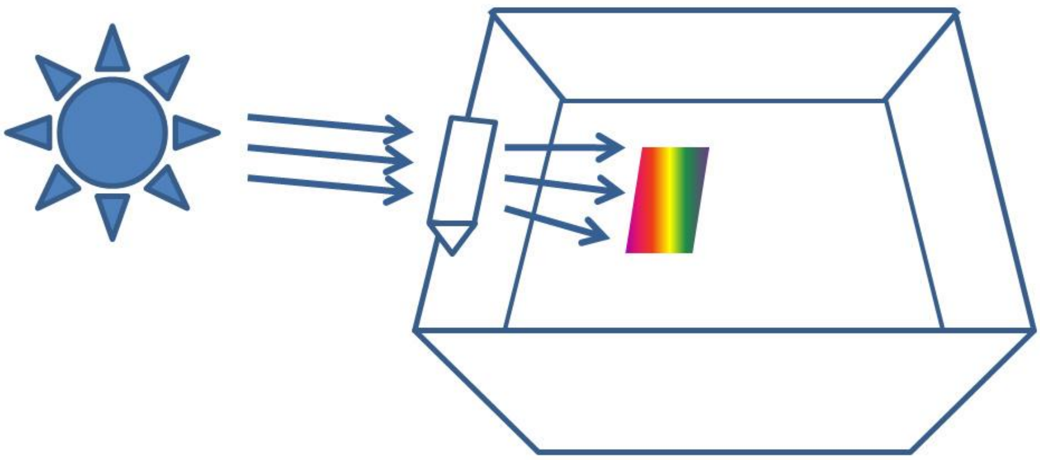


Figure II.5. A scheme of the experimental setup.

Discussion:

- Why is the paper exposed in a larger area than the copied contour?
- From the side of which colour is the exposure outside the contour bigger?
- Why does the ozone hole carry an increased risk of sunburns and its consequences?
- Should we cover our eyes with special eye protection if the light of lamps does not dazzle us through the closed eyelids?
- What should the parameters of sunglasses be to effectively protect our eyes?

Experiment developed by:
http://coolcosmos.ipac.caltech.edu/cosmic_classroom/classroom_activities/ritter_Activity 2.html

Activity II-4: What is the difference between the light from the fluorescent lamp and the light of bulb?

Engaging questions:

- What gases are in the fluorescent lamp?
- Why are there no fluorescent lamps filled with the atomic hydrogen?
- What is the working mechanism of the light bulb and the fluorescent lamp?
- Why does the fluorescent lamp not heat up during working?

Equipment:

- spectroscope from the Activity II-1,
- fluorescent lamp.

Description of the Activity :

Students record the white light spectrum with the use of lamp with a typical bulb, then they exchange it for the fluorescent lamp and compare both images.

Figure II.6. A sample spectrum of the fluorescent lamp.

Discussion:

- Why in the spectrum of fluorescent lamp can only some lines be observed, not the entire set of colours?
- The location of particular bands: to what is it related?
- In the Figure II.7 the emission spectrum of hydrogen atoms is presented. Compare this spectrum with the recorded one. What is the reason for similarities and differences?
- How can the hydrogen spectrum be related to the structure of its atom?
- With what process is the light emission by hydrogen connected?
- The spectrum you recorded is the emission spectrum. Think, how the absorption spectrum of hydrogen and of the fluorescent lamp should look like.
- Emission spectrum of hydrogen presented in Figure II.7 is the atomic spectrum. If we fill the fluorescent lamp with hydrogen, it would be in the molecular form (H_2). Will the emission spectrum of the hydrogen fluorescent lamp be the same as the presented atomic one?

Figure II.7. Emission spectrum of hydrogen atoms. *Derived from Physics for Scientists and Engineers (6th ed.) by Serway and Jewett (Thomson Brooks/Cole, 2004).*

Subunit III - How to measure the colour?

Activity III-1: Construction of a colorimeter

The aim of the Activity is to build a measuring tool – a colorimeter. The constructed device will serve for performing Activity s II.2 and II.3, and its construction is the introduction to the Activity IV.3. Alternatively, a commercial colorimeter can be used (for example: http://www.vernier.com/products/sensors/col-bta/)

Equipment:

- Contact plate (electronic breadboard)
- RGB LED 5 mm
- Photodiode 5 mm
- Resistor 220 Ω - 3 pieces
- Resistor 1MΩ
- 3-channel (or more) programmer
- Voltage regulator - 7805 IC
- 9 V battery
- 9 V battery connector with cables
- Cables
- Superglue (quick-drying glue)
- Plasticine
- Cable cutters
- Tweezer
- Cuvette
- Multimeter
- Cuvette holder – see description below
  - Aluminium tubes
  - Self-adhesive felt or rubber veneer.

Description of the structure:

The whole device is built on the contact plate. The plate provides a base for the next parts as well as an easy connection of resistors and other components without soldering. The plate provides the connection between elements placed in the vertical and horizontal lines of contact regions.

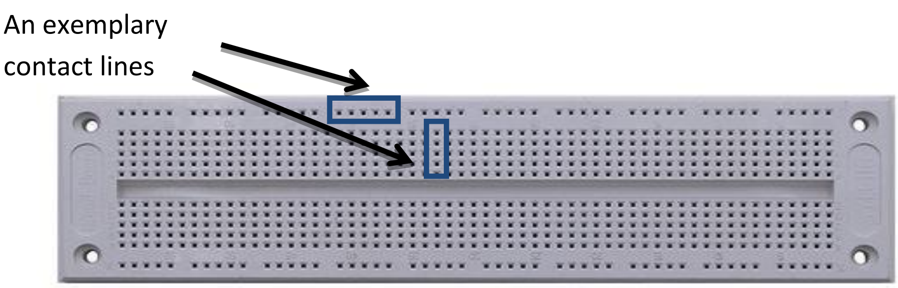


Figure III.1. An sample contact plate (or ’breadboard’).

Cuvette holder preparation:

A role of the cuvette holder may be played by any rectangular box with a matching lid. A convenient solution is the use of rectangular aluminium tubes of: **1**. 20 mm and **2**. 25 mm diameter.

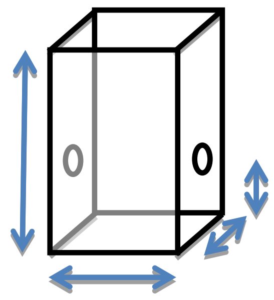


Figure III.2. A diagram of the cuvette holder.

- Cut off the piece of tube:

  - **1.** about 4 cm in length – being a holder for the cuvette
  - **2.** about 1,5 cm in length – being a lid for the holder.

- In the tube No. 1, drill 2 holes of a 8 mm diameter at a height of about 1,5 cm.

In case of difficulties in working with the aluminium tubes, a plastic or cardboard box (e.g. a match box) may be used.

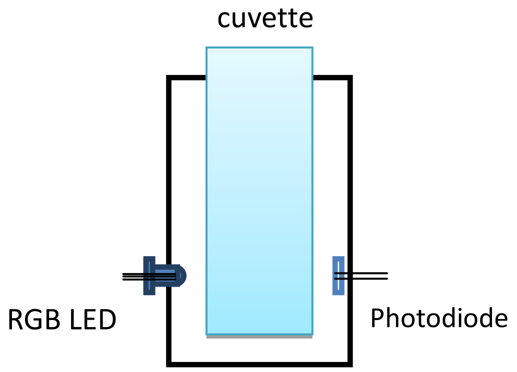
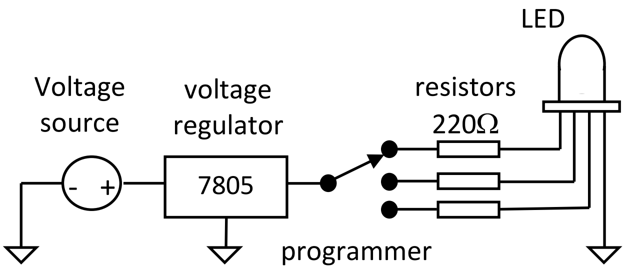


Figure III.3. A diagram of the cuvette holder with the RGB LED and the photodiode installed.

- Wrap around the inner side of the holder with veneer, so that the cuvette fits the place for it in the holder,
- In the holder holes, install the RGB LED and the photodiode. At first, diodes are loosely inserted, so as to have an ability to connect them to contact plate then, their position is fixed with the use of glue.
- Place the cuvette holder on the contact plate.

A diagram of the colorimeter structure:



FigureIII.4. A diagram of the LED circuit.

Connecting the RGB LEDs

- Put a cuvette holder on the contact plate in about 2/3 of its length.
- Connect the RGB LED to the contact pins according to the diagram (Figure III.5).

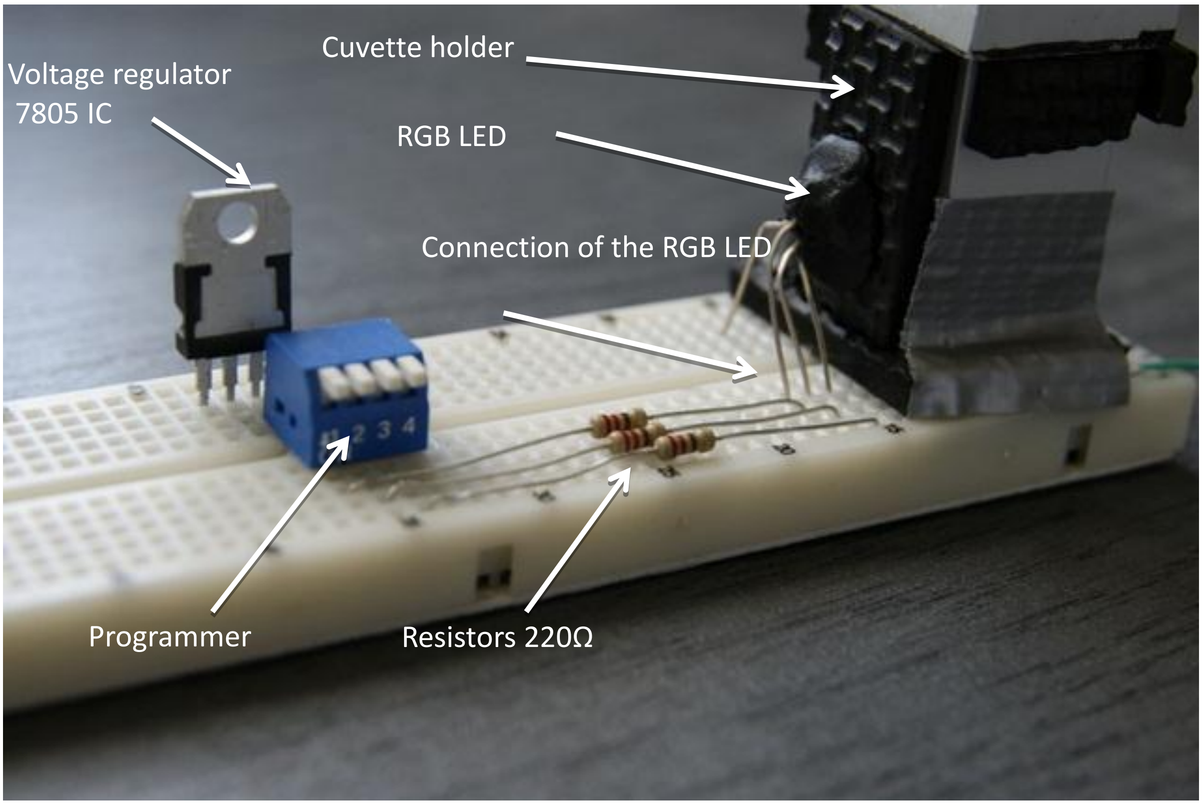


Figure III.5. Power and control system of the RGB LED connected to the contact plate.

The longest leg of the RGB LED is the output, the three others are inputs.

- Plug the legs of the LED into the contact plate according to the Figure III.5.
- After plugging, stiffen the LED position and stick the cuvette holder to the contact plate.
- Then, install the resistors 220 Ω according to Figure III.5/ III.6

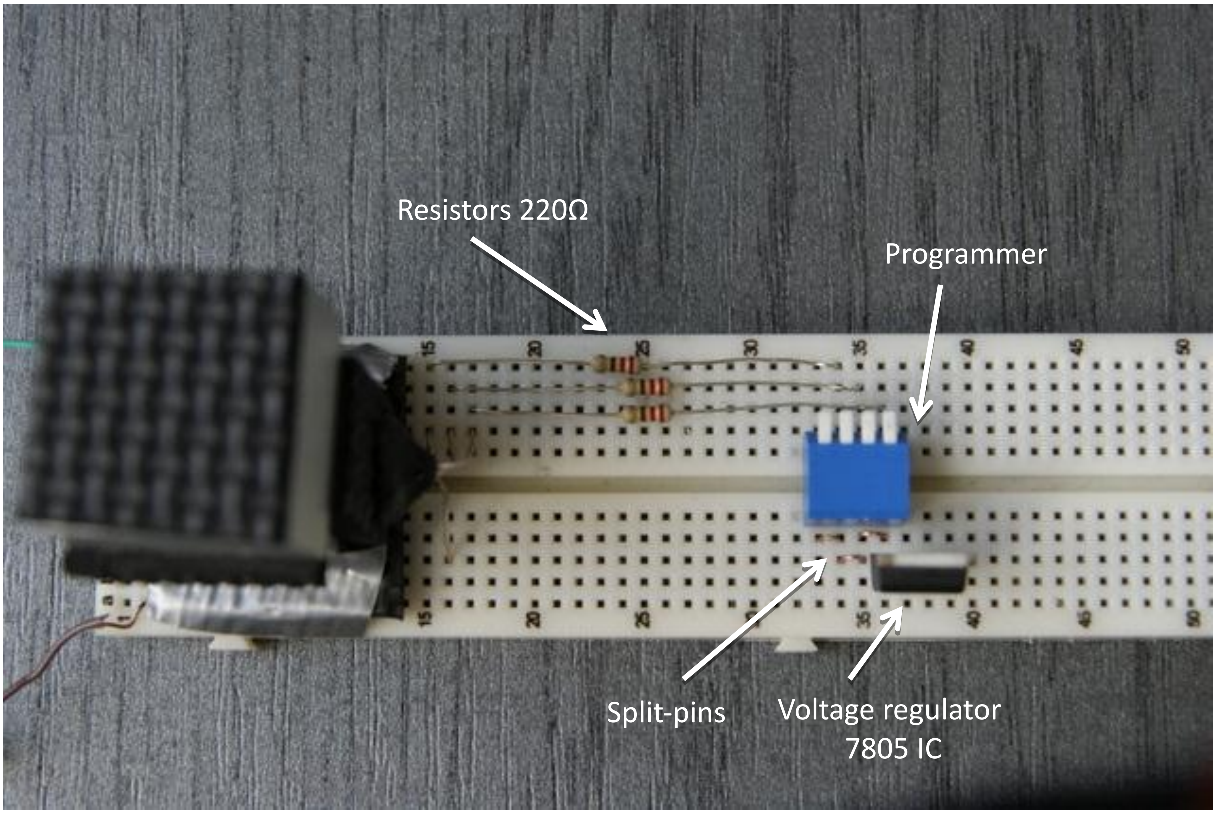


Figure III.6. The control system of the RGB LED connected to the contact plate, top view.

- Install the programmer – 3 joints of the programmer should correspond to the sites of resistors placing.
- From the other side of the programmer, connect all the channels with the split-pins (Fig.III.8).
- Install the voltage regulator in such a way, that the left leg supplies the voltage to the closed programmer channels.
- Connect the voltage regulator
- Connect the power supply (Figure III.7)
- Check the proper working of the system by turning on any programmer channel – the LED lightning should be observed.

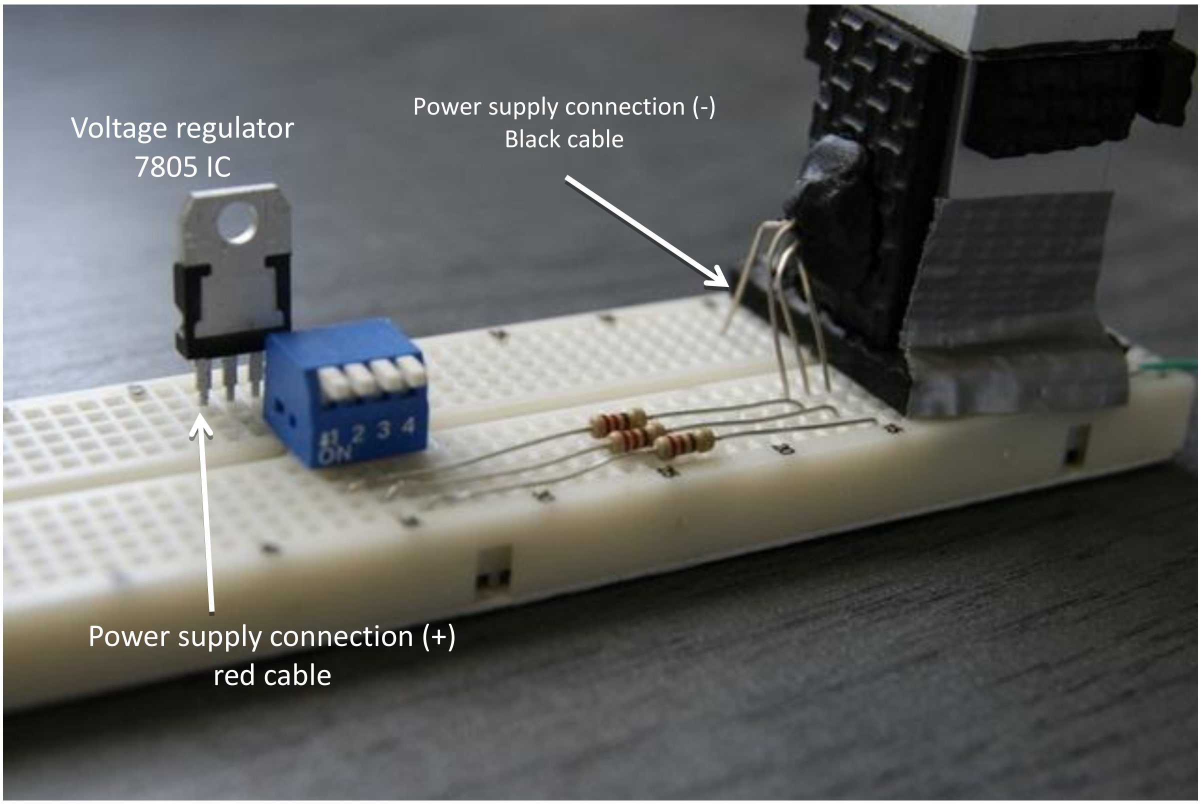


Figure III.7. The power supply connection.

Connecting the photodiode

- Place the photodiode in the cuvette holder (in the opposite side to LED diode).
- Attach two cables to the end of the photodiode – it is best to solder them.
- Plug the cables into the contact plate according to Figure III.8

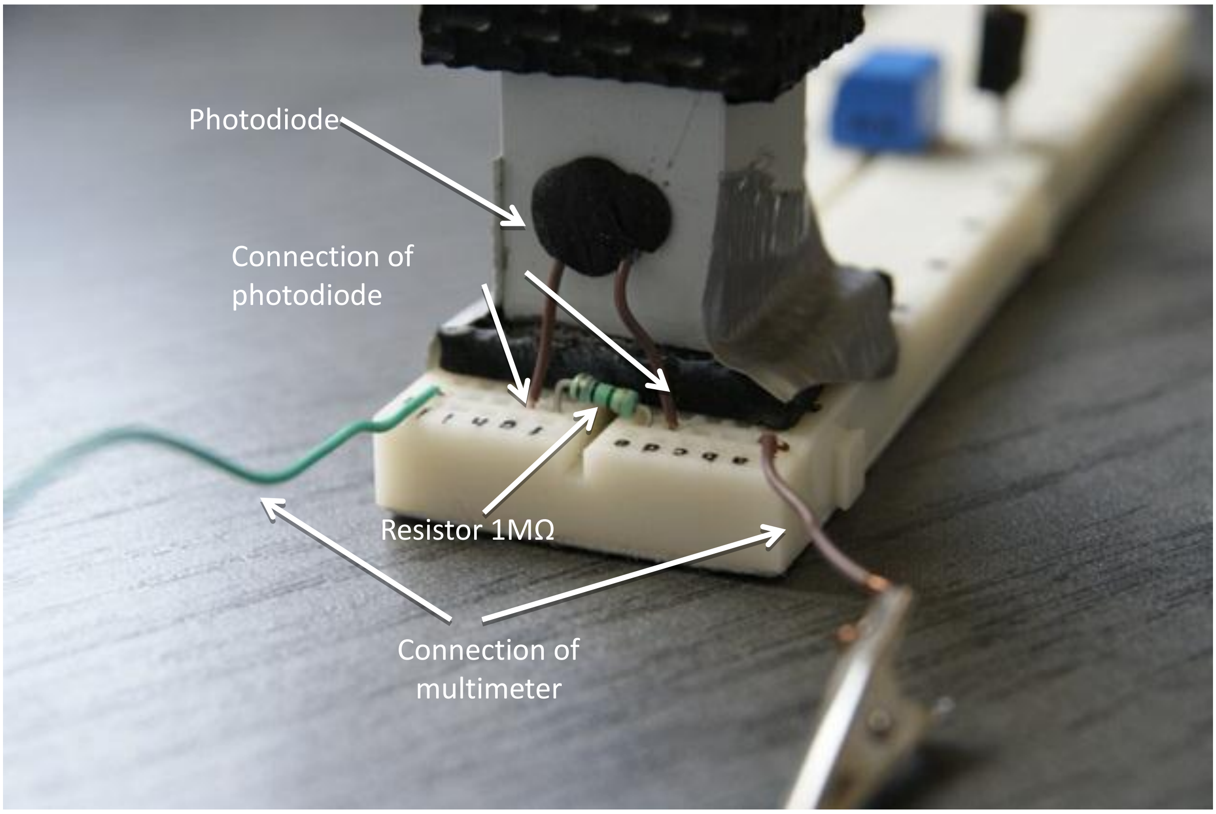


Figure III.8. Connection of photodiode and multimeter.

- Install the resistor 1 MΩ between the photodiode channels,
- Plug the cables supplying voltage to the multimeter into the plate.
- Connect the multimeter – set the DC voltage measurement.
- Control the working of the photodiode – when the cuvette holder is closed and the light is turned off, the voltage should not be observed. The voltage should appear in the multimeter after switching on the light.

The device is ready to use.

Prepared device can be used as PC data logging device. Simple millimetre can be replaced by CMA CoachLab II+ interface and Coach 6 software. In the program the device must be added as new sensor and calibrated.

The shame of the device developed by: Jose H. Bergantin, Jr., and Fortunato Sevilla III University of Santo Tomas, Manila, Filippines

Activity III-2a: Determination of the Lambert Beer's law

Engaging questions:

- What happens to the light when it passes through the solution of the coloured substance?
- How do the so-called tinted windows in cars work?
- How does the floor under the stained-glass window look-like?

- Does the light intensity change after passing through a substance?
- Do the colour of the light influence the change in its intensity when passing through the sample?
- How to choose the colours of light, so as for the sample of a particular colours, the changes in the light intensity would be the greatest?

Chemicals:

- $CuSO_4$ – solution 0.5 mol/dm^3 ,  ,  ,

Equipment:

- colorimeter
- cuvettes – 5 pieces
- pipettes 10 ml – 2 pieces
- beakers 25 ml – 7 pieces

Description of the Activity :

1. Prepare a series of aqueous $CuSO_4$ solutions in range 0.1 - 0.4 mol/dm^3 by diluting the standard solution. A dilution scheme:

Solution [mol/dm^3]	**Preparation**
1. 0.5	standard
2. 0.4	8 cm^3 of solution 1 + 2 cm^3 of water
3. 0.3	6 cm^3 of solution 1 + 4 cm^3 of water
4. 0.2	4 cm^3 of solution 1 + 6 cm^3 of water
5. 0.1	2 cm^3 of solution 1 + 8 cm^3 of water
6. 0	water

2. Perform colorimetric measurements for all the samples for different colours.
3. Plot the voltage dependence on concentration.

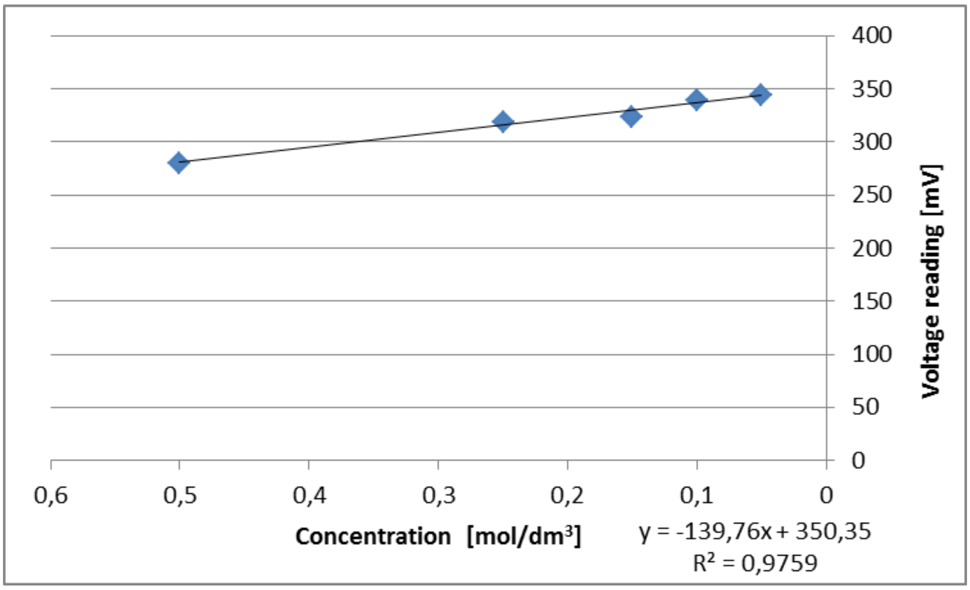


Figure III.8. An example of the dependence of the recorded voltage on the concentration of copper(II) cations for the red colour.

Discussion:

- What light colours should be chosen for the measurements?
- What is the nature of SEM dependence on concentration?
- How could you get similar result, without changing the concentration of the solution?
- You already know the voltage dependence on the sample concentration. Could you use this data to determine the $CuSO_4$ concentration in an unknown sample?
- Why do we perform measurements for pure water?
- Does the test sample concentration have to be in the range 0.1 - 0.5 mol/dm^3?

It is possible to modify the colorimeter described in the Activity III.1, for measuring the dependence of the light intensity that passes through the sample on the optical path length. To do so, the cuvette holder should be prepared in a way that enables placing in it from 1 to 5 cuvettes.

Activity III-2b: Determination of $CuSO_4$ concentration in unknown samples.

Description of the Activity :

- sample 1 – concentration from range 0.1 - 0.5 mol/dm^3
- sample 2 – concentration > 0.5 mol/dm^3

Students perform measurements for unknown samples and basing on the previously performed calibration, determine their concentration using the graphical method.

Activity III-3: Estimation of the iron(III) ions concentration in water.

Engaging questions:

- What substances are present in the tap water?
- Which of those substances are desirable and why?
- What are the differences in composition of the mineral water and the tap water?
- Can the mineral water be used in the water supply?
- The presence of which substances in water may have a negative impact on the human body?
- Who/what institution controls the composition of the tap water?
- Is the rainwater safe for drinking?

Look for answers in following articles:

http://www.filtsep.com/view/18744/ground-water-dealing-with-iron-contamination/
http://www.epa.gov/nrmrl/wswrd/cr/corr_res_iron.html
http://www.ianrpubs.unl.edu/epublic/live/g1714/build/g1714.pdf

Introduction:

The amount of iron(III)[1] in water may be estimated with the use of so-called thiocyanate method. The Fe^{3+} ions, form with the thiocyanate ions, a complex ion of an intense red colour.

$$Fe^{3+} + SCN^{-} = Fe(SCN)^{2+}$$

Ions of iron(III) can form with the thiocyanate several different coordination compounds of similar colour: $Fe(SCN)^{2+}$, $Fe(SCN)_2^{+}$ to $Fe(SCN)_6^{3-}$. In the solutions where the Fe^{3+} cation concentrations are on microgram level, the $Fe(SCN)_2^{+}$ dominates. In addition, this coordination ion may undergo hydrolysis in solutions with a pH>3. The thiocyanate complex is unstable, and degrade with time.

Imagine that to the laboratory where you work, a water sample with unknown amount of Fe^{3+} ions was delivered. Plan an Activity in which you determine the molar concentration of Fe^{3+} by the colorimetric method. Answer the question whether the water is safe for drinking. Compare the result obtained for the sample with the results for the tap water.

You have:

- 0,1% HCl solution
- 20% KSCN solution (CAS: 333-20-0)
- Fe^{3+} standard solution of 1 mg/mL concentration

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[1] After earlier oxidation of iron(II) ions, the total content of iron in the sample may be determined with the use of the thiocyanate method.

Information for the teacher: a maximum acceptable iron concentration in water is 0.2 mg/L (0.3 mg/L in some countries), recommended iron concentration in the sample: 0.05 – 0.5 mg/L.

Discussion:

- Is the delivered water safe for drinking as regards the iron(III) ions concentration?
- What is the influence of the exceeding amount of iron in water on the human body?
- What ways of treatment/purification of water do you know?
- How can the Activity be modified to the concentration of the iron(II) ions be taken into account in the obtained result?

Activity III-4: The equilibrium between cobalt complexes.

Engaging questions:

- Why are the solutions of iron(III), iron(II), copper(II), cobalt(II) coloured, and the solutions of e.g. sodium and potassium ions not?
- What determines the colour of the coordination compounds?

Chemicals:

Substance	CAS number	Dangers
$CoCl_2{\cdot}6H_2O$	7791-13-1	, , ,
HCl 12 mol/dm^3	7647-01-0	, ,
ethanol 95%	64-17-5	.

Equipment: 5 test-tubes, technical scales (giving results in two decimal places), a spatula, measuring cylinder.

Description of the Activity :

On the technical scales, students weigh out 0.1 g $CoCl_2{\cdot}6H_2O$ for each of the test-tubes and for each of them they add 10 drops of concentrated hydrochloric acid. Then, they dilute obtained solutions with a solvent of a composition presented in the Table 1.

Table 1. The composition of a solvent

Number of the test-tube	Solvent [% vol.]
1	100 % of deionised water

2	50% of water - 50% of ethanol
3	20% of water - 80% of ethanol
4	5% of water - 95% of ethanol
5	100% ethanol

Discussion:

- What are the differences in the solution colours in the test-tubes?
- Is there any regularity in the change of colour?
- What ions are present in the test-tube 1 and 5?
- What is the structure of the formed coordination compounds?
- In Figure III.9 the spectra of solutions number 1 and 5 are presented:
    - What determines the position of the peak in the spectrum?
    - What determines the height of the peak in the spectrum?
    - How will the spectra for the test-tubes number 2-4 look like?
- Are Sc and Zn included to transition metals?
- Why +II is the typical degree of oxidation for many d-block elements?

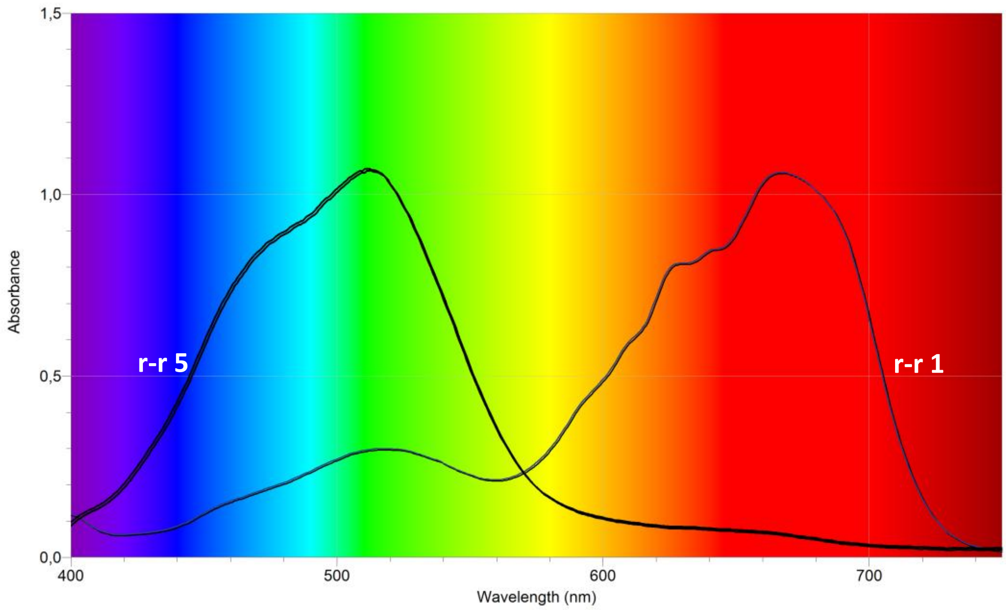


Figure III.9. UV-Vis spectrum for the samples 1 to 5.[2]

Activity III-5: Cyanotype

Engaging questions:

- How does the analog camera work?
- How are the analog photos created?
- What does it mean to develop and fix photos?

[2] Interestingly, a local maximum for the solution 1 spectrum at about 520 nm comes from the water of hydration.

- What coloured coordination compounds of iron II and III do you know?

Note: The Activity can be carried out in one of two ways, depending on the reagents availability.

Reagents:

- $K_3[Fe(C_2O_4)_3]$ CAS:[5936-11-8] (version 1), or
- ammonium iron(III) citrate (preferred – green), CAS: [1185-57-5] (version 2)
- $K_3[Fe(CN)_6]$, CAS: 13746-66-2
- glycerine,
- citric acid.

Note! $K_3[Fe(CN)_6]$ is non-toxic compound, but in contact with strong acids it forms toxic, highly poisonous gases. Citric acid is an irritant compound, during Activity use a laboratory coat, gloves and protective glasses.

a) Making the photosensitive paper and blueprint photo version 1:

1. Dissolve 1g of $K_3[Fe(C_2O_4)_3]$ in 25 cm^3 of water.
2. 10 cm^3 of this solution pour into the Petri dish and immerse a little blotting-paper disc in it.
3. Remove the disc with a tweezer and leave it for a while in an upright position to drain of the solution.
4. Place paper between paper towel sheets and dry (protect paper from the light).
5. Dry paper is ready for exposure. The 'blueprint' photo can be made e.g. by displaying on the paper the image from the multimedia projector. The illumination time is 20 - 30 minutes, depended on the power of lamp and the type of an image.
6. After illumination put the disc in the Petri dish with 25 cm^3 of 0,03 M $K_3[Fe(CN)_6]$.
7. Immerse the blotting paper in the Petri dish with distilled water and dry it again.

b) Making the photosensitive paper and blueprint photo version 2:

1. Weigh out a 90 g of the ammonium iron(III) citrate, transfer it to the flask of 250 cm^3 and filling the flask with distilled water up to the mark.
2. In the second flask of 250 cm^3 put 10 g of potassium ferricyanide and fill with the distilled water up to the mark.
3. Combine the solutions together in a flask or beaker of 1000 cm^3 and add about 1 cm^3 of glycerol. Protect the solution from the strong illumination.
4. Immerse the blotting paper in the prepared solution.
5. Place paper between paper towel sheets and dry (protect paper from the light).
6. Dry paper is ready for exposure. The 'blueprint' photo can be made e.g. by displaying on the paper the image from the multimedia projector. The illumination time is 20 - 30 minutes, depended on the power of lamp and the type of an image.
7. After illumination, immerse the blotting paper in 1% solution of citric acid and dry it again.

Discussion:

- Thanks to what process the photo was made?
- Which areas of the image are brighter and which are darker?

- Blue colour observed on the image is connected with the formation of prussian blue with the formula $KFe[Fe(CN)_6]$. What is an iron degree of oxidation in this compound?
- What processes need to occur on the blotting paper under the light influence to form this compound?
- Design an Activity in which the photo in a form of the positive would be made.

Subunit IV - In the world of energy.

Activity IV-1: Photos from the starch. How do plants get their energy?

Engaging questions:

- What are the mechanisms of the nutrition of plants?
- What is the reserve material of plants?
- Do the plants nourish only during the daytime or also at night?
- How can we detect the presence of starch in the solution?
- What is the starch?

Equipment and chemicals:

- plant – Geranium (stored in a darkness for 48-72 hours before the Activity),
- solution of baking soda or $NaHCO_3$ (10g/200 ml), CAS: 144-55-8
- ethanol 95%, (CAS number: 64-17-5)  ,
- I_2 solution in KI (1 g I_2/25 KI/500 ml of water – prepare the day before, store in a dark bottle) CAS: 7553-56-2 the solution is not classified as dangerous, but is the cause of stains difficult to remove.
- paper towels,
- tweezers/forceps,
- 3 crystallisers.

Description of the Activity :

1. Place 2 layers of paper towels on top of the acrylic glass plate.
2. Drip the towel with the baking soda solution.
3. Place 1 Geranium leaf on the paper towel with the green side (top side) up. The leaf should be "starved". To get this, store the plant in darkness for at least 48 hours before carrying out the Activity . The leaf should be removed from the plant just before the Activity .
4. Place the small object made of the material impermeable to light (e.g. a coin) on top of the leaf.
5. Place the clear plexiglass sheet on top. This way, a sandwich with the Geranium leaf inside would be formed.
6. Hold the sandwich together with rubber or paper clips..
7. Place the sandwich in direct sunlight, or in the light of the projector.
8. Let the leaf to be exposed for 45 minutes.
9. After 30 minutes of exposure, heat about 100 ml of ethanol in the water bath or heating mantle.
10. After exposure, take the sandwich apart. Using the forceps (tweezers) pick up the leaf by the stem (petiole) and place it in the beaker of hot ethanol.
11. After about 5 minutes, the leaf should be nearly white.
12. Fill two crystallising dishes halfway with water. Place the leaf in the first crystallising dish and swirl it under water to remove ethanol.
13. Put the I_2/KI solution to the second crystallising dish.

14. Immerse the leaf in the I_2/KI solution. Watch the changes.
15. Transfer the leaf into the second crystallising dish with water to wash off excess iodine.
16. Dry the leaf on the paper towel.
17. Look at the leaf and record your observations.

Experiment developed by:

http://sites.bio.indiana.edu/~nsflegume/download/Photosynthesis%20Activity.doc

Discussion:

- Explain the observed change in colour.
- Where does the light pass through the leaf and where it was blocked?
- Where is the coloured stain greatest?
- Which areas contain the highest concentration of starch?
- Why is the starch accumulation not uniform?
- How do plants synthesise starch?
- When do plants consume starch?
- What is a role of starch in the human diet?
- How much of starch do we consume every day?

Activity IV-2: The photosynthesis performance.

The purpose of the Activity is to examine the influence of the colour of light on the photosynthesis performance. Students design the Activity by themselves. For technical reasons, it is advisable to use water plants. Houseplants can be used if oxygen or carbon dioxide sensors and data logging devices are available.

Engaging questions:

- What is the mechanism of plant nutrition?
- What is necessary for plants to live?
- Why are leaves of most plants green?
- Why do most plants turn yellow when there is no access of light?
- Why are some algae that live deep under water brown rather than green?
- In what way can we prove the occurrence of the photosynthesis process? Consider the problem theoretically for water plants – what is a reactant and what is a product of this process, how should the pH of the environment and the water level be changed?
- Which water is the best for this Activity : distilled water, mineral still water, mineral sparkling water?

Equipment:

- 5 boxes (may be shoe boxes),
- 25 test-tubes,,

- 3 pieces of LED strip (1. Illuminating red colour, 2. Illuminating blue colour, 3. Illuminating green colour,). LED strip can be bought in most of building materials supermarkets. They are sold by the meter, for the Activity it is enough to buy 0,5 m of the strip of each colour. (http://www.amazon.co.uk/WHITE-FLEXIBLE-STRIP-LIGHT-ADAPTER/dp/B003M7YQXK/ref=sr_1_3?ie=UTF8&qid=1323769498&sr=8-3)
- Canadian waterweed (*Elodea canadensis* Michx.) – 25 pieces of about 5 cm.

An sample description of the Activity :

Install the LED strip of different colours (red, green, blue, white) in the four cardboard boxes. For powering the strip, one power supply of 12 V should be enough. Prepare five sets of test-tubes with the Canadian waterweed (Fig. IV.1). The length of the plant should be similar (preferably the same) in all test-tubes. Pour the same amount of water into the test-tubes and mark its level with a pen. Plug the test-tubes with stoppers or with the use of parafilm. Put the set of test-tubes in the prepared lightning boxes. The 5th set, put into the box with no lightning. Leave the Activity for few days. The photosynthesis performance may be indicated by the number of oxygen bubbles on the walls of the test-tubes.

Alternatively, instead of the LED lightning, the filters of different colours installed in the boxes may be used. As a light source, the lamp with a bulb or a daylight may be used.

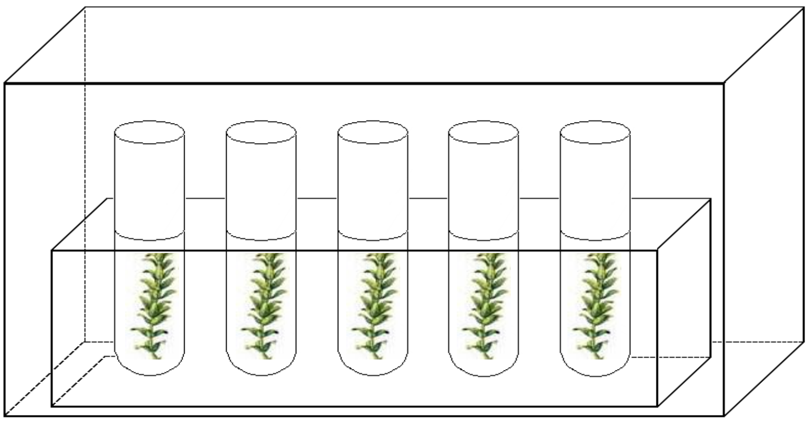


Figure IV.1. A sample diagram of the construction of one out of the five sets.

Discussion:

- What types of measurements can be used to determine the photosynthesis performance besides counting of the gas bubbles formed?
- In what light does the photosynthesis occur and why? In what light is it the most effective?
- In what light do the green plant grow the best?

- At Figure IV.2, an absorption spectrum of the plant pigment from the Canadian waterweed is presented. Does it agree with the results of the performed Activity ?
- Some algae have red leaves. Consider whether the results of the Activity with the use of these plants would be the same? Give reasons for your answer.
- What is the difference between the Activity with the use of the LED lighting and the Activity with the use of filters of different colours? Should the results be the same? Justify your answer (the Figure IV.2 may be useful).
- Is the illumination of the control set with the daylight and with the bulb light leading to different results?

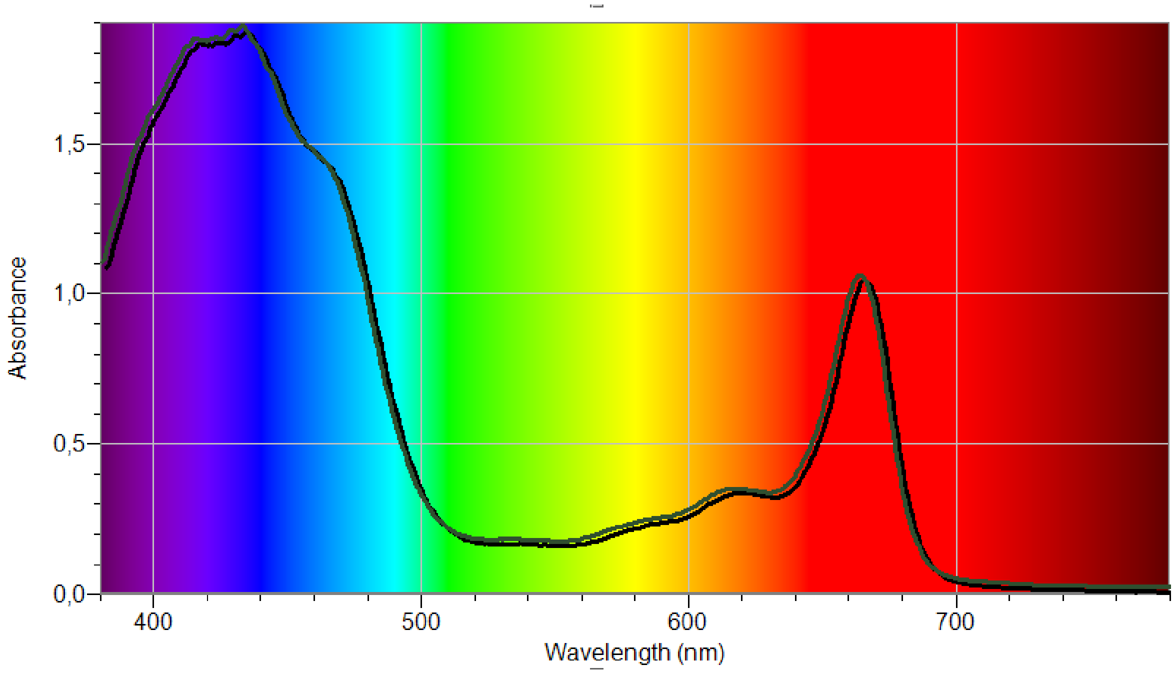


Figure IV.2. Visible absorption spectrum of chlorophyll from the Canadian waterweed.

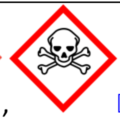
Activity IV-3a: How can we use the solar energy?

Engaging questions:

- What renewable energy sources do you know?
- How do solar panels work?
- Where are the solar cells used?
- What will happen when the calculator powered by the solar cell will be closed in the dark place?
- Why do blueberries ripen despite growing in the dark forest?

Equipment and chemicals:

Substance	CAS number	Dangers
TiO_2	13463-67-7	-

HNO_3 10^{-4} mol/dm^3	7697-37-2	, ,
methanol	67-56-1	, ,
I_2 solution in KI in the ethylene glycol (description of the preparation below)	-	
plates from the conductive glass http://www.sigmaaldrich.com	735140-5EA	-

- fruit (bluberries, cherries, strawberries, etc.) ,
- candle,
- multimeter (voltmeter),
- halogen lamp,
- burner with a tripod,
- adhesive tape,
- a piece of cardboard.

Description of the Activity :

a) Preparation of the I_2 solution in KI: 0,127 g of I_2 dissolve in 10 cm^3 of ethylene glycol, mix, add 0,83 g of KI mixing again. Note! The reagent absorbs moisture. It should be kept in a closed dark bottle, protected by the parafilm.

b) The cell preparation:

The first step is to prepare an emulsion of TiO_2:

1. In a small beaker mix 1 cm^3 of nitric(V) acid solution of a concentration of about 10^{-4} mol/dm^3, pH 3-4 with 3,25 cm^3 of ethanol.
2. Add 0,75 g of titanium(IV) oxide to the prepared solution, stirring all the time.
3. Continue stirring until the suspension appears uniform.
4. Having TiO_2 suspension ready, a layer of titanium(IV) oxide may be put on the electrode cell.
5. The two conductive glass plates (pre-coated with the layer of SnO_2) wash with methanol and dry.
6. Put the plates next to each other on the cardboard underlay and attach them to it with the use of an adhesive tape (in such way, that only edges of the plate are in contact with the tape). The top plate should be turned to the top from the conductive side, and the bottom one – from the non-conductive. The bottom plate will not be covered; it just helps to cover the top plate.

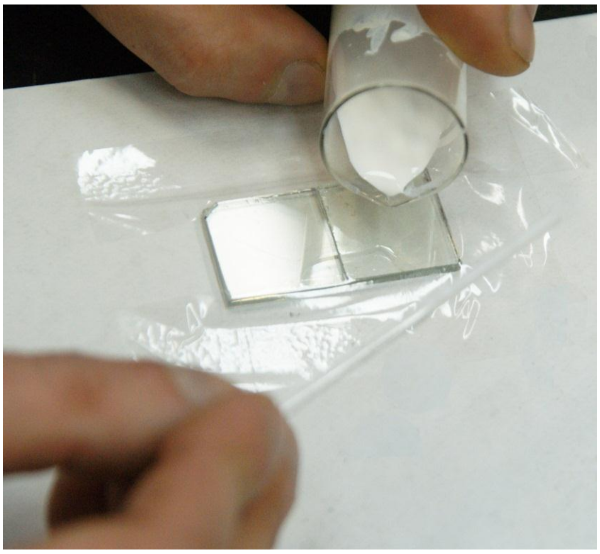


Figure IV.3. Preparation of the plates for the emulsion distribution.

7. Using a dropper, put several drops of TiO_2 emulsion in the straight line along the top edge of the plate.
8. Using a glass rod, spread the suspension of TiO_2 over the top plate. In order to do this, it is recommended to make a few quick moves of the rod up and down.
9. Remove carefully the tape attaching the plates to the cardboard and wash the bottom plate (the one that was not covered) and cover its surface with soot by heating it over the candle.

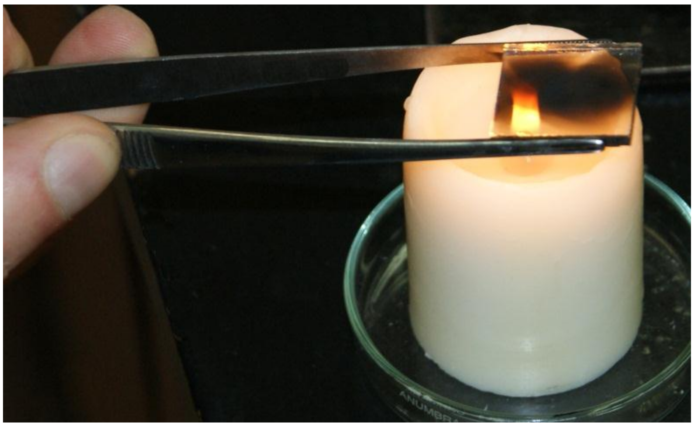


Figure IV.4. Covering the plate with the soot layer.

10. A few minutes after the covering with TiO_2, put the plate on a wire gauze with ceramic centre and heat it over the burner flame for about 20 minutes. After that time, wait until the plate cools to room temperature.
11. In a mortar, smash a few strawberries, (or blackberries, cherries, chokeberry) and add about 2 cm^3 of water.
12. Put the plate covered with TiO_2 in the so-obtained solution (with the TiO_2 layer to the bottom) and leave for about 20 minutes.
13. Rinse the plate with water, and then with methanol and leave for drying. The plate should be strongly coloured as a result of the dye adsorption at the surface of the titanium oxide. Such prepared plate is one of the electrodes.

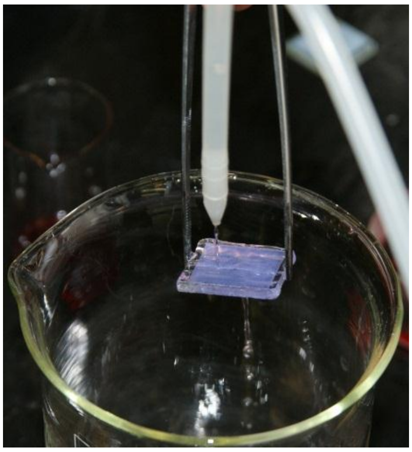


Figure IV.5. Rinsing the plate with methanol.

14. Put the electrode with the adsorbed dye on the flat surface and place from the top, the counter electrode covered with graphite or soot in such way, to enable the contact of plates by the graphite and titanium oxide covered side, with a 4 mm shift between them. The part of the electrode that is has not the titanium(IV) oxide layer, should remain uncovered.

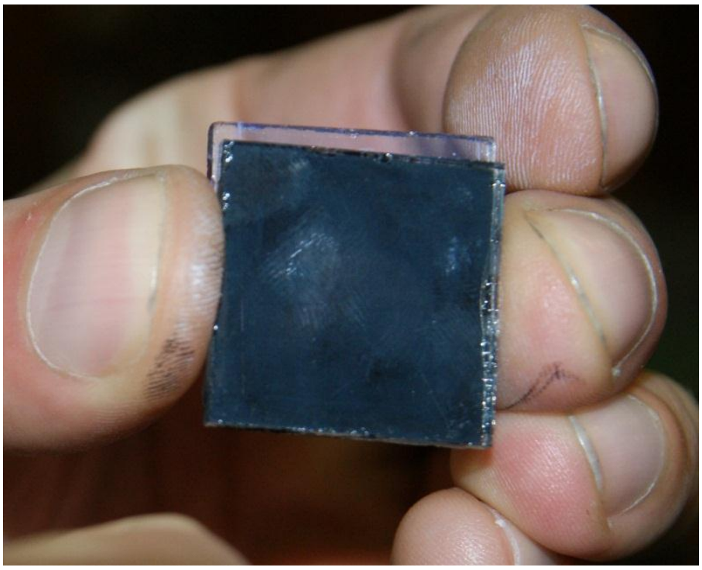


Figure IV.6. Combination of the plates prepared.

15. The plates may be combined with the use of paper clips.
16. Drop an electrolyte between the plates – solution of iodine and potassium iodide in ethylene glycol.

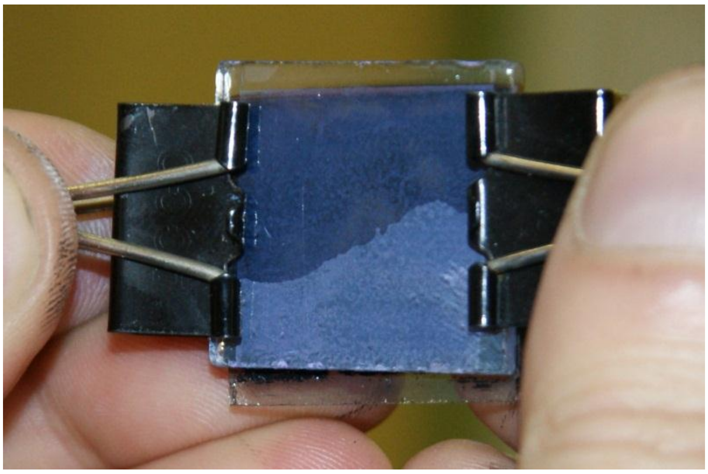


Figure IV.7. The plates combines with the paper clips after dropping an electrolyte.

17. The system prepared in such way, is ready to work.

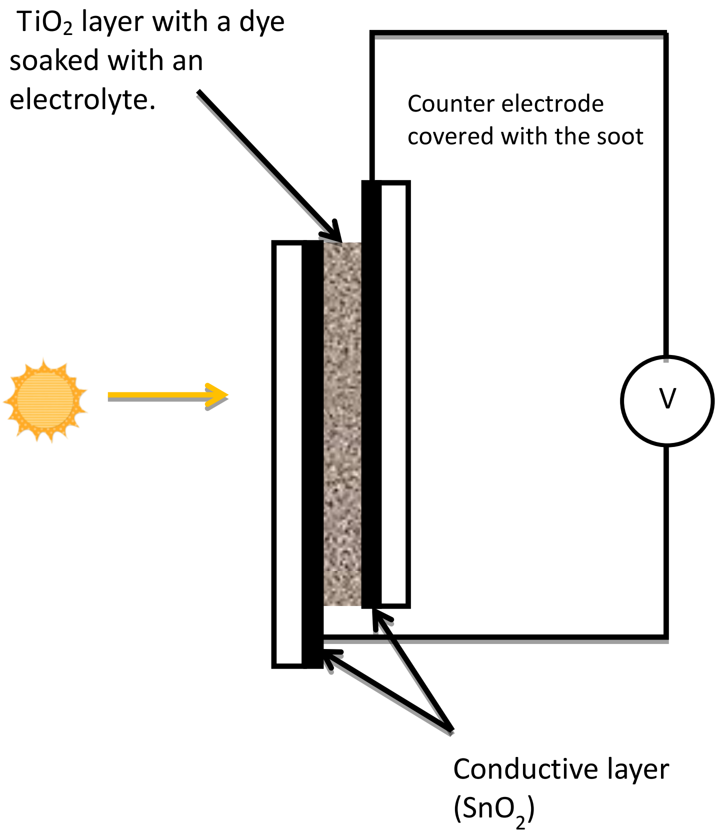


Figure IV.8. A diagram of the solar cell.

18. Connect the multimeter

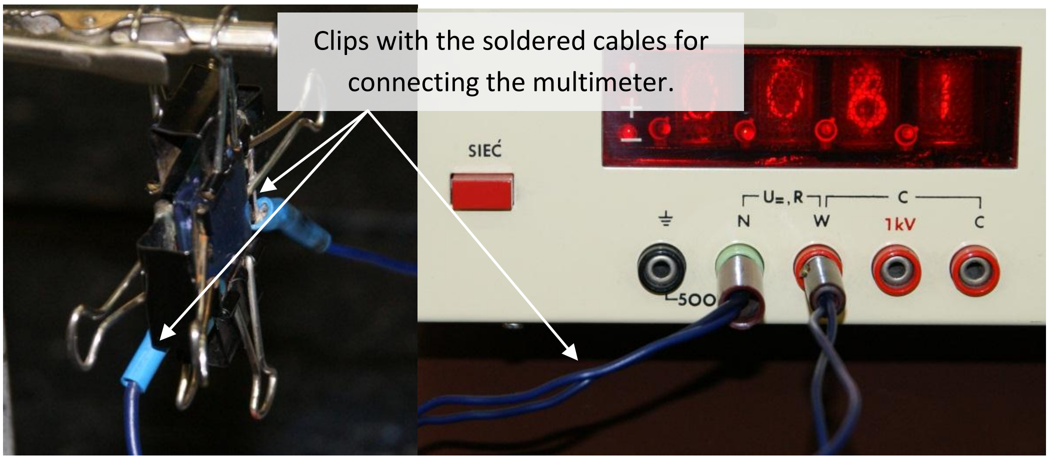


Figure IV.9. An image of the working cell.

19. Illuminate the cell with the halogen lamp and the other types of light (sunlight, torch, laser pointers). Note: You must be careful not to increase the temperature of the cell with the heat emitted by the light sources.

Experiment developed by:
Łukasz Boda, Materiały dydaktyczne: 'Nanokrystaliczne ogniwo słoneczne' Uniwersytet Jagielloński

Discussion:

- How does the voltage generated by the cell depend on the type of the light source? Explain, the effect observed.
- How does the voltage generated by the cell depend on the intensity of light?

Activity IV-3b: How can we use the solar energy?

Determination of the maximum power of the constructed device.

The power **P,** of the cell is equal the product of voltage U and current I from the external circuit:

$$P = U \cdot I$$

Knowledge of this characterictic enables determination of the maximum power that can be taken from the cell. On the other hand, the ratio of this power to the intensity of light falling on the cell gives the efficiency of solar energy conversion into electricity.

Engaging questions:

- How can the current intensity be influenced?
- What parameters should be fixed in subsequent measurements?

Equipment:

- Solar cell (from Activity 3a),
- Decade resistors: *R*=10 kΩ, *R*=1000 Ω, *R*=100 Ω, (multimeters with variable resistance may be used),
- multimeter (ammeter),
- cables for connection.

Students can design the system for measuring the dependence of the voltage on the current intensity by themselves. The exemplary system is presented in Figure 3. Resistance may be changed in the range of 100 Ω -10000 Ω

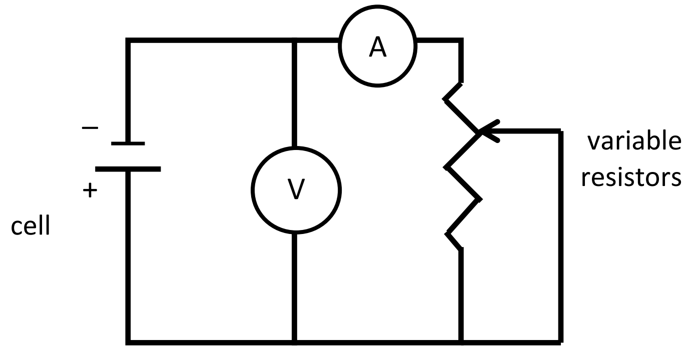


Figure IV.10. A diagram of a circuit for the measurement of the voltage-current characteristic.

Table IV.1. Exemplary results:

U [mV]	*I* [mA]	*R* [W]	*P* [mW]
355	0,038	11100	13,490
331	0,040	9100	13,240
303	0,048	7100	14,544
269	0,056	5100	15,064
214	0,075	3100	16,050
116	0,110	1100	12,760
101	0,115	900	11,615
84	0,123	700	10,332
64	0,130	500	8,320
30	0,145	300	4,350
4	0,155	10	0,620

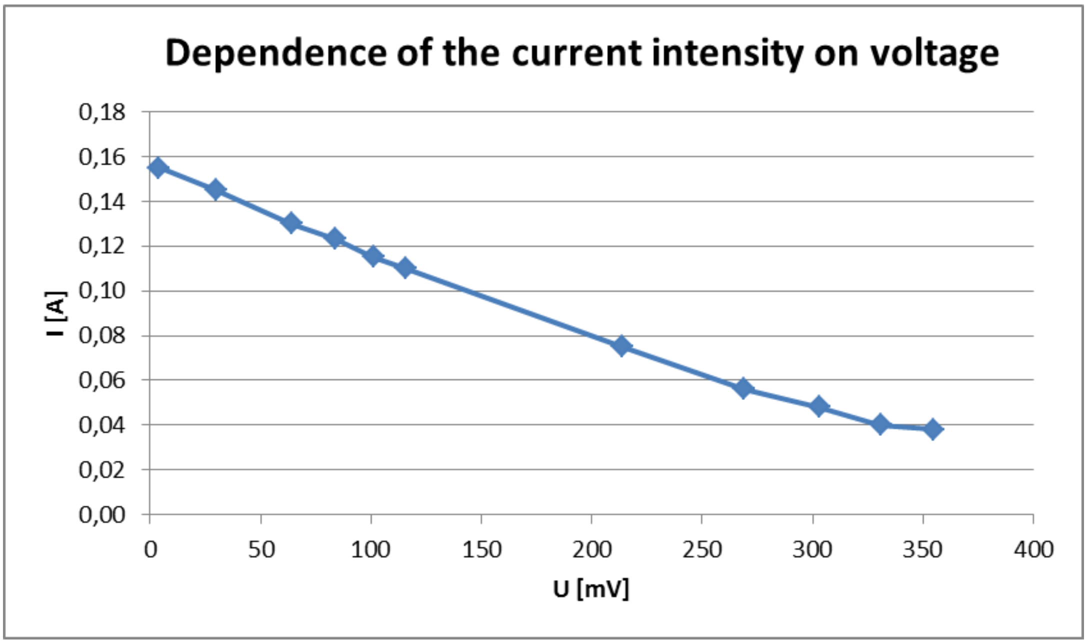


Figure IV.11. An example of the dependence of the current intensity on voltage for the working blueberry cell.

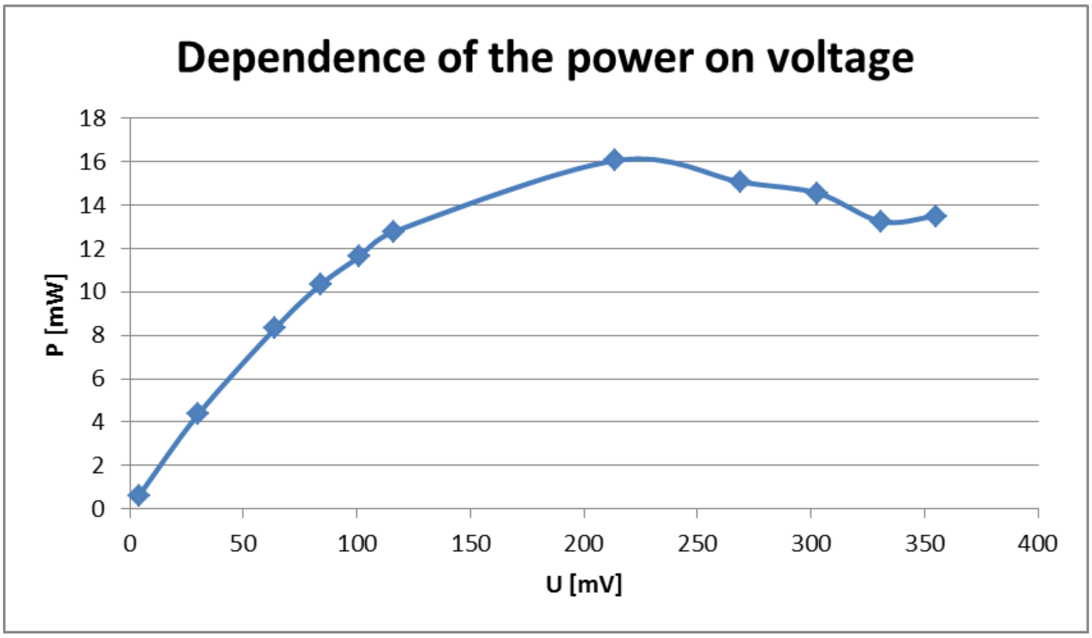


Figure IV.12. An exemplary dependence of the power on voltage for the working blueberry cell.

Discussion:

- Will the use of different fruit change the power of the device? *(the possibility of an Activity al verification)*
- How do the changes in resistance affect the cell power?
- Where can this type of the cell be applied?

WP3
Renewable Energies

European Science and Technology in Action Building Links with Industry, Schools and Home

Work Package 3

RENEWABLE ENERGIES
Teacher Information

European Science and Technology in Action: Building Links with Industry, Schools and Home

Lead partner for deliverable: **Martin-Luther-Universität Halle Wittenberg (MLU)**

The ESTABLISH project has received funding form the European Community's Seventh Programme [FP7/2007-2013] under grant agreement n^{o} 244749
Start Date: 1st January 2010 Duration: 48 months

A. Teacher Information

I. Unit description

Student level: higher secondary level, ages 14+
Disciplines involved: biology, chemistry, physics and science
Estimated duration: at least 10 hours

This unit is supposed to encourage pupils to conduct their own studies about the character and application of renewable energies, with a focus on experimental approaches and an evaluation of the technologies.

The unit is guided by the question “Which energy source is the best?” and is supposed to give students a positive yet critical point of view on renewable energies, and to enable them to participate in discussions about different technologies and different points of view. Furthermore, they will learn to think and work scientifically, acquire a positive attitude toward sciences and train their abilities with tools and electric circuits.

The activities in this unit propose possible experiments to help guide the pupils in their investigations. The teaching and learning aids are not supposed to be step-by-step assignments on purpose, as their idea rather is to hint at possible ways of researching. Most activities require no previous knowledge, only when indicated in the activity description.

II. IBSE Character

The main idea of this unit is that of “open inquiry”, which means the pupils autonomously research on the guideline question “which energy source is the best?” Directing them in this process is done with the help of “bounded inquiry”, i.e. through given questions and criteria, which also adjusts focus on the experimental material at hand. Because the pupils develop their own criteria to assess renewable energies and use them to guide their research and studies, this unit satisfies every aspect of IBSE in the definition used by ESTABLISH. The teaching and learning aids present possible ideas that could be researched.

III. Science Content Knowledge

The much-debated study *The Limits to Growth*, which was published as early as 1972 by Dennis L. Meadows et. al. on behalf of the “Club of Rome”, already predicted shortages of natural resources and especially fossil fuels (coal, oil and gas) alongside irreparable damage to the environment if nothing was done about the world population growth, industrialization, pollution, food industry and exploitation of resources of that time. Oil crises and price increases of the past have shown how nearly every state is dependent on oil. Even the seemingly eco-friendly nuclear power uses limited resources and poses severe and still unsolved problems concerning the permanent disposal of its waste.

With all these insights, the focus is on other eco-friendly and safe approaches to power generation independent of limited resources, yet sufficient in quantity. One concept is the use of renewable energies in connection with storage of excess energy. Before fossil fuels were discovered, mankind relied solely on renewable energy, and fossil fuels really only gained their importance during the course of the industrialization.
Renewable energies include:

- Wind power
  - wind turbines
- Hydropower
  - hydroelectric dam with turbine
  - run-of the-river hydroelectricity
  - Pumped-storage hydroelectricity
  - Tide power
- Solar energy
  - Photovoltaics
  - Solar thermal energy
- Biomass
  - Thermal conversion
  - Chemical conversion
  - Biochemical conversion
- Biofuel
  - Bioethanol
  - Biodiesel
  - Biogas
- Geothermal energy
  - Geothermal heating
  - Geothermal heat pump

One way of storing excess energy is by using electricity to generate hydrogen through electrolysis of water, which can then later be oxidized to generate electric energy from the chemical energy stored in the hydrogen.

Relevant scientific concepts:

Energy	Definition	The ability of a physical system to do work or transmit light or heat.
	Formula	E
	Units	one joule (1J), one watt-second (1Ws), 1J = 1Ws
	Measuring instrument	---
Force	Definition	Any influence that causes an object to undergo a certain change.
	Formula	$F = ma$ (mechanic) or $F=qE$ (electric)
	Units	one Newton (1N)
	Measuring instrument	spring scale
Work	Definition	A physical system does work, when there is movement under the action of a force.
	Formula	$W = Fs$ (mechanic) or $W = qU$ (electric) or $W = \Delta E$
	Units	one newton-meter (1Nm), one joule (1J), 1Nm = 1J
	Measuring instrument	---
Power	Definition	The rate at which energy is transferred, used or transformed.
	Formula	$P = \Delta E/t = W/t$ (mechanic) or $P = UI$ (electric)
	Units	one watt (1W), one joule-second (1Js), 1W = 1Js
	Measuring instrument	---
Electric Current	Definition	A flow of electric charge through a conductive medium.
	Formula	$I = q/t$ or use Ohms law
	Units	one ampere (1A)
	Measuring instrument	ammeter
Voltage	Definition	The „force or push“ that moves electric current through a circuit.
	Formula	$U = W/q$ or use Ohms law
	Units	one volt (1V)
	Measuring instrument	voltmeter, potentiometer
Electrical Resistance	Definition	The opposition to the passage of an electric current through an electric element.
	Formula	$R = U/I$ or $R = \rho\ell/A$
	Units	one ohm (1Ω)
	Measuring instrument	ohmmeter
Temperature	Definition	A measurement of how hot or cold a body is.
	Formula	T or ϑ
	Units	one kelvin (1K) or one degree celsius (1°C)
	Measuring instrument	thermometer
Heat	Definition	The amount of energy that is transferred from one system to another by thermal interaction.

	Formula	$Q = \Delta E$ or $Q = cm\Delta T$
	Units	one joule (1J)
	Measuring instrument	---
Irradiance (Light intensity)	Definition	The power of light per unit area incident on a surface.
	Formula	$I = P/A$
	Units	one watt per square meter (1W/m²)
	Measuring instrument	light sensor

Relevant scientific concepts and phenomena

- Energy conversion
- Heat transfer
- Electric generator
- Direct and alternating current
- Electric circuit
- Ohms law
- Kirchhoffs laws
- Inner photoelectric effect
- Electrolysis
- Fuel cell
- Fermantation
- Ecosystem
    - interaction between animate and inanimate nature
- Water cycle (hydrological cycle)
- …

IV. Pedagogical Content Knowledge

Based on the theory of self-determination by Decy & Ryan, the main idea is that pupils develop their own questions and solve them autonomously. This includes devising own criteria to answer the guiding question, coming up with own experiments as well as estimating the time needed. The pupils should follow the criteria during their studies and also evaluate them accordingly. Another important aspect is that there are no wrong questions or answers, as long as they are on topic.
The answers to the guiding question will vary from pupil to pupil, depending on their criteria. Therefore, the aim of the final discussion should be to find a reasonable compromise between every group, which could be an agreement on a mix of energy sources.
The unit is supposed to be done in the form of project work with small group sizes of 3-4 pupils. If the method of guided inquiry is used, particular stations with relevant activities can be prepared beforehand.

Possible criteria:

- quantity of energy produced
- efficiency of energy conversion
- cost-benefit approach
- environmental sustainability
- …

Possible misconceptions:

- the difference between current and voltage
- the difference between heat and thermal energy
- polarity in electric circuits
- how photovoltaic modules generate electricity (e.g. thermal)
- …

V. Industrial Content Knowledge

Not only the title of this unit hints at a connection to renewable energy industries, including renewable energy products (solar collectors, wind turbines), power plant operators and energy companies as well as research groups. Energy consumers such as simple households, communities or the industry are important to the discussion about the best power source as well.

Some of the activities include design tasks which may require a look at existing systems for inspiration. Talking to industry experts can also be helpful. In any case, industry visits are recommended for every activity.

VI. Learning Path(s)

0 Which energy source will be the best? Open Inquiry, all 5E's

Recommended Activities	***Inquiry Type***	***E-emphasis***	***estimated duration***
1 Designing a wind power plant	Bounded Inquiry		8h
2 The power of a wind power plant	Guided Inquiry		2h
3 Designing a hydroelectric power plant	Bounded Inquiry		8h
4 Cooking with the heat of the sun	Guided Inquiry		2h
5 Designing a solar collector	Bounded Inquiry		8h
6 Building a dye-sensitized solar cell	Guided Inquiry		5h (distributed to 2 days)
7 The power of a photovoltaic module	Guided Inquiry		2h
8 The power of a solar cell garden pump	Bounded Inquiry		4h
9 My iPod works with energy from bull shit!	Guided Inquiry		several days
10 The efficiency of a hybrid power plant	Guided Inquiry		2h
11 Designing a hydrogen car	Bounded Inquiry		2h
12 Designing an island system	Bounded Inquiry		2 days

VII. Assessment

The unit focuses on devising guideline criteria, following them during the course of the studies and also applying them to evaluate the results. Assessment can be done various ways.
The teacher could monitor the process of the studies with the help of lab notes and other documentation by the pupils.
Predictions and assumptions as well as descriptions of the experiments and a summary of results should either be written down on worksheets or collected in personal interviews.
The teacher should observe the activities of every member of a group and also of the group discussion on the whole, but not interfere too early. He should rather let pupils also move in a not so promising direction, at least for a while.
The presentation of the results in the penal discussion and the ensuing discussion shows how extensively the pupils have worked on their topics and questions.
Furthermore, pupils could also asses themselves and each other within their respective groups.

WP3
Renewable Energies

European Science and Technology in Action Building Links with Industry, Schools and Home

Work Package 3
RENEWABLE ENERGIES

Student Activities & Classroom Materials

Establish

European Science and Technology in Action:
Building Links with Industry, Schools and Home

Lead partner for deliverable: **Martin-Luther-Universität Halle Wittenberg (MLU)**

The ESTABLISH project has received funding form the European Community's Seventh Programme [FP7/2007-2013] under grant agreement n^{o} 244749

Start Date: 1st January 2010 Duration: 48 months

VIII. Student learning activities

Which energy source will be the best?

Unit description and learning aims:

- The students have to prepare a penal discussion to answer the given question. They will figure out that fossil fuels run out in future, so that the focus lies on renewable energies. During the preparation phase they should find several renewable energy sources. To answer the question they will survey properties, advantages and disadvantages of several energy sources and compare them. The survey can be in any form that guides to the aim: finding an answer.
- knowledge: renewable energy sources; energy conversion; functional principles of several energy converters; energy transport

  inquiry: observation; description; hypothesise and prove of hypothesis; systematize; planning, conduction and evaluation of experiments; generalizations; usage of models and analogies; comparison

  communication: online research; literature research; lab notes; schemes; manuals; group discussion; penal discussion; tables; diagrams; formula

  appraisal: critical dealing with views of lobby groups, appraisal of accuracy of measurements

Materials:

- laptops, internet, crafting material, writing material, a choice of experiments and related equipment, tools, ICT…
- Recommended experimental kits and manuals:

  Horizon Kits (e.g. renewable energies, etc)
  http://www.horizonfuelcell.com/store_euro.htm#
  http://www.conrad.com/Experimental-cases-alternative-energy.htm?websale7=conrad-int&ci=SHOP_AREA_17618_2420141

  Fischertechnik Kits (Oeco Tech, Hydro cell Kit, E-Tec),
  http://www.fischertechnik.de/en/desktopdefault.aspx/tabid-20/38_read-2/usetemplate-2_column_pano/
  http://www.conrad.com/Fischertechnik-Experiment-Kits.htm?websale7=conrad-int&ci=SHOP_AREA_17618_2420170

  KOSMOS Kits (fuel cell, wind energy, solar energy, solar master, solar generation, solar cooker),
  http://www.kosmos.de/content-824-824/alternative_energy/
  http://www.conrad.de/ce/de/overview/2420160/?page=0&filter_selection_1=ATT_TOPIC%3B~Erneuerbare+Energien~&filter_selection_2=&filter_selection_ATT_GLOBAL_Brandname=&filter_selection_ATT_TOPIC=ATT_TOPIC%3B~Erneuerbare+Energien~&filter_selection_ATT_PRODSPEC_0071=&pricerange=&bvRating=&feature=&orderBy=&orderSequence=&indivPriceRangeA=&indivPriceRangeB=
  http://www.kosmos.de/produktdetail-838-838/solar_kocher-318/

  Mansolar solar cells kit (dye-sensitized solar cell)
  http://www.mansolar.nl/products.html

http://www.solaronix.com/documents/dye_solar_cells_for_real.pdf
http://www.camse.org/scienceonthemove/documents/DSSC_manual.pdf
see also ESTABLISH unit "Photochemistry" chapter IV experiment IV-3a

Software HOMER
https://homerenergy.com/download.html;

Solar fountain system

http://www.conrad.com/Solar-fountain-system-Palermo.htm?websale7=conrad-int&pi=551132&Ctx={ver%2F7%2Fver}{st%2F3ec%2Fst}{cmd%2F0%2Fcmd}{m%2Fwebsale%2Fm}{s%2Fconrad-int%2Fs}{l%2Fint%2Fl}{sf%2F%3Cs1%3Epalermo+pump%3C%2Fs1%3E%2Fsf}{p1%2Fd332d0672e5b87438ed004a8593081ff%2Fp1}{md5%2F3448a6f48751c6ef3267c1153f8b7bdc%2Fmd5}

Biogas (My iPod works with energy from bull shit)

http://www.parsel.uni-kiel.de/cms/fileadmin/parsel/Material/Berlin/neu2/08FUB4b-Teachers_Bull_Shit.pdf

http://www.parsel.uni-kiel.de/cms/fileadmin/parsel/Material/Berlin/neu2/Overall_Bull_Shit.zip

Suggestions for use:

- To carry out the topic and raise students awareness could use:
  - Newspaper articles or headlines(e.g. http://www.teenink.com/hot_topics/environment/article/491395/Fossil-Fuels-Are-a-Dead-End/)
  - Science journal articles
  - Book chapters (e.g. Jorgen Randers (2012). 2052 – *A Global Forecast for the Next Forty Years*; Donella H. Meadows (1972). *The Limits to Growth*)
  - Movie chapters (e.g. *An Inconvenient Truth*, by Al Gore)
  - TV report
  - …
- The recommended activities show possible experiments that could be suggested by the students or used as mandatory activities
- Link to industry (see ICK description)
- Teaching method: inquiry learning (see IBSE description)

Possible student criteria:

- Quantity of energy
- Efficiency of energy source
- Cost-benefit considerations
- Environmental compatibility
- Social acceptance
- Regional/local energy independence (island system)
- Wide field of application
- …

Activity 1 Designing a wind turbine

Activity description and learning target:

- The pupils are supposed to build a functional model of a wind turbine to power an electric device, e.g. a lamp. They may take cues from existing turbines and work with their form and features. They should discuss their own designs and determine the needed materials. Try and error methods may be required to get the electric device running. Pupils should then determine the power output of the model.
- knowledge: energy conversion in a wind turbine; functional principles and properties of wind turbines;

  inquiry: observation; description; creating and proving a hypothesis; systematizing; planning, conducting and evaluating design task; using models; comparison

  communication: online research; literature research; lab notes; schemes; manuals; group discussion; tables; diagrams; formula

  appraisal: evaluation of design task; controversy about wind turbines

Materials:

- see unit description

Suggestions for use:

- an industry visit at wind turbine factory is recommended
- documenting steps in development and scheduling tasks

Recommended questions:

- How does a wind turbine work?
- Which types of wind turbines exist, which are planned?
- How much useful energy could be generated by your wind turbine?
- Which parameters influence the power of a wind turbine?
- Why are wind turbines so expensive?
- What do you need for building a wind turbine? Which materials are useful?
- Is your wind turbine efficient enough to …?
- What do experts know about building a wind turbine?

Activity 2 The power of a wind turbine

Activity description and learning aims:

- The pupils are supposed to evaluate the capacity of a wind turbine depending on a number of different influences. The model provides methods to change the number, form and angle of attack of the rotor blades. They can also determine favorable wind velocities with the help of suitable devices.
- knowledge: energy conversion in a wind turbine; functional principles and properties of wind turbines;

  inquiry: observation; description; creating and proving a hypothesis; systematizing; planning, conducting and evaluating design task; using models; comparison

  communication: online research; literature research; lab notes; schemes; manuals; group discussion; tables; diagrams; formula

  appraisal: evaluation of experiment; discussion about using wind power in regions with little wind.

Materials:

- e.g. Renewable energies kit from Horizon (see unit description);

Suggestions for use:

- The pupils come up with possible influences on the power of a wind turbine, test them and present them easy to understand
- An industry visit at a wind turbine factory or expert interview is recommended.

Recommended questions:

- How does a wind turbine work?
- Which types of wind turbines exist, which are planned?
- How much useful energy could be generated by a wind turbine?
- What factors influence the power of a wind turbine?
- How can you measure the power of a running wind turbine?
- How much power is generated by a local wind turbine?

Activity 3 Designing a hydroelectric power plant

Activity description and learning aims:

- The pupils are supposed to build a working model of a hydroelectric power plant and power an electric device (e.g. a lamp) with it. They may copy design ideas from existing plants and should make a list of needed material. Try and error methods may be necessary to get everything working. They should then determine the power output of their model.
- knowledge: energy conversion in a hydroelectric power plant; functional principles and properties of hydroelectric power plants;

  inquiry: observation; description; creating and proving a hypothesis; systematizing; planning, conducting and evaluating design task; using models; comparison

  communication: online research; literature research; lab notes; schemes; manuals; group discussion; tables; diagrams; formula

  appraisal: evaluation of design task; controversy about hydroelectric power plants

Materials:

- see unit description

Suggestions for use:

- Pupils should determine possible influences on the power of a hydroelectric power plant and test these out, then present their findings easy to understand.
- An industry visit at a hydroelectric power plant or expert interview is recommended.

Recommended questions:

- How does a hydroelectric power plant work?
- Which types of hydroelectric power plants exist, which are planned?
- How much energy can be generated by your hydroelectric power plant?
- Which values influence the power of a hydroelectric power plant?
- Why are hydroelectric power plants so expensive?
- What do you need for building a hydroelectric power plant? Which materials are useful?
- Is your hydroelectric power plant efficient enough to …?
- What do experts know about building a hydroelectric power plant?

Activity 4 Cooking with the heat of the sun

Activity description and learning aims:

- The pupils are to build a working model of a solar oven in order to boil water with it. They may build along the lines of existing models and copy their form and features. They should discuss own design ideas and make a list of needed material. Try and error techniques may be necessary to get the water to boil.
- knowledge: energy conversion; law of reflection; properties of mirrors

  inquiry: observation; description; creating and proving a hypothesis; systematizing; planning, conducting and evaluating design task; using models; comparison

  communication: online research; literature research; lab notes; schemes; manuals; group discussion; tables; diagrams; formula
- appraisal: evaluation of design task; controversy about glass pollution in environment

Materials:

- e.g. solar cooker from KOSMOS (see unit description)

Suggestions for use:

- The pupils should consider possible influences on the efficiency of their solar oven, test them and present the results easy to understand.
- An industry visit at a solar thermic power plant or expert interview is recommended.

Recommended questions:

- Which materials are needed for building a solar oven?
- Which values influence the temperature of the oven?
- Which food could be cooked by your solar oven?
- Can you cook a whole menu?

Activity 5 Designing a solar collector

Activity description and learning aims:

- The pupils are to build a working model of a solar collector, following the example of existing ones and copy their form and features. They should discuss own design ideas and make a list of needed material. Try and error methods may be required to maximise the efficiency of the model.
- knowledge: energy conversion in a solar collector; functional principles and properties of solar collectors

  inquiry: observation; description; creating and proving a hypothesis; systematizing; planning, conducting and evaluating design task; using models; comparison

  communication: online research; literature research; lab notes; schemes; manuals; group discussion; tables; diagrams; formula

  appraisal: evaluation of design task; controversy about solar collectors

Materials:

- see unit description

Suggestions for use:

- The pupils should think of possible influences on the efficiency of their solar collector, test them and present their results easy to understand.
- An industry visit at a solar collector factory or expert interview is recommended.

Recommended questions:

- How does a solar collector work?
- Which types of solar collectors exist, which are planned?
- How much energy can be collected by your model?
- Which values influence the power of a solar collector?
- Are solar collectors more expensive than other methods of power generation?
- What do you need for building a solar collector? Which materials are useful?
- Is your solar collector efficient enough to …?
- What do experts know about building a solar collector?

Activity 6 Building a dye-sensitized solar cell

Activity description and learning aims:

- The pupils are supposed to build a dye-sensitized solar cell (DSC) with the help of material found in the kit from Mansolar. They should then measure the power output of the cells.
- knowledge: energy conversion in a DSC; functional principles and properties of DSC; production of solar cells

  inquiry: observation; description; creating and proving a hypothesis; systematizing; planning, conducting and evaluating design task; using models; comparison

  communication: online research; literature research; lab notes; schemes; manuals; group discussion; tables; diagrams; formula

  appraisal: evaluation of experiment; controversy about hazardous material used in production of solar cells

Materials:

- e.g. solar cell kit from Mansolar (see unit description).

Suggestions for use:

- The pupils should think of further dye suitable for use in DSC, test their ideas and present the results easy to understand.
- An industry visit at a solar cell factory or expert interview is recommended.

Recommended questions:

- How do dye-sensitized solar cells work?
- Which chemicals are used to produce solar cells?
- How are solar cells produced?
- What is the electric power of a DSC?

Activity 7 Measuring the power of a photovoltaic module

Activity description and learning aims:

- The pupils are supposed to evaluate the power output of a photovoltaic module with regard to various factors. A kit provides methods to change the number, connection (series/parallel), lighting and load of the module.
- knowledge: energy conversion in a solar cell; functional principles and properties of solar cells

  inquiry: observation; description; creating and proving a hypothesis; systematizing; planning, conducting and evaluating design task; using models; comparison

  communication: online research; literature research; lab notes; schemes; manuals; group discussion; tables; diagrams; formula

  appraisal: evaluation of experiment; controversy about photovoltaic modules in areas with bad incidence angles / low light yield

Materials:

- Photovoltaic module, two multimeters, light source, variable resistor, load

Suggestions for use:

- The pupils should determine possible influences on the power output of a single solar cell and test their ideas. They should also work out how to connect multiple cells to a photovoltaic module of a predefined electric power, and present their findings easy to understand.
- An industry visit at a solar cell factory or expert interview is recommended.

Recommended questions:

- What is the definition of electric power?
- Which parameters influence the power of a solar cell?
- How good are your results?

Activity 8 The power of a solar powered garden pump

Activity description and learning aims:

- The pupils are supposed to determine the power of a solar powered water pump. They can measure the maximum height the water can be pumped and the amount of water per time interval.
- knowledge: energy conversion; mechanical work and power

  inquiry: observation; description; creating and proving a hypothesis; systematizing; planning, conducting and evaluating design task; using models; comparison

  communication: online research; literature research; lab notes; schemes; manuals; group discussion; tables; diagrams; formula

  appraisal: evaluation of experiment; controversy about measurement results

Materials:

- Solar cell and garden pump (e.g. solar fountain system; see unit description), bucket, water, ruler, clock, beaker or measuring cylinder

Suggestions for use:

- Introduction: *„Imagine you want to know the power of the solar cell but you only have a garden pump!"*
- The pupils should come up with ideas to measure the power output and create convenient tests for them. They may approach the problem deductively by deriving a formula or inductively by testing. They should compare the results with the product specifications and present them easy to understand.
- A connection to industry could be an online research for similar products with different parameters.

Recommended questions:

- How can power and work be described / defined?
- Which parameters influence the power of a solar cell?
- How good are your results?

Activity 9 My iPod runs on bullshit energy

Activity description and learning aims:

- This activity is about using biogas as energy source. The material is taken from the PARSEL project.
- *http://www.parsel.uni-kiel.de/cms/fileadmin/parsel/Material/Berlin/neu2/08FUB4b-Teachers_Bull_Shit.pdf*
- http://www.parsel.uni-kiel.de/cms/fileadmin/parsel/Material/Berlin/neu2/Overall_Bull_Shit.zip

Materials:

- See activity description.

Suggestions for use:

- See activity description.
- For more inquiry aspects: ask for prediction and evaluation.
- An industry visit at a biogas plant or expert interview is recommended.

Recommended questions:

- How is biogas produced?
- What are the main difficulties in biogas production?
- Which material do you need for building a biogas plant?
- How efficient is your biogas plant?
- Is your biogas plant efficient enough to …?

Activity 10 The efficiency of a hybrid hydrogen power plant

Activity description and learning aims:

- The pupils are supposed to determine the efficiency of a hybrid hydrogen power plant with regard to various primary energy sources. The kit provides methods to change the energy sources, connection (series/parallel) and load.
- knowledge: energy conversion; functional principles and properties of fuel cells; energy storage

  inquiry: observation; description; creating and proving a hypothesis; systematizing; planning, conducting and evaluating design task; using models; comparison

  communication: online research; literature research; lab notes; schemes; manuals; group discussion; tables; diagrams; formula

  appraisal: evaluation of experiment; controversy about hydrogen

Materials:

- e.g. renewable energies kit from Horizon (see unit description)

Suggestions for use:

- The pupils should think of possible ways to determine the efficiency of a hybrid hydrogen power plant, use them on different combinations of power plants and present their results easy to understand.
- An industry visit at a hydrogen factory or expert interview is recommended.

Recommended questions:

- How does a fuel cell work?
- How does a hybrid hydrogen power plant work?
- Which types of hybrid power plants are possible?
- How efficient is your hybrid power plant?
- Which parameters influence the efficiency of a hybrid hydrogen power plant?

Activity 11 Designing a hydrogen vehicle

Activity description and learning aims:

- The pupils are supposed to build a working model of a hydrogen vehicle. They may take cues from existing vehicles and copy their form and features, discuss their own design ideas and make a list of needed material. Try and error methods can be used to achieve maximum efficiency.
- knowledge: energy conversion; functional principles of fuel cell and electric motor; properties of fuel cells and electric motors

  inquiry: observation; description; creating and proving a hypothesis; systematizing; planning, conducting and evaluating design task; using models; comparison

  communication: online research; literature research; lab notes; schemes; manuals; group discussion; tables; diagrams; formula

  appraisal: evaluation of design task; controversy about hydrogen

Materials:

- e.g. Hydrocar or H_2 Racer from Horizon (see unit description)
- electric motor(s), fuel cell, electrolytic cell, electric supply, cables, hydrogen storage

Suggestions for use:

- The pupils should determine what factors influence the efficiency of a hydrogen vehicle, test them and present their results easy to understand.
- An industry visit at a hydrogen vehicle factory or expert interview is recommended.

Recommended questions:

- How does a fuel cell work?
- Which materials do you need for building a hydrogen vehicle?
- Which values influence the efficiency of your hydrogen car?
- Whose hydrogen car is the best?

Activity 12 Design an island system!
Activity description and learning aims:
• The pupils are to build a working model of an island system that may be based on existing instances and copy their elements and features. They should discuss own design ideas and make a list of needed material. Try and error methods may be needed to achieve a high efficiency at all times. They should then determine the overall performance. • knowledge: energy conversion; functional principles of energy converters and storage; properties of energy converters and storage facilities inquiry: observation; description; creating and proving a hypothesis; systematizing; planning, conducting and evaluating design task; using models; comparison communication: online research; literature research; lab notes; schemes; manuals; group discussion; tables; diagrams; formula • appraisal: evaluation of design task; controversy about hydrogen
Materials:
• See unit description.
Suggestions for use:
• The pupils should investigate the local situation regarding energy production, find suitable solutions for energy transformation and eventually a continuous energy supply, and present their findings easy to understand. • An industry visit at an existing island facility or expert interview is recommended.
Recommended questions:
• What are possible ways of energy transformation? • Which way is most effective? • How is energy stored? • How is the facility managed? • Which materials are needed? • What is the power output of our facility?

Which energy source will be the best?

Energy is one of the very important and expensive goods of today's society; it is used for heating and to power every electric device. The world's most utilised energy sources are fossil fuels such as coal, natural gas and petroleum, a resource which is only available in limited supply. The same applies to fuels for nuclear power, uranium and plutonium, which additionally burden us with the problems of safely depositing the nuclear waste, a problem we still have no viable long-term solution for.

Which source of energy will therefore be the best in the future?

1. Form a committee and try to work out an answer to this main question.
2. Develop criteria to guide your further investigations.
3. Use your findings to prepare for a panel discussion at the end of the project, where you present your results and your answer to the main question.
4. Discuss your answer with other groups and comment on their answers to arrive at a common solution.

WP3
Light

European Science and Technology in Action Building Links with Industry, Schools and Home

Work Package 3
UNIT LIGHT
Teacher Information

European Science and Technology in Action:
Building Links with Industry, Schools and Home

Lead partner for Unit: **Dublin City University (DCU)**

The initial version of this learning module has been generated by collaboration between Eilish McLoughlin and James Fryar in association with ESTABLISH partners.

The ESTABLISH project has received funding from the European Community's Seventh Programme [FP7/2007-2013] under grant agreement no 244749

A. Teacher Information

I. Unit description

The Light Unit is divided into two subunits that can be used independently or sequentially, and within a hierarchical curriculum. The subunits follow the natural divide typically employed in relation to the topic of Light: Subunit 1 is aimed at an introductory level and takes a 'ray-based' approach, whereas Subunit 2 is more appropriate for the higher stages of secondary school and incorporates 'wave-based' phenomena. Light is a subject area that often involves curriculum-prescribed demonstrations and experiments, for example the dispersion of white light by a prism and image formation by lenses. The activities presented in this unit are suitable for demonstrations / experiments in a format consistent with an IBSE approach.

Subunit 1: Introducing Light
In this subunit, students examine the basic physical properties of light and its interaction with materials in a predominately qualitative fashion. They learn that sources of light have specific physical characteristics and these can determine properties of light, such as its colour and intensity. They investigate the interaction of light with matter and explore phenomena such as reflection and refraction.

Student level: Lower secondary school level, ages 11 – 15

Discipline(s) involved: Physics

Estimated duration: 5-6 class periods

Subunit 2: Investigating Light
In this subunit, students re-examine a number of the concepts of Subunit 1 in a more quantitative way. They investigate refraction, the refractive index of materials, and the formation of images by mirrors and lenses. Additional topics such as polarization, diffraction, and scattering of light are introduced. Students also learn that, through an understanding of its behaviour, light can be manipulated for technological goals.

Student level: Higher secondary school level, ages 15+

Discipline(s) involved: Physics

Estimated duration: 5-6 class periods

II. *IBSE Character*

Subunit 1: Introducing Light

As an introductory course on Light, the main IBSE approaches employed here are interactive discussion/demonstration, guided discovery and guided inquiry. Through the activities the students develop basic skills to perform and plan scientific inquiry:

- Asking and answering appropriate questions
- Planning and conducting simple scientific investigations
- Giving priority to empirical evidence
- Using empirical evidence as the basis for their explanations of phenomena
- Communicating and discussing their observations and explanations
- Revising explanations based on further investigations

Although light is a subject with which students have familiarity, questioning their conceptual understanding can quickly reveal gaps that can be exploited to form the basis of the subsequent investigations. The difficulty for the teacher lies in balancing the requirement that students (re)evaluate and (re)develop their own concepts, while simultaneously guiding them away from misconceptions and misguided interpretations. Therefore a key part of the IBSE character of this unit is to allow discussion between students of the pros and cons of particular lines of thought, interpretation of data, and conclusions drawn.

Subunit 2: Investigating Light

As this subunit is aimed at the higher levels of secondary education, the main IBSE approaches are guided discovery, guided inquiry, and bounded inquiry. Skills developed by students include:

- Performing experiments
- Analysing results
- Communicating results with the use of graphs
- Comparing experimental results to theoretical models
- Deciding if results support or falsify previous hypotheses

The difficulty for the teacher in this case arises if experimental errors are large and students reach incorrect conclusions. An important part of maintaining the IBSE nature of the investigations is to examine these results in the context of the wider opinion, i.e. how one set of results compare to those of other students. The aim should be to establish that a single experiment is insufficient to draw conclusions, that the results from multiple experiments should be analysed as a whole, and to promote discussion on why certain methodologies employed by the students were less error-prone than others.

III. Science Content Knowledge

Subunit 1: Introducing Light
In this subunit it is assumed that students have no prior formal knowledge of the subject beyond their existing own conceptions. The activities introduce students to the following ideas and concepts:

- Objects may be classified by their optical characteristics
- Light has physical properties such as colour and intensity
- Shadows are caused by the absence of light
- Light may not necessarily be visible to the naked eye
- Light is emitted as a wave
- The direction of propagation of these waves may be represented as rays
- Mirrors reflect light and, for a plane mirror, the angle of incidence is equal to the angle of reflection
- The direction of light can change as it passes from one medium to another
- White light is the combination of lots of different colours of light
- White light can be produced using just red, green, and blue primary colours
- Filters pass certain colours of light and absorb others
- Lenses alter the direction of light and can be used to form images

Subunit 2: Investigating Light
In this subunit it is assumed that students have studied basic trigonometry and are familiar with graphing data. The activities introduce students to the following concepts and ideas:

- An image is formed in a plane mirror and this image is located on the opposite side of the mirror to the observer
- Snell's Law describes how the direction of light changes as it passes from one medium to another
- At a particular angle, light will be reflected from an interface rather than transmitted as it passes from a high refractive index material to a low refractive index material
- When light travels from some medium to air, comparing the actual position or width of an object to its apparent position or width allows one to determine the refractive index of the medium
- The position and magnification of the image created by a lens depends on the focal length and the distance of the object to the lens
- Light can be polarised, and the intensity of light through two polarisers can be described by Malus's Law
- Light can be diffracted by small objects and the width of the diffraction pattern depends on the size of the objects
- Different wavelengths of light can be scattered by varying amounts

IV. Pedagogical Content Knowledge

Light is a topic that exposes students to a fundamental aspect of science – different models are employed depending on the information one wishes to obtain about a physical system.

- The properties of visible light (~400 – 700 nm) examined through the activities are representative of electromagnetic waves (EM) in general.
- EM waves are transverse, which can be demonstrated through polarization.
- The 'ray model' can be used to understand the formation of shadows, reflection and refraction. This model simplifies the analysis of situations where the direction of light is altered.
- The 'wave model' can also be used to understand shadows, reflection, and refraction, but is required to understand phenomena such as polarization, diffraction and interference.
- Phenomena such as the decrease in measured intensity of light as a function of distance, or partial absorption/transmission through neutral density filters, are difficult to explain on the basis of the 'ray model'. These can readily be explained by the 'wave model' as changes in the amplitude.
- The concept of energy is useful in explaining absorption/transmission, with the energy loss occurring as a result of the interaction of light with materials.
- It is the interaction with materials that result in reflection, refraction, shadows, polarization, absorption, and diffraction.

Science Education research has revealed a number of student misconceptions around the topic of Light:

- A recurring theme in studies is that light is said by students to illuminate objects and once 'lit up' these objects can then be seen. Students conceptualise light as a 'local brightness' and the act of seeing is often not considered to require that light travel directly to the eye.
- Students often ask questions of the form: 'If I can see light and it travels as a ray, then why don't I see bright rays crossing the room?' This type of question demonstrates that, although students may accept that light is present in the space around them, they fail to understand the relationship between the image they see and the spatial-distribution of light in their environment (thereby altering their view of objects depending on their position).
- Students tend to classify light sources into those that are 'natural' and those that are 'artificial' and, accordingly, can attribute unique properties to the light produced in each case. Although the classification into 'natural' and 'artificial' sources is somewhat flawed (is a burning candle producing light through natural or artificial means?), it nevertheless demonstrates that students have actively attempted to distinguish between the properties of different light sources and the properties of

the light produced. This can form the basis for a more scientific approach at classifying the optical properties of objects.

- Students tend to relate the reflection of light specifically to mirrors and 'shiny surfaces'. They often fail to see the relevance of reflection in relation to the visible objects within their environment that are not 'sources' of light.
- Students often conceptualise that the image formed in a mirror is located on the surface of the mirror rather than behind it.
- Students often fail to understand the role of filters, even having studied the dispersion of white light by a prism. Many students consider that filters 'alter the colour of light' rather than allowing or preventing certain colours from passing through them.

Further reading:
'Student Conceptions of Light: A Case Study', D. M. Watts, Phys. Educ. 20, 183 (1985)
'Exploring Students' Concepts of Light', B. F. Stead and R. J. Osborne, Australian Science Teacher's Journal 26(3), 84 (1980)
'Student Misconceptions about Light in Algeria', D. Blizak, F. Chafiqi, and D. Kendil, http://spie.org/etop/2009/etop2009_4.7.35.pdf (Proceedings of the 2009 Conference on Education and Training in Optics and Photonics).
SPIE is the International Society for Optics and Photonics (www.spie.org) and maintains many excellent resources and tools for teachers and educators.

With regard to the features of an inquiry approach, teachers especially need to gain pedagogical content knowledge enabling them to "engage students in asking and answering scientific questions, designing and conducting investigations, collecting and analyzing data, developing explanations based on evidence, and communicating and justifying findings". This mainly involves teachers being able to:

- Provide questions to frame unit and questions for discussion
- Suggest approaches for using technology as laboratory and cognitive tools.
- Suggest approaches for collecting and analysing data.
- Support students in designing their own investigations.
- Suggest approaches to help students construct explanations based on Evidence
- Provide approaches for communicating science knowledge.

V. Industrial Content Knowledge

There are numerous industrial applications of light, from communications systems to laser-guided drilling equipment, but a particularly interesting and, from the students' perspective, contemporary area is display and image-capture technology. Examples of industry links to the activities within the unit are:

Activity	Relevance to Industry
1.1 Sources of light	Solids and gases are used in LCD and plasma screens to produce white/coloured light
1.2 How does light travel?	Altering the direction of light so each eye sees a different image is the basis of 3D lenticular displays such as those used in the Nintendo 3DS
1.4 Exploring white light and filters	Some LCD TVs use white light sources and filters to produce red, green, and blue pixels
1.5 Exploring primary colours	RGB pixels are used in virtually all display technology to produce coloured images. Conversely, RGB sensors are used in cameras to record colour images.
1.7 Exploring refraction 2.2 Investigating Snell's law	The refractive index of screens must be relatively constant across visible wavelengths or distortion of the image/colours would occur depending on viewing angle
1.8 Exploring lenses 2.4 Investigating lenses	Lenticular lenses are used in 3D displays that do not require glasses, and are obviously a key part of camera systems
2.5 Optical Storage	Interference patterns form the basis of holography, and holographic 3D TVs are expected to move from development to production stage in the next few years.
2.6 How do sunglasses work?	Polarization of light and acceptance/rejection by polarization filters is the method by which current-generation 3D movies (eg. Avatar, Tintin, etc) display different images to each eye

The activities within the Light unit can be readily shown to have 'practical' and 'technological' applications beyond the classroom. Professions requiring an understanding of the behaviour of light with regard to imaging technology is not limited to the production of screens and cameras, but includes such areas as computer animation (where scenes are 'rendered' or 'ray-traced' to provide realistic images), photography and cinematography (the use of filters, lenses, and lighting to achieve a distinctive 'look' in films), and in special effects.

VI. *Learning Path(s)*

Since the Light unit is divided into activity subunits, each of which is largely independent, different directions and emphasis can be taken depending on the requirements of the curriculum or learning aims of the teacher. For example, Activity 1.6 (Exploring Mirrors) replaces the traditional ‘parallax and pins’ method of determining the relationship between the angle of incidence and reflection from a plane mirror with a method involving straws that students must look through. Although the experiment yields the same end result, the use of straws reinforces the ‘ray model’ of light since only light travelling through the straws (ie in a straight line) is used. Activity 1.6 could therefore be used as a precursor to Activity 1.3 involving the formation of shadows.

Subunit 1: Introducing Light

Activity	Inquiry Type	E-emphasis
1.1 Sources of light	Interactive discussion	Engagement
1.2 How does light travel?	Interactive discussion/demonstration, guided discovery	Engagement, Exploration, Explanation, Elaborate
1.3 Understanding shadows	Guided inquiry	Exploration, Explanation, Elaborate
1.4 Exploring white light and filters	Guided discovery	Exploration, Explanation, Elaborate
1.5 Exploring primary colours	Interactive discussion/demonstration	Engagement, Exploration, Explanation, Elaborate
1.6 Exploring mirrors	Guided discovery	Exploration, Explanation, Elaborate
1.7 Exploring refraction	Interactive discussion/demonstration	Engagement, Exploration, Explanation, Elaborate
1.8 Exploring lenses	Guided discovery	Exploration, Explanation

Subunit 2: Exploring Light

Activity	Inquiry Type	E-emphasis
2.1 Investigating mirror images	Guided discovery	Exploration, Explanation, Elaborate
2.2 Investigating Snell's law	Guided inquiry	Exploration, Explanation, Elaborate
2.3 Studying real and apparent depths	Interactive discussion/demonstration, guided discovery	Engagement, Exploration, Explanation
2.4 Investigating lenses	Guided inquiry	Engagement, Exploration, Explanation, Elaborate
2.5 Optical Storage	Guided discovery	Exploration, Explanation, Elaborate
2.6 How do sunglasses work?	Guided inquiry	Engagement, Exploration, Explanation, Elaborate
2.7 Why are sunsets red?	Interactive discussion/demonstration	Engagement, Exploration, Explanation

VII. Assessment

Although the assessment strategy will ultimately depend on the nature of the curriculum, it is preferable that such strategies would employ both a theoretical test and a practical assignment. Some form of research project might also be considered.

For younger students (Subunit 1) a research project might involve examining a particular piece of technology, such as a Plasma/LCD TV screen or digital camera. The assessment in this case might be based on how well students are able to link aspects of their physics course to its construction and operation. For older students (Subunit 2) a research project might involve a comparison of different technologies, for example CRT and LCD displays, digital and film cameras, different strategies of producing a 3D image (lenticular displays versus polarized glasses), or the differences between CD and Blu-ray read heads.

A practical assignment could be based on any of the activities in the subunits, or experiments on the curriculum that are not specifically covered but related to these activities.

An example of a theoretical test is given at the end of this document. It can be modified for either the younger or older student groupings, and could involve either qualitatively or quantitatively determining the behaviour of light after interaction with a number of optical components. In the case of the older groups, values could be added, for example the wavelength of light or refractive index of the materials.

VIII. *Student Learning Activities*

Activity 1.1: What are sources of light?

Learning aims:

- *Triggering the students' interest in light*
- *Differentiating between objects that are sources of light and those that are not*
- *Understanding that sources of light have different properties*
- *Understanding that light may not necessarily be visible to the human eye*

Materials:

- *Candle, Torch, Infrared TV remote control, Overhead projector/acetate or Whiteboard/marker, Mobile phones (with cameras)*

Suggestions for use:

Hand out *Worksheet 1.1*. The students should be asked to consider what objects they can see in the classroom, and a (brief!) list made of their choices. The discussion should then turn to whether these objects are 'sources of light'.

Next, the students should subsequently attempt to describe the differences between the candle and the torch on the basis of physical characteristics (i.e. is the intensity of light constant, what colour does the source produce, is the source hot, does the source require a battery, etc). Having developed a list of criteria and expanded this to a number of different light sources, the students should then discuss whether objects that are sources of light have similar properties to those that are not.

This is undoubtedly a difficult exercise and intentionally so! The problem students will face is that other than the obvious 'light sources emit light' it is difficult to find a unifying principle that distinguishes light sources from other objects. This is a relatively robust way of challenging any preconceptions students may have: for example, that light sources need to be electrical in nature or that all objects are sources of visible light because we can see them.

Finally, the IR remote control should be introduced. The students can examine whether this is a source of light using mobile phone cameras and imaging the remote control LED while the teacher presses a button. Although invisible to the naked eye, the sensors used in mobile phones are typically sensitive to the IR light produced.

Possible questions:

- *Which of the light sources are also hot? Are all light sources hot?*
- *Which of the light sources are solids, liquids, or gases?*
- *Which of the light sources involve chemical reactions?*
- *If we can see walls, tables, and chairs, are they also sources of light? If not, why can we see them?*
- *Is there a single physical characteristic that explains why some objects are sources of light and some are not? Does energy play a role in some way?*

Activity 1.2: How does light travel?

Learning aims:

- *Understanding that light is present in the space around a light source*
- *Understanding that the direction light travels to an observer may be modelled as a straight line ray*

Materials:

- *Cardboard box with a hole cut in one side, Incandescent light bulb (~40 W), Overhead projector/acetate or Whiteboard/marker*

Suggestions for use:

The incandescent bulb is placed in the centre of a darkened classroom and switched on. The students gather close to the bulb and, if they can see light from the bulb, should be asked to raise their hands. They then line up around the walls of the classroom with a large space between each of them and the process repeated. The teacher should then ask whether they would be able to see light from the bulb if they stood in the gaps that were deliberately left between each of them. Finally, the students should face the wall of the classroom and asked to raise their hands if they can still see light from the bulb. The bulb should be turned off for a moment, and then turned back on, and the students asked if they wish to reconsider whether they can see light from the bulb when not facing it. Using the acetate and overhead projector, the bulb is represented by a dot in the centre and the relative positions of the students and their direction of view marked on the acetate with arrows for the three cases. This forms roughly-concentric rings of different diameters. The students should then discuss how they think the light reached them and the teacher should guide this discussion towards conclusions that involve light ‘spreading out’ from the bulb. This can be directly compared to sound waves. They should then discuss how they think light reached their eyes when facing the wall and consider the direction that light appears to travel from the bulb to each observer. The teacher can guide the discussion towards conclusions involving straight line paths or ‘rays’ from the bulb.

The aim of this exercise is to establish in the students’ minds that light is a wave, that light exists in the space around them, that light reflects from the wall, and that light can be modelled using rays. These concepts are reinforced in *Worksheet 1.2*.

As an additional component, the students could be asked to consider where they would need to stand to see the light from the bulb after a box (with a small hole in the side) is placed over it. They can then test their ideas by performing a similar ‘hands-up’ experiment to that at the beginning of the activity, and can map the positions from which they can see the light from the bulb. This can be used to show the validity of the ‘ray’ model in predicting where the students need to stand to see the light exiting the box.

Possible questions:

- *If you changed the size of the hole in the box, would this change where in the room you could see the bulb?*
- *What happens to the light that doesn’t come out of the hole in the box?*

Activity 1.3: Understanding shadows

Learning aims:

- *Understanding that a shadow is the absence of light*
- *Understanding what determines the size of the shadow on a screen*

Materials:

- *Small torches or small incandescent bulbs, Small cardboard squares that are a few cm on each side (to cast the shadow), Retort stands to hold the torch, White sheet to use as a screen*

Suggestions for use:

The students begin by drawing the arrangement of apparatus they would require to observe a shadow on a screen. They then qualitatively investigate the formation of shadows in an attempt to deduce what parameters affect its size, with the teacher guiding them towards providing answers to the following questions:

1. If the projection screen and torch are fixed in place, how does the size of the shadow change as the cardboard square is moved towards or away from the torch?

2. If the torch and cardboard square are fixed in place, how does the size of the shadow change as the projection screen is moved towards or away from the cardboard square?

3. If the screen and cardboard square are fixed in place, how would the size of the shadow change as the torch is moved towards or away from the cardboard square?

The challenge for the students is then to try and explain their observations based on what they know about the propagation properties of light.

Possible questions:

- *If I place a green bottle in front of the bulb, I see a green 'silhouette' cast on the wall. This grows in size and decreases in size depending on the bottle's distance from the screen and torch. Is this also a shadow?*

Activity 1.4: Exploring white light and filters

Learning aims:

- *Understanding that white light is composed of many different colours*
- *Understanding that filters only allow some colours through*

Materials:

- *Torches with a narrow cardboard slit attached, glass prisms, good quality (ie theatre quality) red, green, or blue transmission filters, coloured cardboard 'screens'*

Suggestions for use:

Hand out *Worksheet 1.4.*

Each student will project light from the narrow cardboard slit on their torch through a prism and onto a white sheet of paper. They will see the familiar red, orange, yellow, green, blue, indigo and violet rainbow colours. The students are then presented with two alternative explanations for this phenomena: either the prism 'converts' white light into coloured light or white light is a mixture of colours that are subsequently 'separated' by the prism through different angles.

Although students may already know the correct interpretation, they cannot distinguish between these alternatives on the basis of their observations. They should then be asked to suggest an experiment that could resolve this problem. One experiment often suggested is the use of two prisms to show that the spectrum of colours can be recombined to give back white light. This should be done as a demonstration although it does not resolve the problem as presented – even with two prisms it is still not clear whether the spectrum of colours is present in the white light before the interaction with the prisms.

The students should then investigate the use of coloured filters. By placing a red, green, or blue transmission filter between the prism and screen they will observe that only the corresponding colour is transmitted. If they now place this filter between the torch and prism, they will observe that red light is transmitted through the filter, passes through the prism, and arrives at the screen. The students can repeat this process with different filters, hence proving that white light is a mixture of different colours and these are spatially dispersed by the prism.

The key to this experiment is the quality of the filters. If this poses a problem in terms of quantity, then the activity could be run as an interactive demonstration with students invited to place filters in the appropriate positions and record the results.

A suitable resource for this activity is freezeray.com/physics.htm which gives an interactive applet to investigate the effect of different coloured filters.

Possible questions:

- *If the sun produces white light, then what must happen to the light to make leaves appear green in summer?*
- *In autumn, why do leaves then appear red and orange?*
- *How are rainbows formed?*

Activity 1.5: Exploring primary colours

Learning aims:

- *Understanding that white light can be produced by mixing red, green and blue light*

Materials:

- *Overhead projector, sheet of card ~300 x 300 mm with three identical holes approximately 15 x 30 mm in dimension, red, green and blue filters, 3 small plane mirrors, Neutral Density filters with low optical density, magnifying glass*

Suggestions for use:

Tape the red, green and blue filters over each of the holes in the sheet of card and position this on the overhead projector to produce three distinct beams of coloured light. Invite students to intercept each primary colour with a mirror, deflect it onto the ceiling or whiteboard and hence observe and note the colour that results when any two beams are mixed and when all three are mixed.

Next, the students should be asked to consider what would happen if the red, green, or blue beam was not as intense as the others – for example, if red was weaker than green, what colour would be produced by mixing them? The students can then test their ideas by placing the neutral density filters on top of each of the coloured filters and mixing the light.

Finally, the students should discuss whether any devices they know of produce different colours by mixing just red, green, and blue light of different intensities. They can verify that a TV, laptop or mobile phone screen does exactly this by examining the pixels with a magnifying glass.

Additional experiment: Using a single red, green, or blue filter and an OHP, project a small coloured spot onto a screen and have the students stare at it for at least 1 minute. Once the filter is removed (and the OHP left on), the students will see a small spot that persists for a moment in their vision that is a different colour to the spot that was projected – most people see red where it was green and vice versa.

The human retina contains cone cells that are sensitive to red, green and blue primary colours. Staring at a red spot breaks down the pigment in the red-sensitive cone cells and when the filter is removed these 'bleached' cells will be less sensitive than the green- and blue-sensitive cones, subsequently leading to the persistence of a spot of different colour. This can be used as a demonstration that the eye is sensitive to primary colours and that our perception of colour is due to red, green, and blue mixing.

Possible questions:

- *Is it possible to create white light without using the seven colours of the rainbow?*
- *If you can create all visible colours by mixing red, green, and blue, then can you detect all colours by just measuring how much red, green, and blue arrives at a sensor? Is this how the eye sees colour?*

Activity 1.6: Exploring plane mirrors

Learning aims:

- *Understanding that light rays travel in straight lines*
- *Understanding that plane mirrors reflect light*
- *Understanding that the angle of incidence equals the angle of reflection*

Materials:

- *White sheets of paper, plane mirrors, retort stands, straight drinking straws, pencils, protractors, rulers*

Suggestions for use:

The activity begins with students being posed a question of the form: 'If you look through a straw at an object, what direction must the light travel from the object to your eye in order for you to see it?'

The students are then asked to consider the same question but for two straws forming a V-shape. What might one use to get light to alter its direction so that light passing into the first straw could be seen through the second straw? The teacher should guide the discussion towards the notion of 'reflection' from a mirror.

The students can then use *Worksheet 1.6* and clamp a mirror at one edge so it is held vertically by a retort stand. The bottom edge of the mirror should be in contact with the mark on the paper. They can then position a drinking straw at some random angle in front of the mirror and attempt to position a second straw so that when they look through it, they will see the reflected light that passed through the first straw.

The students should then be asked how they would need to alter the setup if they changed the angle of one of the straws, or the angle of the mirror.

Possible questions:

- *Do you notice anything about the angles the straws have to be in order for light to pass from one to the other?*
- *Does this relationship hold when the mirror is angled?*
- *What would happen to light at different points on the mirror if the surface of the mirror was curved inwards or outwards?*

Activity 1.7: Exploring refraction

Learning aims:

- *Understanding that light is refracted when it travels from one medium to another*
- *Understanding that light can be reflected from and transmitted through an interface*

Materials:

- *Laser pointers (red, low wattage), large plastic lunch boxes with transparent/semi-transparent walls, salt or milk, water, plastic sheets (e.g. bin bags), plastic spoons, green or blue laser pointer*

Suggestions for use:

The plastic sheets are placed on the desks in case of spillage. Students fill a plastic lunch box with water and add salt or milk until the water appears cloudy. Plastic spoons can be used in the case of salt to agitate the water during the investigations. The lunch box should be positioned close to the edge of the desk to allow for a wide range of possible angles.

The students begin by shining the laser pointers from air into the water and investigating how the path of light alters as they change the angle. They should draw a diagram to illustrate what they observe.

Next they investigate how the path of light changes if they shine the laser pointer through the side of the lunch box, through the water, and into the air. Again, they should draw a diagram to illustrate what they observe.

The teacher should then use the green or blue pointer side-by-side with a red pointer to illustrate that light of different colours will refract by different amounts.

Possible questions:

- *How does the direction of light change when it travels from air into water?*
- *How does the direction of light change when it travels from water into air?*
- *Is it possible to pick an angle so that light travelling from water into air is reflected from the interface between the media?*
- *Why is not possible to see the beam of laser light passing through the air when it can be seen passing through the water?*
- *Why does a prism disperse white light into its constituent colours?*

Activity 1.8: Exploring lenses

Learning aims:

- *Understanding that lenses produce images*
- *Understanding that lenses do not necessarily 'magnify' objects*

Materials:

- *Incandescent bulbs, short focal-length bi-convex lenses, paper 'screens'*

Suggestions for use:

The students should take a bi-convex lens and attempt to form an image of their bulb on their paper 'screens'. This should take the form of a challenge to see how small they can make their image by changing the relative positions of the bulb and screen.

The students should then be asked to describe what they needed to do to minimise the size of their images and whether the lens 'magnifies' the object. Next the students should consider what must happen to the direction of light when it passes through the lens if the image is smaller than the object.

Next the students remove the screen and look through the lens in an attempt to 'magnify' the bulb (ie in a magnifying glass configuration when the object is inside the focal length). They should then be asked to describe where their eye and the bi-convex lens need to be positioned to produce this 'magnified' image. If they now place a screen where their eye was, is an image formed?

The students should consider what must happen to the direction of the light through the lens in order to produce this 'magnified' image.

A suitable resource for this activity is freezeray.com/physics.htm which gives an interactive applet to investigate the effect of different types of lenses.

This activity can lead on to discussing how the human eye works and how we can correct for long- and short-sightedness. Again freezeray.com/physics.htm gives an interactive applet to investigate the effect of different types of lenses on the human eye.

Possible questions:

- *Why is the image upside-down when it is small? Does this fact change the conclusion as to what happens to the direction of light when it passes through the lens?*
- *Why is no image formed on the sheet of paper when your eyes can see a magnified image?*
- *What is the purpose of wearing glasses?*

Activity 2.1: Investigating mirror images

Learning aims:

- *Understanding that the image in a plane mirror is not located at the mirror surface*

Materials:

- *Three thick whiteboard markers, Plane mirror, Retort stand, Paper, Pencil, Cocktail sticks, Shiny metal tin*

Suggestions for use:

The students should initially investigate the phenomenon of parallax by placing one of the markers vertically on their desk and lining up the other two behind it. They should describe what they observe when they look along this line of markers, with one eye closed, and move their head sideways -

Does the nearest marker appear to move a greater or lesser distance than the farthest marker?

Where would the markers need to be placed so they appear to move together?

The students should then be asked to determine how they might use this method of parallax to determine where the image in a plane mirror is formed. They can hold the mirror vertically and use the paper to mark the locations of the object pen, the mirror plane, and the image itself. The students should plot the path the light takes to the eye, and the path to the image.

Finally, the students should set their tin on the sheet of paper and attempt to angle a number of cocktail sticks on the paper so that they appear to lie parallel in the tin. They should then attempt to explain how the image is formed in this convex mirror based on their understanding of ray optics.

Possible questions:

- Does the angle of incidence equal the angle of reflection for a curved mirror?
- How does the curve affect the direction of light reflected from different points?
- Where is the image formed in the convex mirror? What if it was concave?

Activity 2.2: Investigating Snell's Law

Learning aims:

- *Understanding that Snell's Law describes the change in direction of light moving from one medium to another*
- *Understanding that at some angle, light will totally reflect from the interface when travelling from high to low refractive index*

Materials:

- *Red laser pointer, Block of glass, White paper, Pencil, Protractor*

Suggestions for use:

The students should be given the materials and asked to discuss how they might go about studying what happens to the direction of light when a laser passes from air into glass and back into air. The students should examine questions such as:

How will I determine the direction that light takes through the glass?

How will I measure and quantify the direction into and through the glass?

How will the measurement be standardised so that the results from different people can be compared and combined?

Which parameters of the experiment should I keep constant and which should I alter?

Once I take my data, how will I tabulate and graph it to investigate the relationship between the direction of light into and through the glass?

Next, the students perform the experiment they have devised and report their results in *Worksheet 2.2*. If they have standardised their measurements, the data can be entered into a software package such as Excel and projected on a screen for the students to see. A plot of 'angle of incidence' versus 'angle of refraction' will not yield a straight-line graph and the teacher should then show the students how this changes if the Sine (or Cosine, depending on whether the students have measured the angle from the normal or surface of the glass) of the angles are plotted. The students can then use the slope of this line to extract the 'refractive index of glass' (assuming the refractive index of air is 1) and hence extract Snell's Law. Finally the teacher should check if the data contains evidence that at some angle the light did not escape from the block of glass, and whether any student reports this observation. If not then the students should be instructed to check this, and discuss why they failed to discover this phenomenon.

Possible questions:

- *What property of the light changes to cause the change in angle as it passes from one medium to another?*
- *Is light reflected from the surface of the glass when the beam travels from air to glass? Does this reflected beam change in intensity as the angle of light onto the surface changes?*
- *How might we use the total internal reflection of light to transmit a laser beam?*

Activity 2.3: Studying real and apparent depths

Learning aims:

- *Understanding that the refraction of light alters its direction*
- *Understanding that refraction can affect the appearance and apparent depth of objects*
- *Understanding that comparing the real and apparent depths gives a measure of refractive index*

Materials:

- *Graduated cylinders of different volumes, Coin, thin circle of Cork with a diameter equal to that of the coin, Mobile phones (with cameras)*

Suggestions for use:

The students should drop the thin slice of cork into the graduated cylinder. Placing their mobile phone on the top of the cylinder, they take a photograph of the cork. *It is important that the same optical/digital zoom settings are used throughout the experiment.* They then add some water and measure its height inside the cylinder before photographing the now-floating piece of cork. The students should repeat the process at least six times for different water levels and finally should measure the height of the cylinder itself.

The purpose of this exercise is to allow the creation of a 'calibration graph' that relates the diameter of the cork circle in image pixels to its distance from the camera (obtained by subtracting the height of the water in the cylinder from the height of the cylinder).

The students then empty the cylinder and drop a coin to its base. They photograph the coin in the absence of water, then completely fill the cylinder and photograph the coin through the water. By comparing the diameter of the coin (in pixels) when imaged through the water to their calibration graph, they can determine the apparent depth of the coin. This analysis can be performed by the students at home. Since each student will have used different levels of water, a graph of real depth versus apparent depth can be created in Excel that includes data from each of the students. The slope of this graph then gives the refractive index of water.

One simple method of analysing the images is to load them into software such as Microsoft Picture Manager (found in Office tools) and crop the photo so that only the coin remains. Since the coin is circular, the image dimensions then give the diameter in pixels. The experiment provides a good introduction to a number of topics. Firstly, the calibration graph will not be linear and so students must draw 'best fit curves'. Secondly, it provides a good example of experimental errors – cameras with a higher megapixel count will be more accurate than those with lower counts, and the apparent diameter of the coin is related to both the height of the cylinder (ie the distance of the camera from the base of the cylinder) and the height of water added.

Possible questions:

- *Why does a swimming pool look shallower than it actually is?*

Activity 2.4: Investigating lenses

Learning aims:

- *Understanding that the lens equation describes the position of the image, given the object position and focal length*
- *Understanding that the magnification of a lens is given by the ratio of image to object distance*

Materials:

- *Stands to hold (1) Bulb, (2) Short focal-length convex lens, (3) Paper screen, Metre rule, Pencil*

Suggestions for use:

The activity can progress in one of two directions: either the students have previously studied the lens equation and the experiment will subsequently test the law, or the students have not studied the equation and will derive it on the basis of their results.

Firstly, the students should determine the focal length of their lens or verify the value given. This can be achieved by focusing light from a distant object (the ceiling lights are a good source) onto the desk and measuring the height of the lens from the table. The students should then discuss the method by which they will investigate the relationship between object and image distance using the equipment supplied, and how they will graphically show the relationship. The teacher should guide this discussion so that students will standardise all measurements of distance to be relative to the lens.

The students can then conduct an experiment by which they fix the screen in place, adjust the position of the bulb relative to the screen, and subsequently move the lens to produce an image. They should record and tabulate their data into columns corresponding to object distance, image distance, and focal lengths. To investigate the magnification, students should also measure the width of the bulb filament they observe on the screen for each combination of image/object distance and compare this to the actual width.

The students should then plot a graph of the relationship between image and object distance. For students who have not covered the lens equation, the natural tendency will be to plot object distance versus image distance (or vice versa) which will generate a curved graph. The teacher should discuss with the students what this shape might indicate in terms of the relationship, and the students can subsequently plot the reciprocal of object distance versus the reciprocal of image distance to yield a straight line.

Possible questions:

- *If you examine the x and y intercepts of the graph, what does this relate to? (1/f)*
- *What is the equation of the line if M is the slope? (M=v/u)*
- *How does this slope relate to the width of the filament at each object/image combination?*

Activity 2.5: Optical Storage

Learning aims:

- *Understanding that light can be diffracted by small objects*
- *Understanding that examining the diffraction pattern can tell us the dimension of those objects*
- *Understanding that the diffraction pattern depends on wavelength*

Materials:

- *CD, DVD and/or Blu-ray discs, Red laser pointer, Retort stand, Graph paper 'screen', adjustable slits*

Suggestions for use:

The students should be asked to consider the differences between a CD and DVD/Blu-ray disc with the discussion being guided towards the amount of information each disc can store (CD: 740 MB, DVD: 4.7 GB, Blu-ray: 25 GB for single sided discs). They should then be asked to compare the physical size of each disc (120 mm diameter x 1.2 mm thick) and discuss why, if the discs are the same physical dimensions, the information content is different.

Hand out *Worksheet 2.5*.

The students then set up their laser so it is incident at some angle on the CD surface and should observe and sketch the diffraction pattern observed on the screen. If the students have not previously covered the topic of diffraction, they are likely to explain this pattern in terms of reflections from multiple objects. This observation will conform to their knowledge of CDs having 'pits' on the surface. They then replace the CD with a DVD and should note that the pattern is now broader.

These observations should now be related to the amount of information stored on each disc. The conceptual difficulty students may encounter is that the pattern obtained from a DVD seems broader, which they may attribute to larger features on the DVD. However, the storage capacity of the DVD is larger than a CD, which suggests the features should be smaller!

The students should then investigate how the diffraction pattern changes as laser light is passed through a slit that is made progressively narrower. This serves to reconcile the broad pattern obtained from the DVD and the smaller features on that disc.

The exercise can be used as an introduction to diffraction, with the teacher providing the subsequent theory.

Possible questions:

- *What does the size of the pits mean in relation to the amount of information that can be stored on the discs?*
- *Why are red lasers used to read CDs but blue lasers are needed for Blu-ray discs?*
- *Why do optical microscopes have a limit on their magnification?*

Activity 2.6: How do sunglasses work?

Learning aims:

- *Understanding that light can be polarized*
- *Understanding that the intensity through two polarizers may be described by Malus's Law*

Materials:

- *Two polarizers, two neutral density filters*

Suggestions for use:

The students should be asked to discuss how sunglasses work. Typical responses will involve 'coloured glass/plastic' that 'only allows some of the light through' which could be used as a starting point for a discussion on absorption, filters, and energy.

Next, the students are invited to examine the properties of 'neutral density' filters of the kind found on most sunglasses and asked to consider the following questions:

If each filter only allows 50% of the light through it, what percentage is transmitted through both filters when placed on top of one another?

This question establishes that the total transmission is found by multiplying (50% of 50% is 25% or 0.50 x 0.50 = 0.25). The students are then posed the question as to whether the order or orientation of the filters makes a difference.

The students are then given Polaroid filters and asked to examine their properties:

Does the relative orientation of the filters change the light intensity transmitted? If zero degrees is defined as the relative orientation providing maximum throughput, what relationship in terms of angle gives minimum throughput?

Does the order of the filters make a difference?

The Worksheet includes an optional experiment utilising a data logger to examine Malus's Law.

Possible questions:

- *How can you use a polarizer to remove reflections from a surface?*
- *How do 3D movies work and why do you have to wear glasses?*

Activity 2.7: Why are sunsets red?

Learning aims:

- *Understanding that light can be scattered by small particles*
- *Understanding that scattering is wavelength dependent*

Materials:

- *Large transparent plastic or glass container of water, Projector or Overhead projector, White screen, Dropper containing Dettol*

Suggestions for use:

The container of water should be placed in front of the projector and a beam of white light passed through it. Alternatively, a circular hole can be cut in a sheet of card and placed on an overhead projector. The container should then be placed over the card to allow the circular beam to pass through the water.

The students should be asked to consider how the on-screen spot of light will change as Dettol is added to the water. The teacher then gradually adds a few drops of Dettol, causing the transmitted light to change colour from yellow, through orange, to red.

The students should be asked to explain what they think is happening and should be invited to examine the colour of light escaping from the sides of the water container (blue light).

Possible questions:

- *What is the difference, in terms of the wave model, between blue and red light?*
- *What property of the Dettol determines which wavelength is scattered?*
- *Why is the sky blue during the day and red at sunrise and sunset?*
- *Why are clouds white?*

WP3
Light

European Science and Technology in Action Building Links with Industry, Schools and Home

Work Package 3
UNIT LIGHT
Classroom Materials

European Science and Technology in Action: Building Links with Industry, Schools and Home

Lead partner for Unit: **Dublin City University (DCU)**

The initial version of this learning module has been generated by collaboration between Eilish McLoughlin and James Fryar in association with ESTABLISH partners.

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Worksheet 1.1 What are 'sources' of light?

1. Light is all around us. It allows us to see, but where does light come from? Have a look around your classroom and list five objects that you can see:

2. Are any of these five objects a source of light?

3. Are a candle and torch sources of light? Explain.

4. What are the differences between the candle and torch in terms of their physical properties?

5. In science we attempt to characterise objects in our universe and group them together according to common properties. In the table below, write down four properties you think light sources have and then list five light sources.

Source of light	**Property 1** ________	**Property 2** ________	**Property 3** ________	**Property 4** ________
1.				
2.				
3.				
4.				
5.				

6. Does each source of light have the same properties?

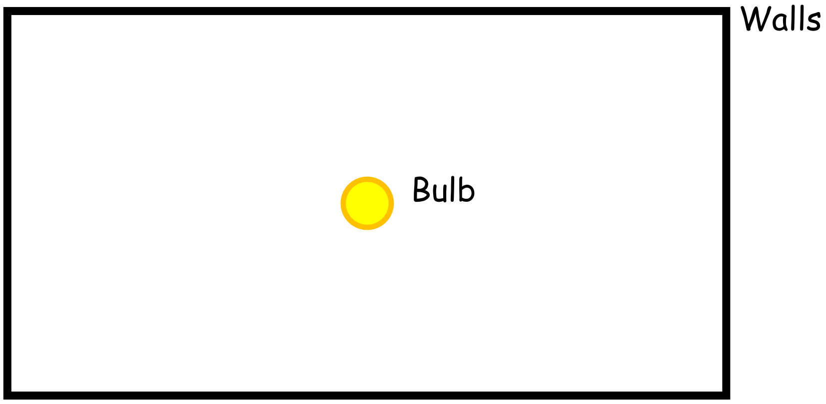
7. Do the properties you have listed only apply to sources of light or do they apply to objects that are not sources of light as well?

8. Why can you see objects that are not sources of light?

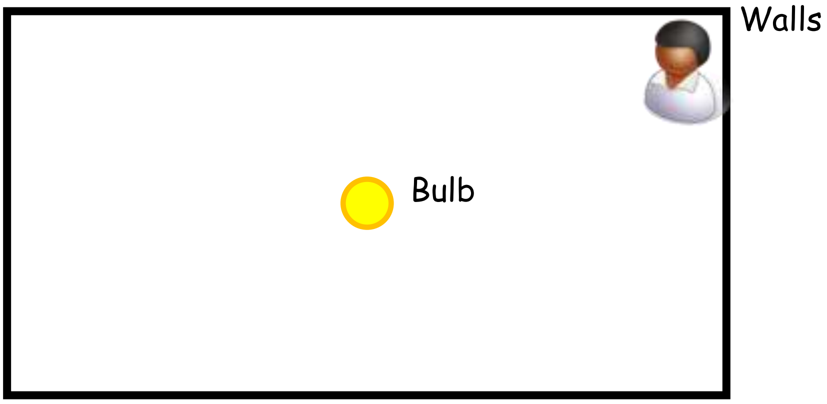
Worksheet 1.2 How does light travel?

A light bulb is set in the middle of a classroom and turned on.

1. In the diagram below, the rectangle represents the walls of the room and the circle represents the position of the bulb. Where in the room would it be possible to detect light from the bulb? Mark this/these position(s) in the diagram.



2. Consider a person standing in the corner of the classroom.



Does light from the bulb travel as far as this person? How do you know?

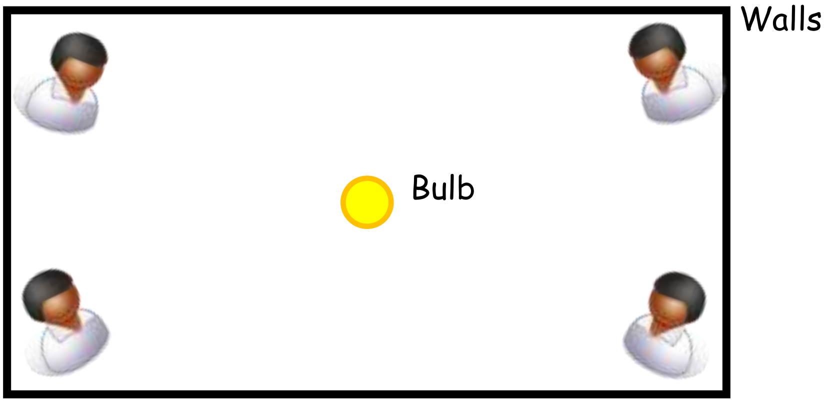
____

On the diagram, draw in the path that light takes from the bulb to the person.

How does this path change if the person closes their eyes?

____

3. Now consider that four people are facing the bulb.



Draw in the path that light takes from the bulb to each person.

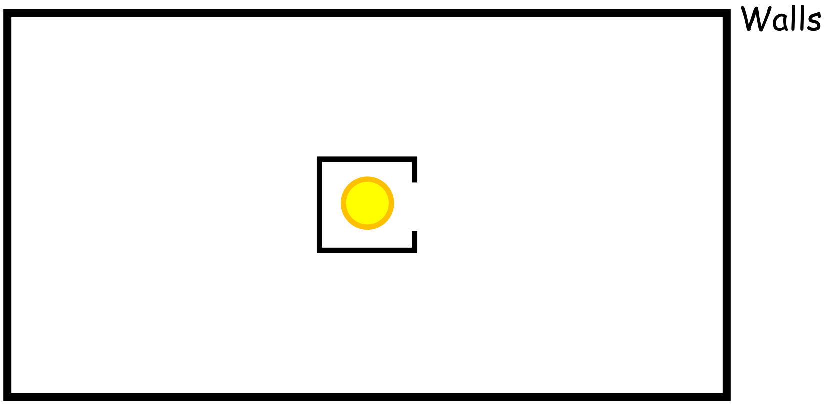
4. Suppose the four people above faced the wall instead. Would they still see light from the bulb? Explain.

____

____

____

5. A box with a small hole in the side is placed over the bulb.



Draw in the diagram where you would need to stand in order to see light from the bulb. Is there only one position? Explain.

____

____

Worksheet 1.3 Understanding Shadows

1. In the space below, draw a diagram of how you would set up a bulb, cardboard square, and paper screen in order to show a shadow.

2. Now set up the apparatus as you've drawn in the diagram. When you turn on the bulb, do you see a shadow of the cardboard piece on the paper? Why do you think the shadow is formed?

____

____

____

3. Adjust the set up to make the shadow larger on the screen. Explain what modification you needed to make.

____

____

____

4. Is there another way of the making the shadow larger? (Hint: What did you move in order to answer Question 3? Is this the only part of your set up you can change?)

____

____

____

5. In this investigation there are 3 'variables' that can be changed to alter the size of the shadow. What are these 3 variables?

____

____

6. Choose one variable you have not already examined. Predict how you should adjust that variable in order to make the shadow smaller. What alteration to your set up will you make?

____

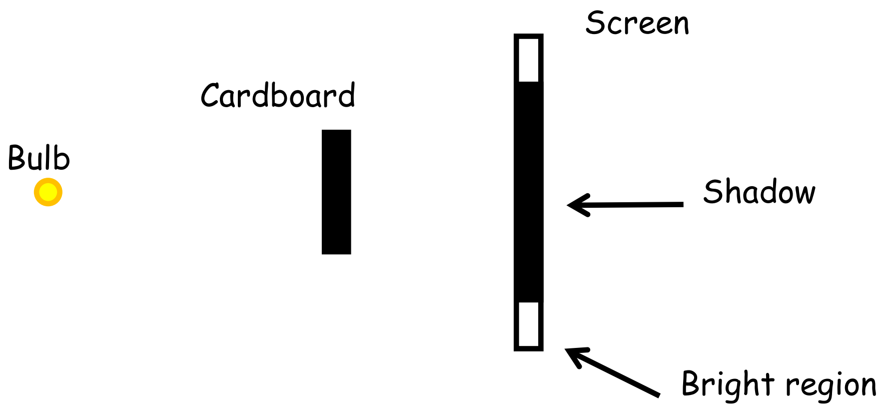
____

Now adjust the variable in your experimental set up. Does the experimental result match your prediction? Explain.

____

____

7. The diagram below shows the relative positions of the bulb, cardboard piece, and paper screen.



(i) Draw in the path that light travels from the bulb to the cardboard piece. Does this light reach the screen? Explain.

____

____

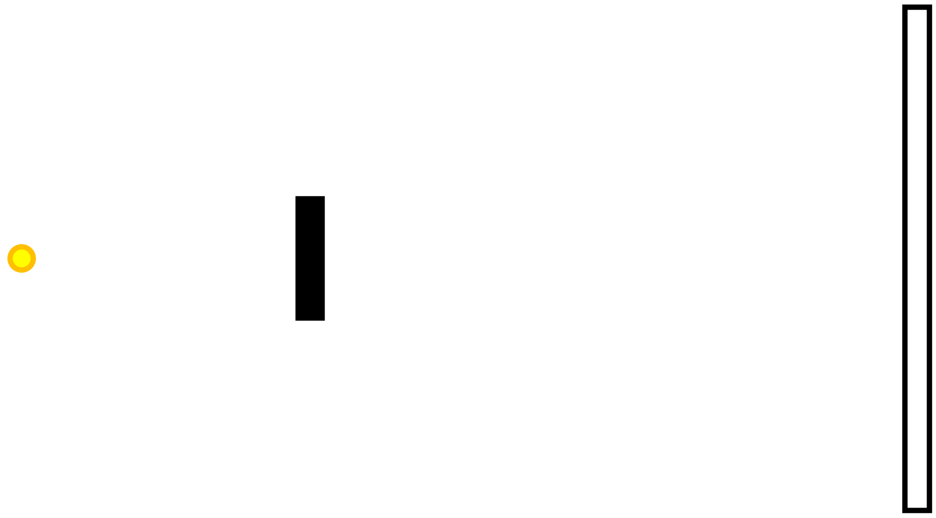
(ii) Draw in the path that light travels from the bulb to the screen. Does light reach all parts of the screen? Explain.

____

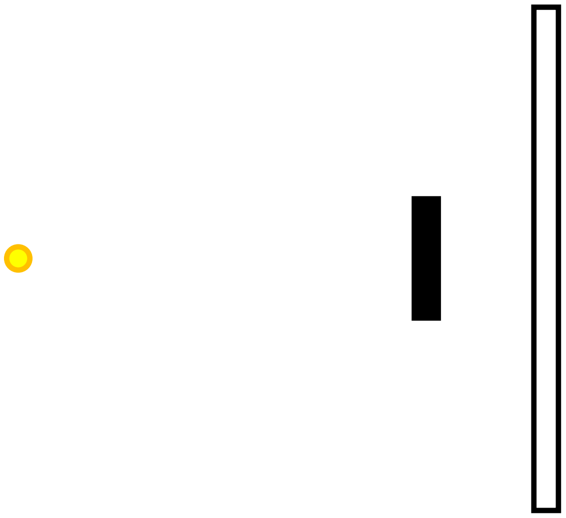
____

8. Draw the shadow you'd expect to see in each of the following cases:

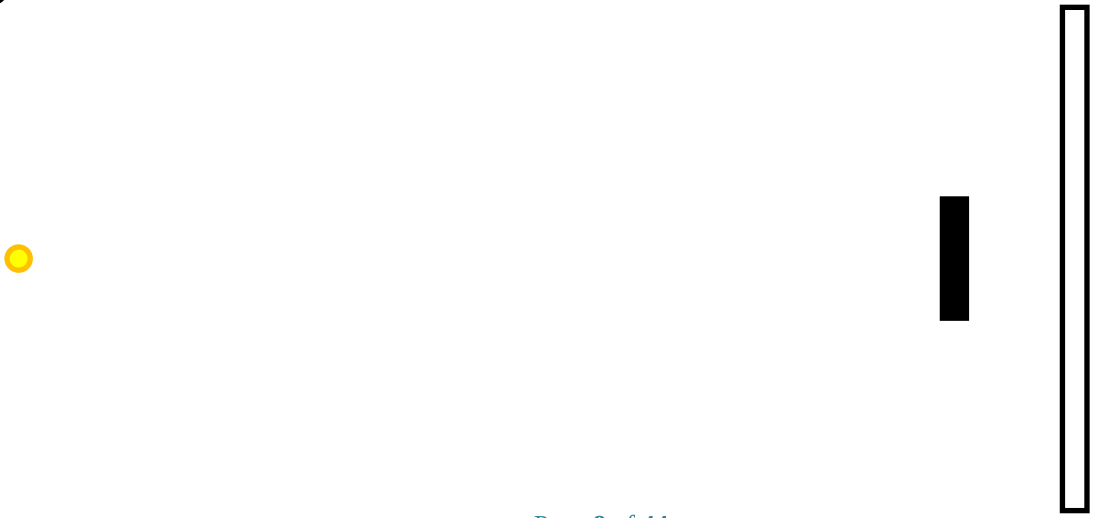
(i)



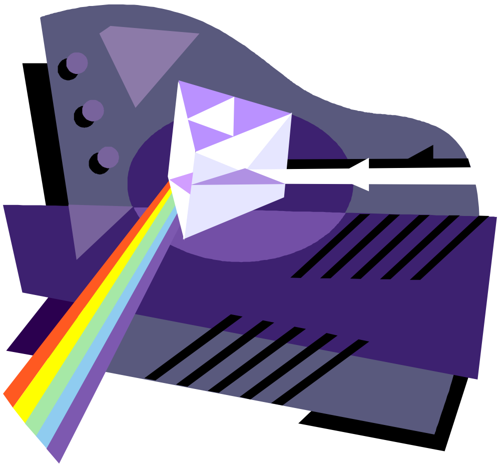
(ii)



(iii)



Worksheet 1.4 Exploring White Light and Filters



In this experiment you will investigate what happens to white light when it passes through a prism.
Take the torch and ensure that the narrow cardboard slit is securely fastened. Shine the torch through one side of the prism and try to align the prism and torch so that light leaving the prism will arrive on a white sheet of paper and form a 'spectrum' of colours.

1. Describe what you observe and draw a diagram of the relative positions of the torch, prism, and screen. Show in the diagram the relative position of red light and violet light on the screen.

____

____

____

2. There are two possible explanations for the colours you have observed on the screen. These are:

   (a) The prism changes white light into different colours

   (b) White light is a mixture of different colours to begin with and the prism separates them

Which of these explanations is correct? How do you know based on your observations?

____

____

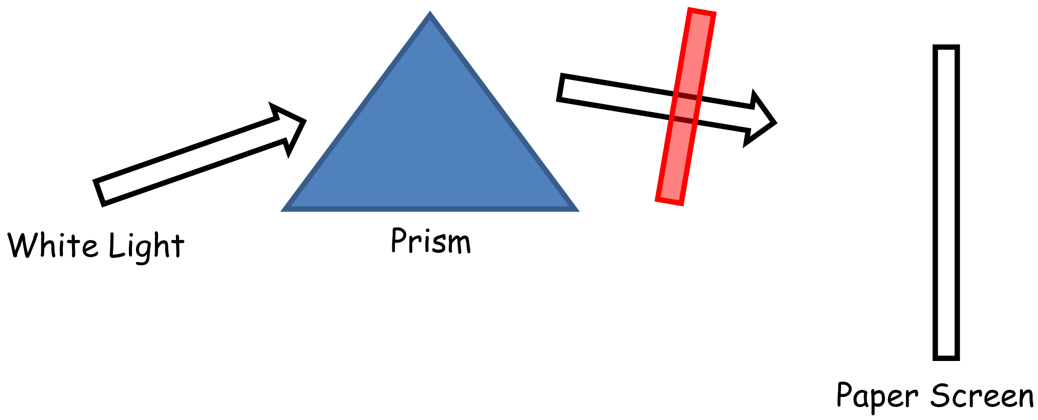
Can you suggest an experiment that might be able to resolve which of the two possibilities is correct?

____

____

____

3. Take a coloured filter and place it in the path of the light leaving the prism.



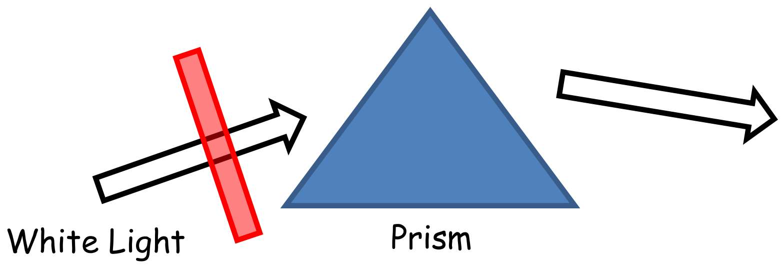
What colour is the light arriving on the screen? ____________

Explain how you think the filter affects the light.

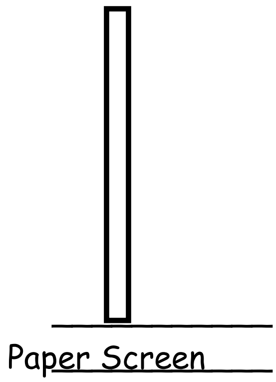
____

____

4. Take a coloured filter and place it in the path of the light entering the prism.



What colour is the light arriving on the screen?
What colour is the light after passing through the filter?



5. Which of the two possibilities in Question 2 is supported by your observations? Explain.

____
____
____
____
____
____

Worksheet 1.5 Exploring Primary Colours

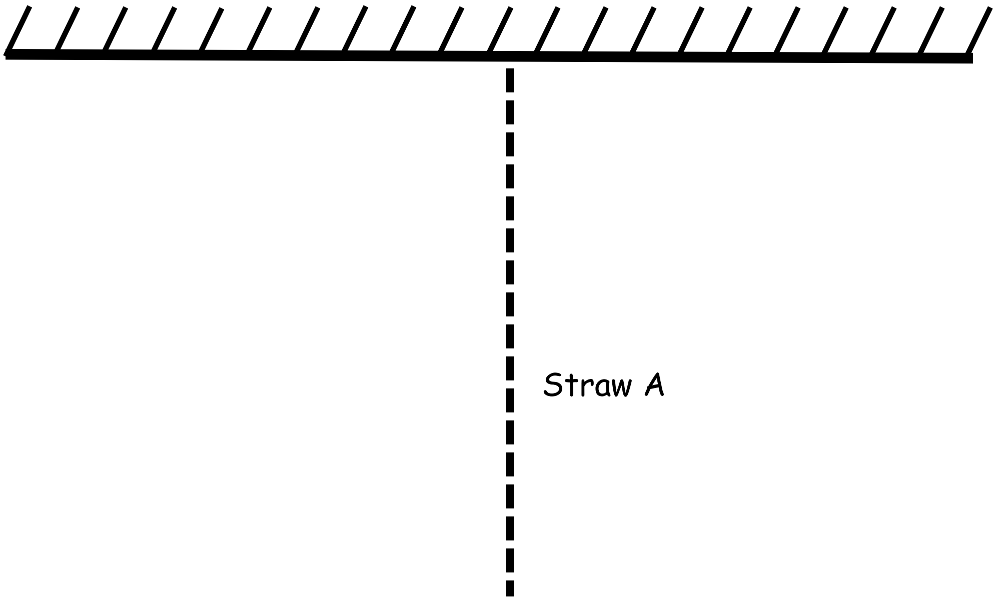
1. What is observed when you mix the different colours of light?

2. What is observed when you mix different colours that aren't the same intensity?

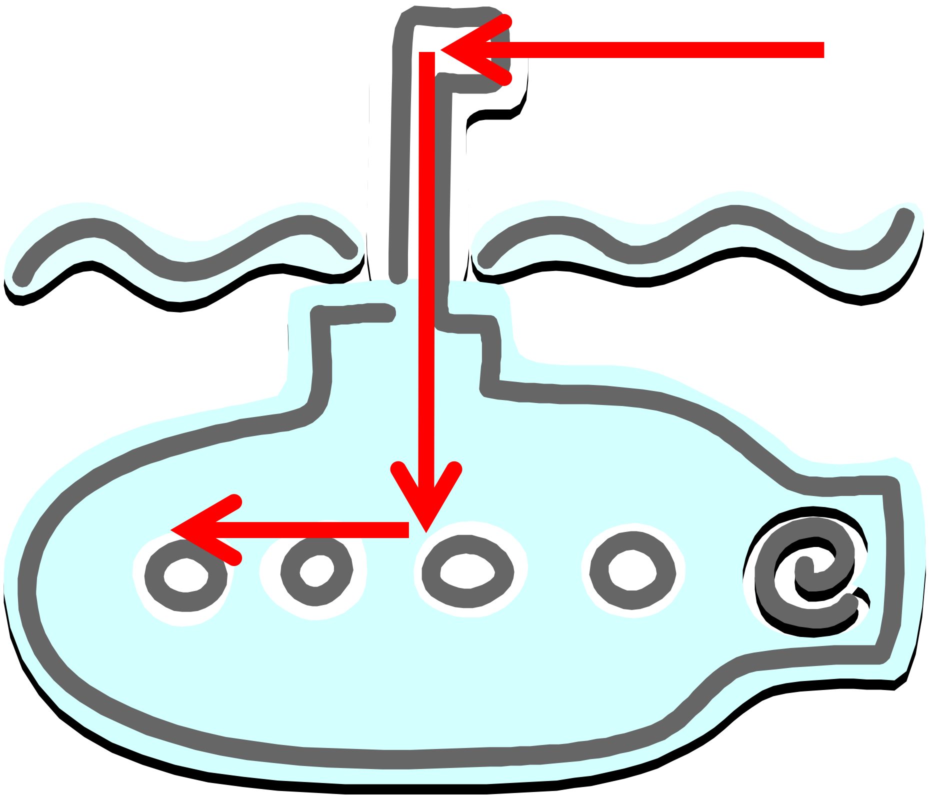
Worksheet 1.6 Investigating Mirrors

1. Position a mirror on the indicated line (held vertically) and two drinking straws in such a way that light passing through one straw (straw A) is reflected from the mirror and can be seen through the second straw (straw B). Mark in the positions of each straw on the diagram and the direction light travels through the straws to your eye. You should do this for three different orientations of straw A.

2. Suppose the mirror is rotated by 45 degrees as below. If straw A is positioned on the dotted line, where should straw B be placed?



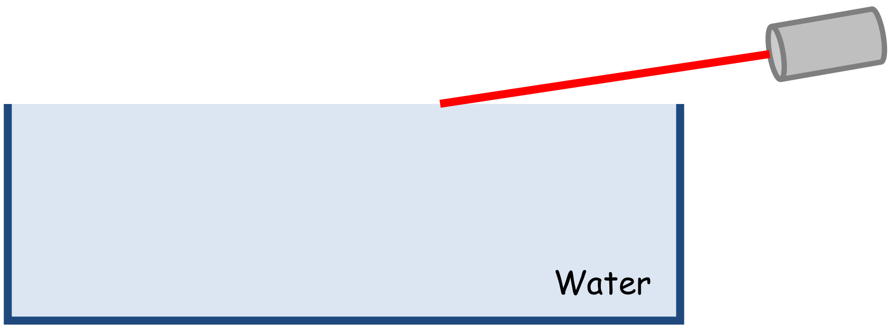
3. A submarine captain uses a periscope to see what is on the surface of the water. The arrows indicate the direction light must travel through the periscope to reach his eyes. How would you position mirrors to achieve this?



Worksheet 1.7 Investigating Refraction

In this lab you will investigate the phenomenon of 'refraction'. On your desk you will have a tub of cloudy water and a laser pointer.

1. Consider that light from the laser pointer is directed towards the surface of the water, as in the diagram below. What happens to the path of light after it hits the surface of the water? Draw what you observe.



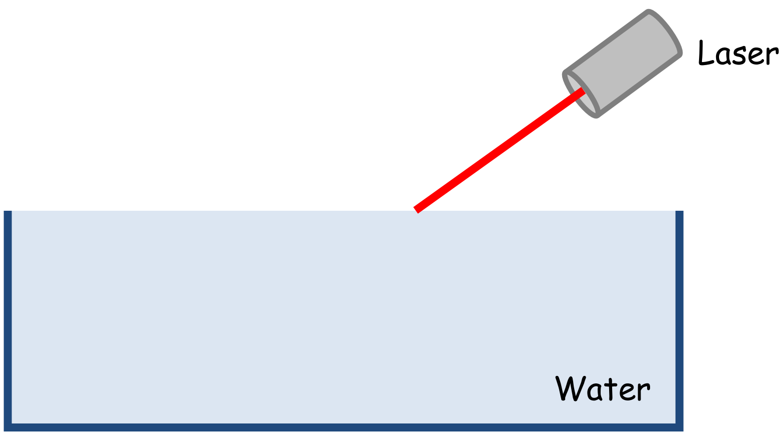
Does all of the laser light pass into the water? Explain.

____

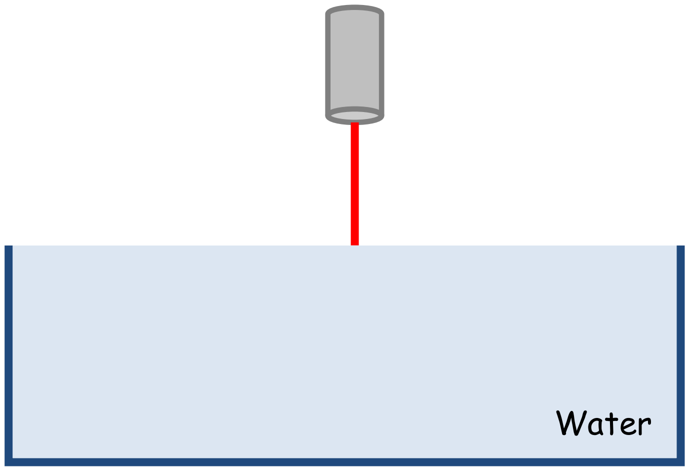
____

____

2. Suppose that you change the angle at which light from the laser hits the surface of the water. Draw what you observe in this case.



3. The laser is aimed at right angles to the surface of the water. Draw what you observe in this case.



4. How would you summarise your observations? Can you be specific about the change in direction that occurs when light passes from air into water?

5. Position the laser so that the beam passes through the water into air. Experiment with the angle that the laser hits the surface of the water. Summarise your observations below. Can you be specific about the change in direction that occurs when light passes from water into air?

Worksheet 1.8 Investigating Lenses

1. Position the bulb, lens, and screen so that an image of the bulb is formed on the screen. Draw a diagram of your set up in the space below.

2. How do you make the image as small as possible? Explain what you need to change in your set up.

3. How does the orientation of the image of the bulb compare to the orientation of the actual bulb? How can you tell?

4. Remove the screen and, with your eye close to the lens, position the bulb so that you see a magnified image of the bulb. How did you achieve this? How does your answer compare with your answer to Question 2?

5. If you place the screen where your eye was located, do you see a magnified image of the bulb on the screen?

6. What is the smallest distance between the bulb and the lens that forms an image of the bulb? How does the size of the image compare to the size of the actual bulb?

Worksheet 2.1 Investigating Mirror Images

Part 1: The Parallax Method

Using Sheet 1, on the next page, place three upright markers on each of the points indicated. Close one eye and look along the line connecting the markers.

What do you observe as you move your head right and left along the arrows indicated on the sheet?

____
____
____

How, by moving your head in this manner, can you tell which pen is farthest away?

____
____

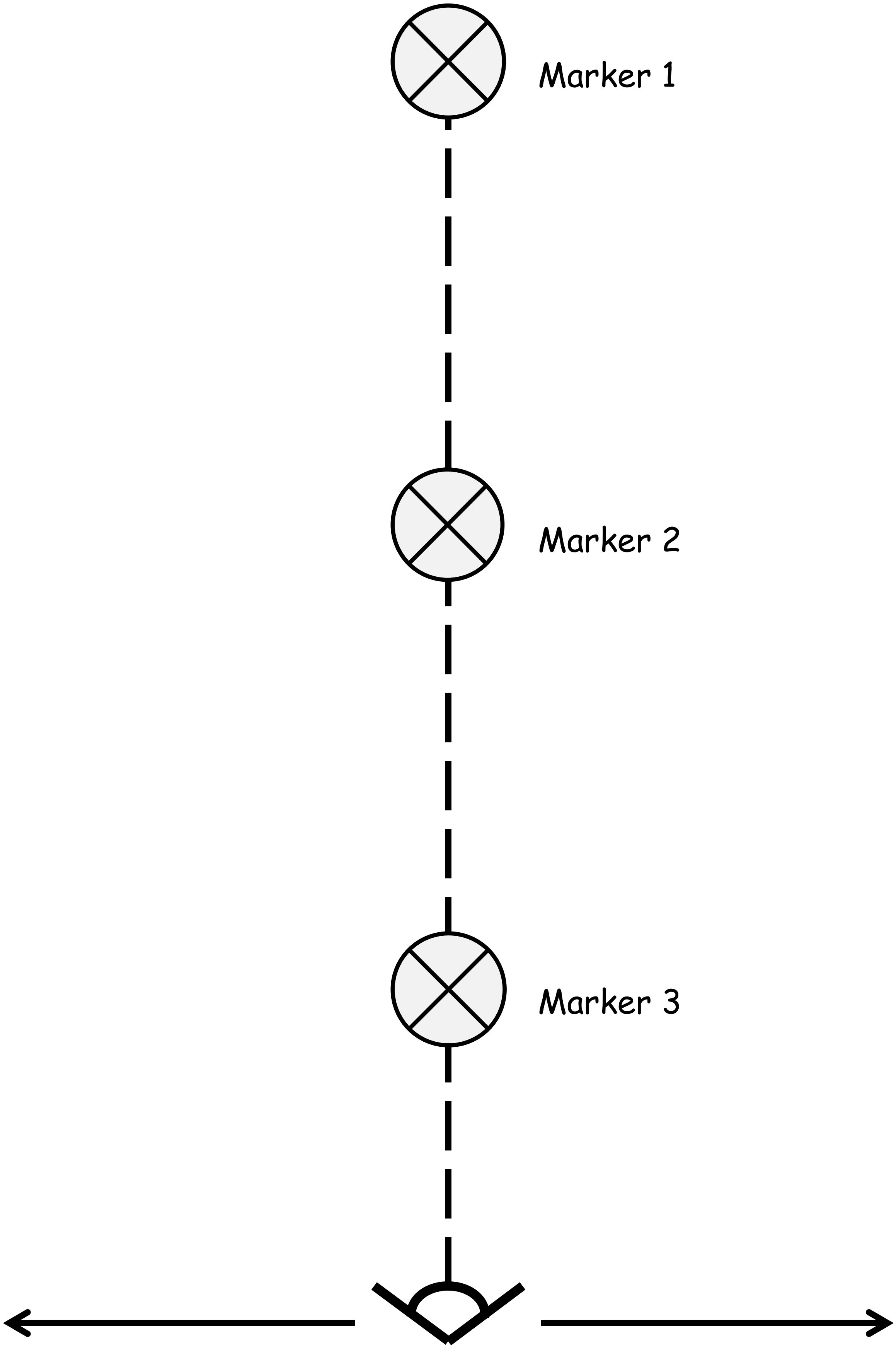
How can you tell which pen is closest?

____
____

What would you observe if all three pens were the same distance away from you?

____
____

Sheet 1:



Part 2: Plane Mirrors

Place a plane mirror on the line indicated on Sheet 2, and an upright marker on the spot labelled 'Marker'. When you look in the mirror you will see an image of the marker.

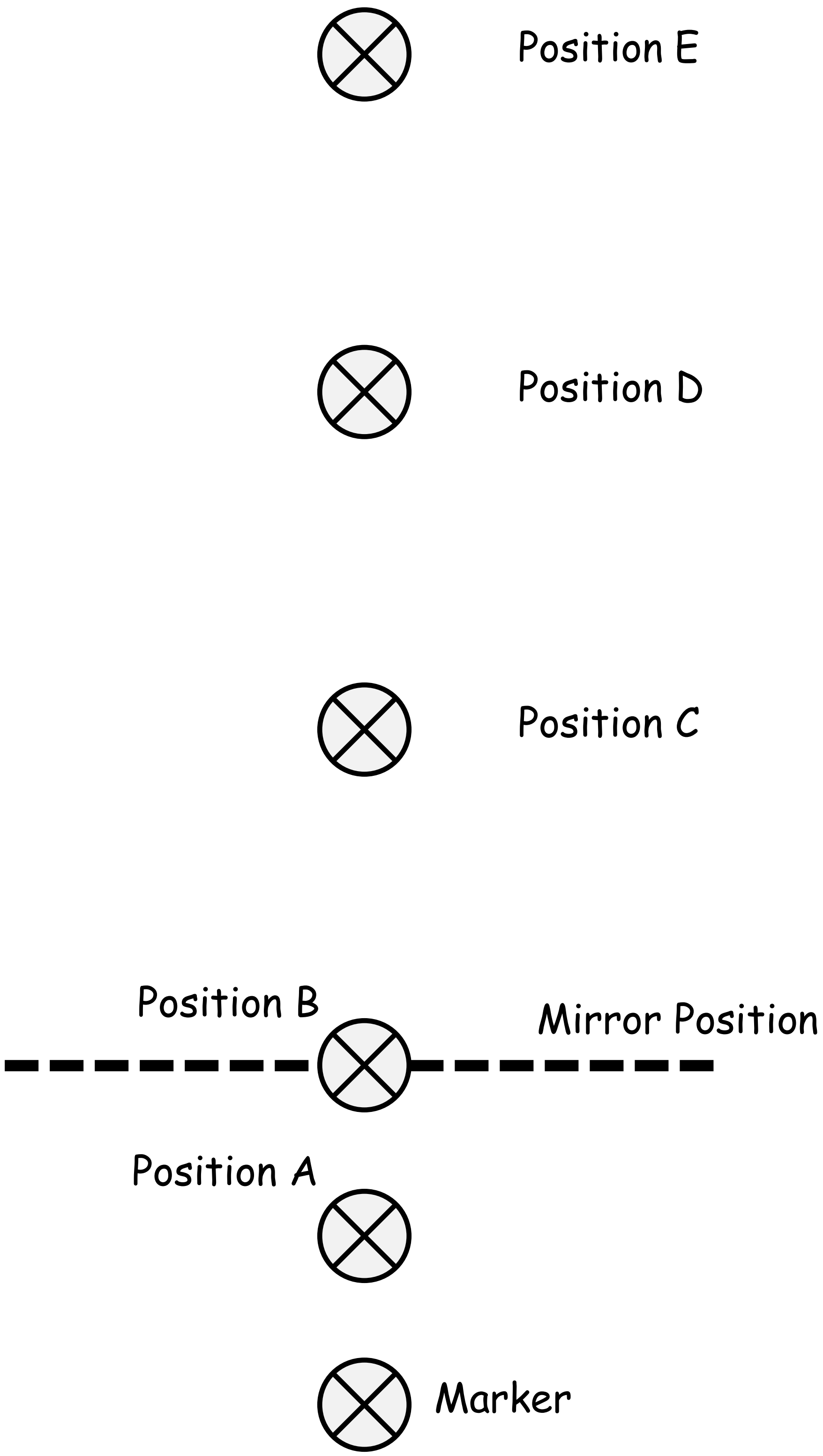
1. This image might be located in front of, on, or behind the mirror surface. How might you use the parallax method to determine which of these three possibilities is correct?

2. Which of these three possibilities do you think is correct – is the image located in front of, on, or behind the mirror? Why?

3. Investigate whether the image of the pen is located in front of, on, or behind the mirror surface. Do any of the positions (labelled A to E) on Sheet 2 represent the position of the image? Explain how you deduced this.

4. Did your investigation confirm or falsify the deduction you made in Q2?

Sheet 2:


Position E
Position D
Position C
Position B
Mirror Position
Position A
Marker

Part 3: Path of light from a mirror

Position the laser at point P on Sheet 3. Angle the laser so that light travels along one of the arrows towards the mirror. You will see that the light is reflected at some angle from the mirror surface.

1. On the sheet, draw a line indicating the direction of the reflected light for each of the initial directions shown.

2. Extend each line you have drawn backwards so that it passes through the mirror. What do you notice about these lines?

____

____

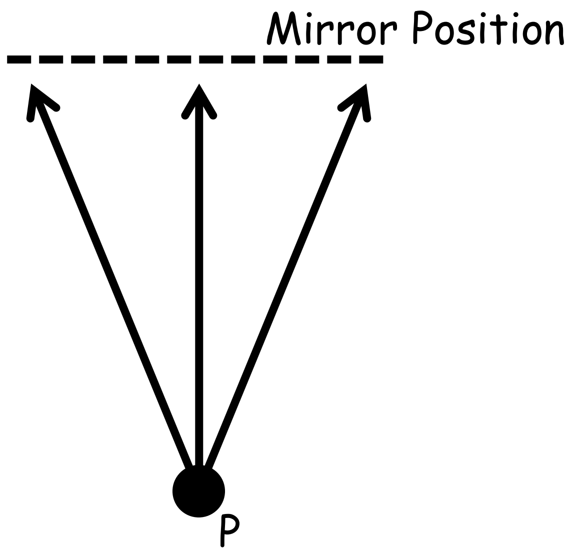
3. On the basis of your diagram, explain why the image formed in a plane mirror appears as though it comes from behind the mirror.

____

____

____

Sheet 3:

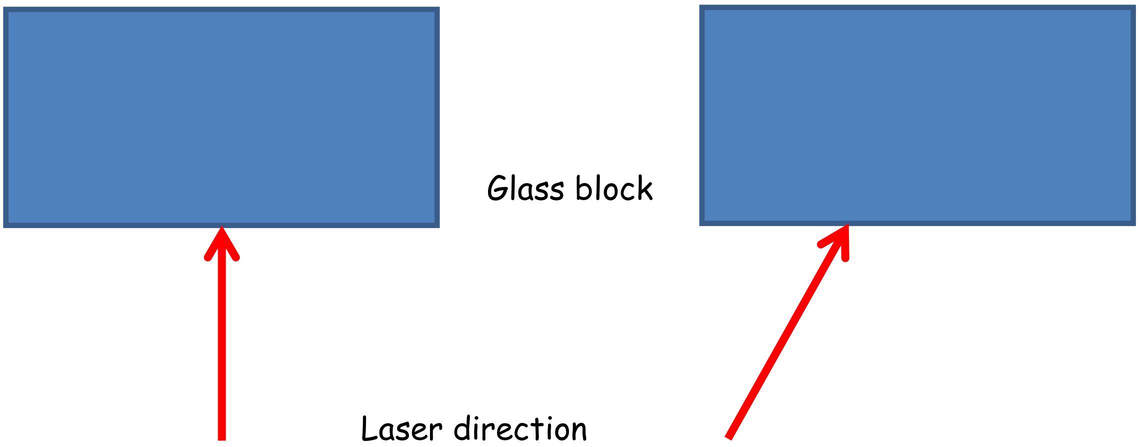


Worksheet 2.2: Investigating Snell's Law

In this activity you will design an experiment to examine the change in direction that occurs when light travels from one medium (air) to another medium (glass), and vice versa.

Preliminary Investigation:

1. Suppose you shine laser light into the block of glass as in the diagrams below. Draw the direction you would expect light to be travelling when it leaves the glass block in each case.



2. Does the direction of light leaving the block depend on the direction of light entering the block?

____

____

3. How can you tell what path light takes <u>inside</u> the glass block? Draw this path on the previous diagrams.

____

____

Experimental Procedure:

You will now design an experiment to investigate the relationship between the direction that light enters the block and the direction that light travels inside the block.

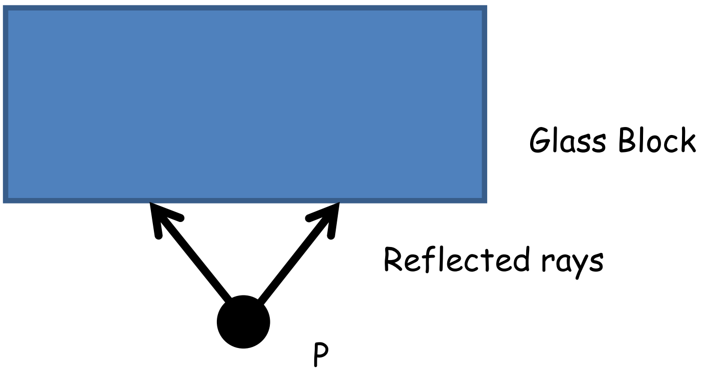
Write down a description of how you will carry out this investigation. You should consider the following points:

a) How will you measure or 'quantify' the directions in each case?
b) How will you standardise that measurement so that the results from everyone in the class can be compared and combined?
b) How many different directions for light entering the block will you need to examine?
c) How will you tabulate your results?
d) If you wish to investigate the relationship between the direction of light travelling to the glass and through the glass, what graph should you plot?

Tabulate your results in the box below.

Worksheet 2.3: Studying Real and Apparent Depths

1. An object is placed at point 'P', as in the diagram, and illuminated by a light source. Two reflected rays from this object are shown in the diagram, and both are incident on a glass block.
Roughly sketch the path that light takes through the glass, and the path light takes on leaving the glass block.



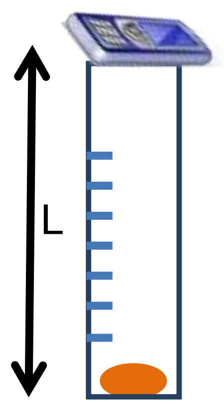
2. An observer now looks at the object at point P <u>through</u> the glass block. From your sketch above, is it possible to determine where this object will appear to be located? How did you determine this?

____
____
____

Show this apparent position of the object on the above diagram.

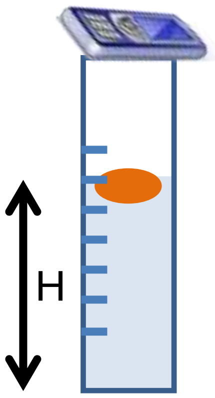
3. Place the small piece of cork at the base of your graduated cylinder. Position your mobile phone at the top and take a photograph of the cork.

Measure the distance from the base of the cylinder to the phone.



L = ____________ cm

4. Now add some water to the cylinder and measure the height of the water from the base. Take a photo of the cork again.



Repeat this for at least five different heights of water.

H_1 = ____________ cm
H_2 = ____________ cm
H_3 = ____________ cm
H_4 = ____________ cm
H_5 = ____________ cm

As the cork gets closer to the phone, would you expect the cork to appear larger, smaller, or stay the same size in the photograph? Why?

____

____

5. Pour the water out of the cylinder and place a coin at the base. Take a photo of the coin, as before. Fill the cylinder completely with water (leave enough room so the phone doesn't get wet!). Now photograph the coin through the water.

6. Upload your images to a computer and use software to crop the images so that they only include the cork/coin.

Determine the width of each cropped image in pixels and use this information to fill out the following tables:

Cork	
Distance from Camera (cm)	Width of Image (pixels)
$L - H_1$ =	
$L - H_2$ =	
$L - H_3$ =	
$L - H_4$ =	
$L - H_5$ =	

Coin	
	Width of Image (pixels)
Through Air:	
Through Water:	

Does the width of the coin in the image change with the addition of water?

____

7. Plot a graph of Width of Image (in pixels: y axis) versus Distance from Camera (cm: x axis) for the cork.

Since you know the size of the image when the coin was photographed through the water, can you determine from your graph how far the coin appeared to be from the camera?

Apparent depth = ____________________ cm

What was the actual depth of water?

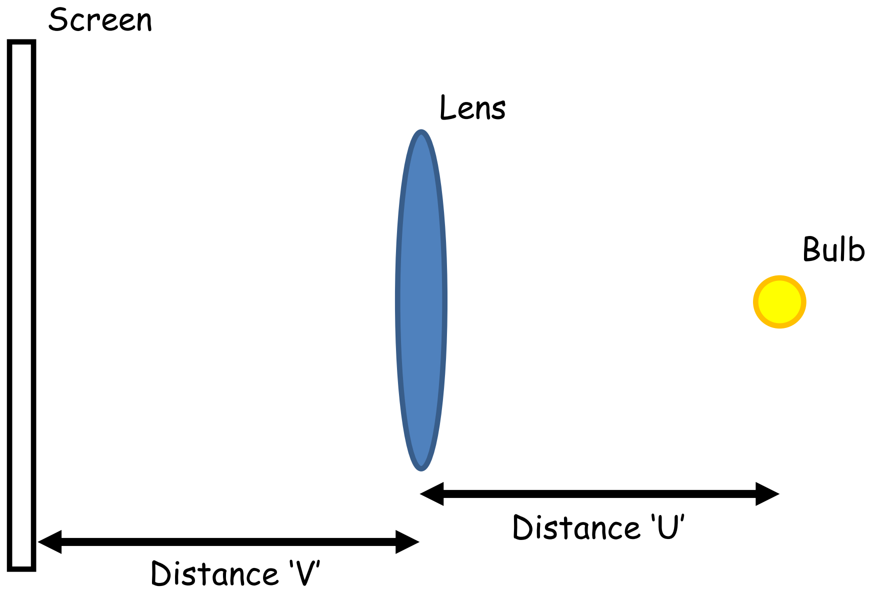
Real depth = ____________________ cm

Worksheet 2.4 Studying Lenses

What is your estimate for the focal length of the lens?

____

You will now investigate the relationship between the object distance (U) and the image distance (V). You should also measure the width of the image formed on the screen and compare this to the actual width of the object (the magnification).



Tabulate your results:

Plot a graph of image distance versus object distance.

What do you notice about the shape of this graph?

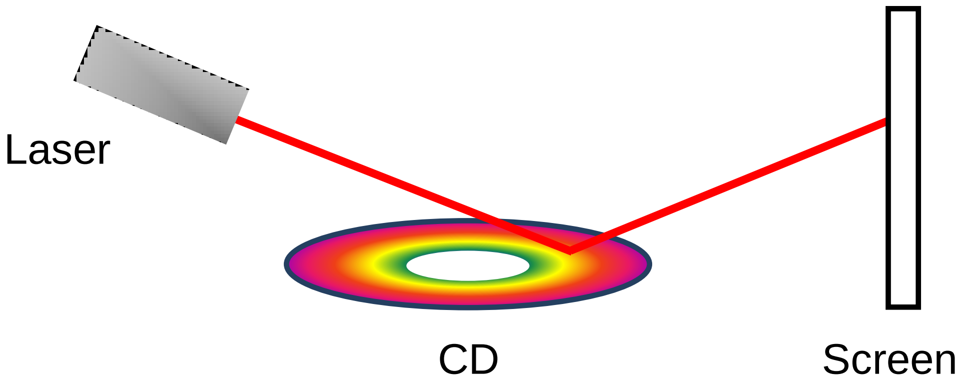
Worksheet 2.5 Optical Storage

1. Compare the diameter and thickness of a CD and DVD/Blu-ray disc. Describe how their physical dimensions compare.

2. Which of the discs can store the most information? Which stores the least?

3. Considering your answer to Question 1, explain how you think the discs can store different amounts of information.

4. Clamp the laser in place with a retort stand and angle it so that the light reflects from the 'shiny' surface of the CD, as in the diagram.



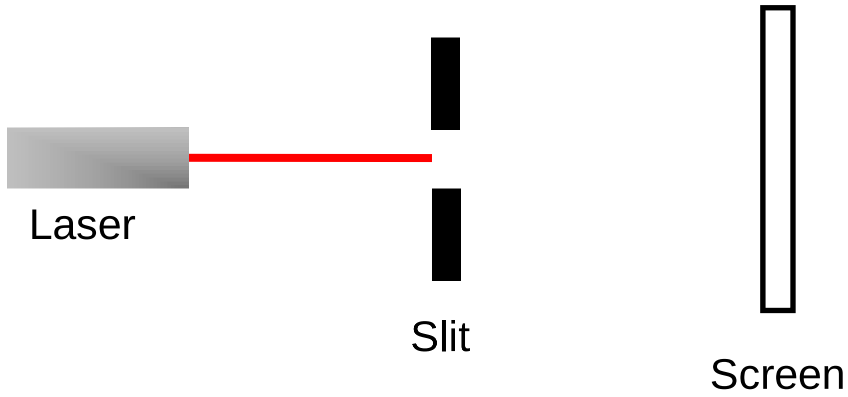
In the space below, draw a sketch what you observe on the screen.

5. Why do you think there is more than one laser spot on the screen?

6. Replace the CD with a DVD, but keep the laser fixed in place. Draw a sketch of what you now observe on the screen.

7. Is there a difference between the CD and DVD in terms of what you observe on the screen? If so, what do you think causes this difference?

8. Now, take the laser and pass it through the narrow slit.



9. What do you observe on the screen as the width of the slit is reduced?

10. Based on your answers to questions 7 and 9, why do you think a DVD can store more information than a CD?

Worksheet 2.6 How do sunglasses work?

In the 1800's Malus proposed a law to predict the light transmission through two polarizing filters. The relationship is

$$I = I_0 \cos^2(\theta)$$

where I_0 is the maximum intensity when the angle θ between the polarizer axes is zero. You will see if this law is useful in describing your polarizing filters.

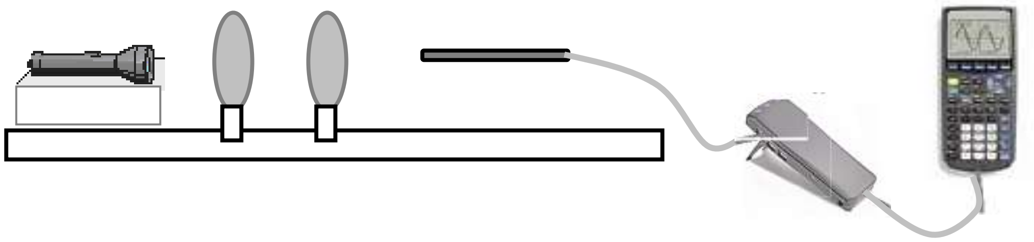


Figure 1. Set-up for polarization of light.

This activity is described using a Texas Instruments TI-83 Graphing calculator.

1. Turn on the calculator. If your calculator is in radian mode change it to degree mode.
   - Press MODE to access the settings screen.
   - Use the cursor keys to highlight DEGREE.
     Press ENTER.
   - Press 2nd [QUIT].

2. Align the light source, polarizing filters, and Light Sensor so light passes through the filters and then into the sensor. You will rotate only one filter to change the transmission; the other filter, the light source, and the sensor must not move. Turn on the light source.

3. Attach the Light Sensor to Channel 1 on the CBL2 interface. If your sensor has a range switch, set it to 600 lux. Use the black link cable to connect the CBL2 unit to the calculator. Firmly press in the cable ends.

4. Start the DATAMATE program from the APPS menu.

5. If CH 1 displays a Light Sensor and its current reading, skip the remainder of this step. If it does not, set up DATAMATE for the sensor manually. To do this,

a. Select SETUP from the main screen.
b. Press ENTER to select CH 1.
c. Choose LIGHT from the SELECT SENSOR list.
d. Choose LIGHT 600 (LX) from the LIGHT list.
e. Select OK to return to the main screen.

6. Set up the calculator and the interface for the appropriate data collection mode.
   a. Select SETUP from the main screen.
   b. Press ▲ to select MODE and press ENTER.
   c. Select EVENTS WITH ENTRY from the SELECT MODE menu to collect light data as a function of distance. In this mode you will trigger the interface to record the light intensity for each position you choose.
   d. Select OK to return to the main screen.

7. The main screen will display a new light intensity every second. Rotate the analyse until the reading on the calculator is maximized. This is your zero angle. The axis marks on the two filters should be parallel, or 0°.

8. In the *event with entry mode* light intensity will only be measured when the ENTER button is pressed. You will then type the analyzer angle in degrees and press ENTER to complete the data point.
   a. Select START from the main screen to prepare for data collection.
   b. Rotate the analyzer to the 0° position.
   c. Press ENTER to take the first point and enter "0" for the angle. Remember to press ENTER to complete your numerical entry.

9. Rotate the analyzer by 15°, press ENTER and enter "15" for the angle. Repeat this process, entering "30" for the next angle, and so forth, until you have rotated the analyzer through one revolution, or 360°. After the last point, press STO▶ to end data collection.

Now answer questions A1 on the answer sheet

Analysis

1. Display the graph of light intensity *vs.* angle on the screen.

2. Trace across your graph with the ◄ and ► keys. Note the maximum value of the intensity and record it in the data table A4. The maximum value does not quite correspond to the constant I_0 in the Law of Malus since it includes the background light.

3. Note the minimum value of the intensity (at 90°) and enter this in your data table A4 as the back ground intensity.

4. To plot the Law of Malus $I = I_0 \cos^2(\theta)$ with your data, you need to enter the equation "A*(cos(X))^2 + B" in your calculator. The variable A will correspond to the maximum intensity I_0. The + B term is present to represent the effect of background light. To enter the equation in your calculator, you need to temporarily leave the DATAMATE program. Press ENTER and select QUIT.
   a. From the calculator home screen, press Y=.
   b. Press CLEAR to clear the Y1 equation.
   c. Enter "A*(cos(X))^2 + B" in the Y1 line.
   [Hint: To enter letters A, B and X press the green Alpha button and the corresponding letter key.]
   d. Press ENTER and select QUIT.

5. To plot your data and the Law of Malus model on the graph at the same time
   a. Start the DATAMATE program.
   b. Select ANALYZE from the main screen.
   c. Select ADD MODEL from the ANALYZE OPTIONS.
   d. Select CH1 from the SELECT GRAPH screen.
   e. Select ADJUST B.
   f. Enter the background intensity you observed.
   g. The graph you see may not yet show the model, since you have not set the constant A. Press ENTER to prepare to set A.
   h. Select ADJUST A.
   i. Enter the difference between the maximum intensity from Step 2 and the background intensity from Step 3.

Now answer questions A2 through A6 on the answer sheet

ANSWER SHEET

A1. Place one polarizing filter on top of a second so you have to look through both of them. Rotate the top filter. What do you notice?

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____

____

A2. Record the values of the analyser angle and the intensity.

Angle (°)	Intensity (lux)

A3. Prepare a sketch of the variation of intensity with angle. Label your axes.

A4. From your graph record the maximum and minimum intensity values.

Maximum Intensity	**Io + B**	**lux**
Background Intensity	**B**	**lux**
Difference in Intensity	***A***	**lux**

A5. How well does your results agree with Malus's Law, $I = I_0 \cos^2(\theta)$

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A6. What happens when you pass laser light through the two polarizers?

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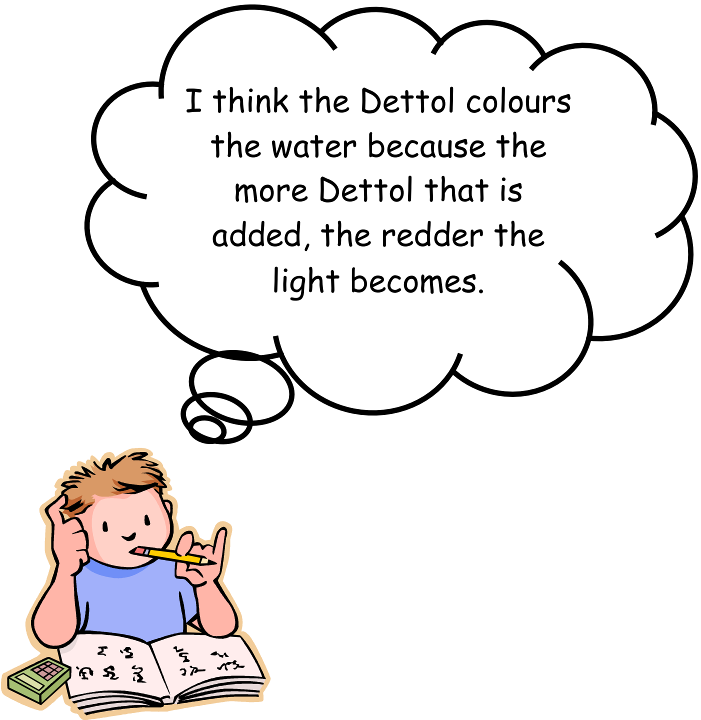
Worksheet 2.7 Exploring the Scattering of Light

1. Describe what happens to the light on the screen as more Dettol is added to the water?

____

____

2.



Do you think this student's explanation is a good one? Why?

____

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3. What colours make up white light?

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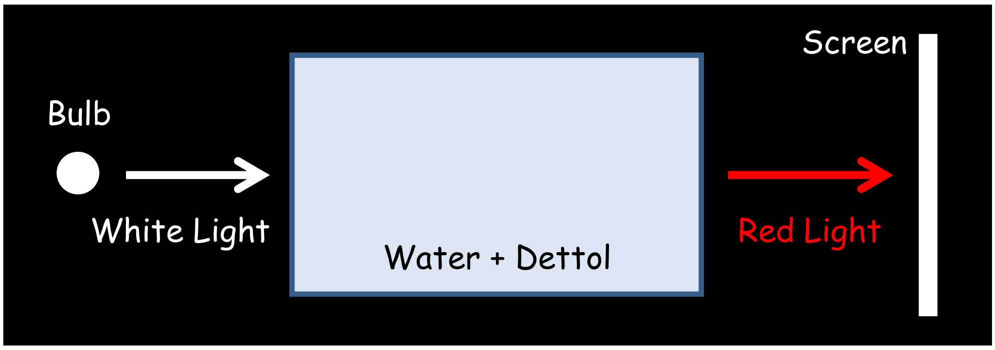
4. If white light enters the tank of water and Dettol, and red light leaves the tank and arrives on the screen, what do you think happens to light inside the tank?



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5. What colours of light do you see when you look through the sides of the tank that aren't facing the screen?

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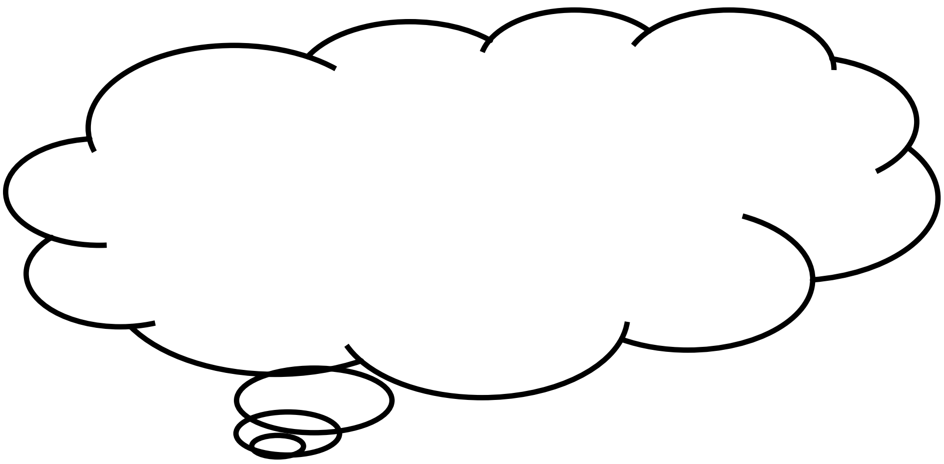
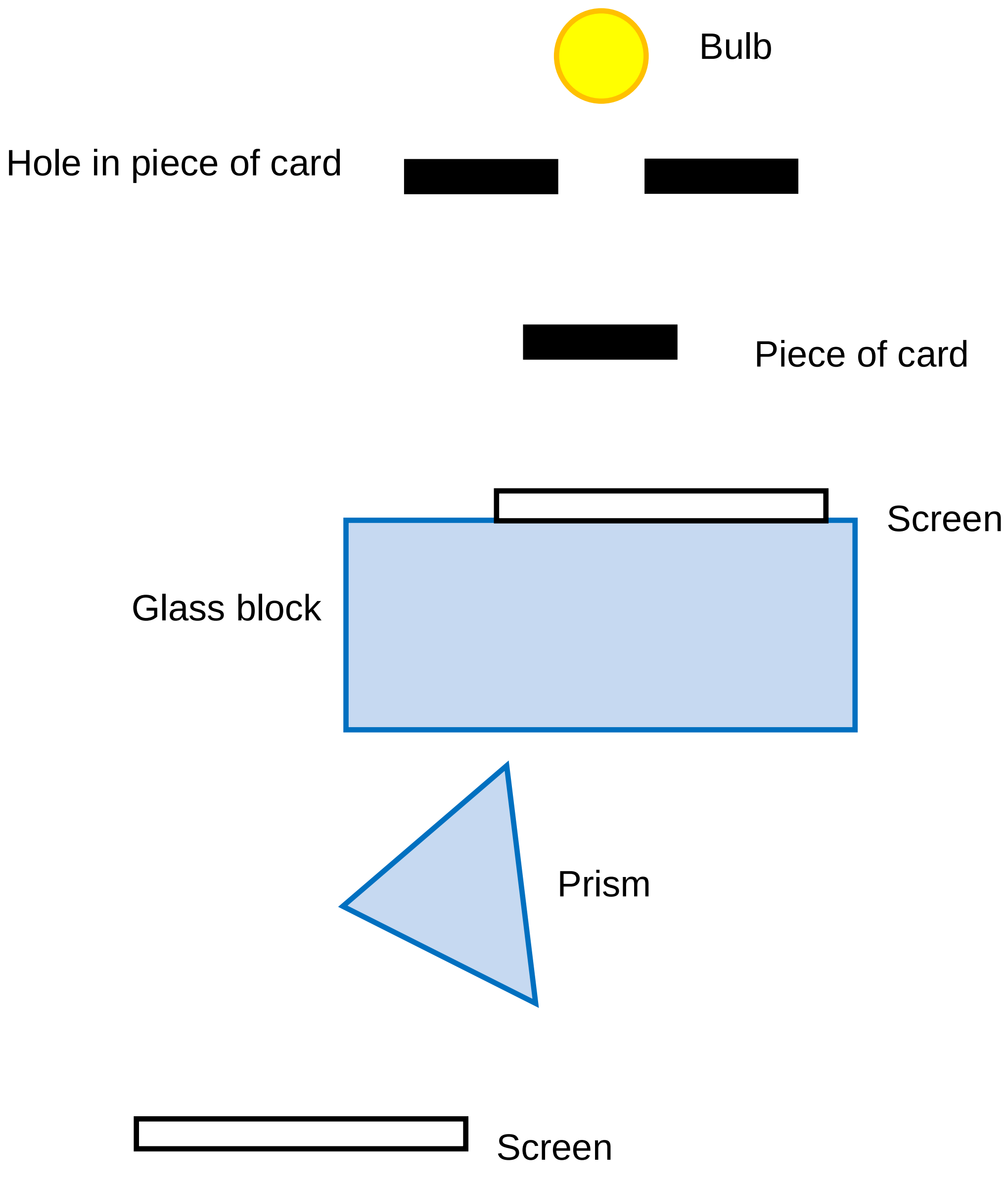
6. Is your answer to question 4 correct on the basis of your observations? If not, then explain what happens to the light inside the tank of water and Dettol.



Light *Sample* Assessment Sheet

The bulb in the diagram produces white light. Using rays, predict what you would observe on the two screens.



WP3
Photosynthesis

European Science and Technology in Action Building Links with Industry, Schools and Home

Work Package 3
Photosynthesis
Teacher Information

European Science and Technology in Action:
Building Links with Industry, Schools and Home

Lead partner for deliverable: **University of Tartu**

The development of the package was made by Katrin Vaino, Miia Rannikmäe, and Jack Holbrook.

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Start Date: 1st January 2010 Duration: 48 months

A. Teacher Information

I. Unit description

Greenhouses on Mars?!

In this unit, learning of photosynthesis is triggered by introducing students with the idea of Martian greenhouses for producing oxygen and food for living there. Problem questions relating to how basic conditions for long term living can be created in an artificial environment are posed to students. The solving process is expected to lead to the idea that plants and other organisms are able to carry out photosynthesis thereby providing the station with oxygen and at the same time absorbing carbon dioxide. During the unit they are also expected to answer to the question “How do we know, what we know about photosynthesis?” through researching the development of related scientific discoveries. Through student inquiry the factors that influence photosynthesis are explored providing students with ideas needed for designing their own space greenhouse.

Student level: Students aged 16-19

Disciplines involved: Biology, physics, chemistry

Estimated duration: 7- 10 lessons

II. IBSE Character

In this unit students are given an opportunity to develop a number of scientific process skills including aspects related to higher order learning:

- planning an investigation, discussing procedures, searching for information, developing argumentation skills and/or making justified decisionsin addition to conceptual science acquisition;
- using empirical evidence to assist learning and decision-making;
- using creative and critical thinking skills.

The unit of photosynthesis also has learning objectives/ outcomes which include nature of science aspects such as the conceptions that scientific ideas are subject to change, science demands evidence and science is a complex social activity.

III. Science Content Knowledge

Photosynthesis is a process whereby light energy is converted to chemical energy and that chemical energy is stored in the bonds of carbohydrates. While this process mainly takes place in plants, it also occurs in some bacteria and algae. Because photosynthetic organisms can produce their own food, they are called *autotrophs.* In the process of photosynthesis in plants, algae and cyanobacteria, carbon dioxide and water are used to produce carbohydrates and relase oxygen as a by product of the process. Photosynthesis is necessary for the existence of all aerobic life on Earth. Namely, photosynthesis helps maintain normal levels of oxygen in the atmosphere and is the source of energy for nearly all life on earth. The role of photosynthesis in energy production is both direct, through primary production, and indirect, as the ultimate source of the energy in food. Photosynthesis is performed in the **chloroplasts**, specifically using **chlorophylls**, the green pigments involved in photosynthesis.

Photosynthesis takes place in green parts of plants. A typical leaf is made up of the **upper and lower epidermis**, the **mesophyll**, the **vascular bundle(s)** (veins), and the **stomata** (See Figure 1). Because the upper and lower epidermal cells do not contain chloroplasts, photosynthesis does not occur there. Instead, the primary function of these cells is the protection of the rest of the leaf. The stomata are pores that can primarily be found in the lower epidermis. Their function is to facilitate gas exchange, letting in CO_2 and out O_2. The vascular bundles or veins in a leaf form part of the plant's transportation system. They move water and nutrients to different parts of the plant as needed. The mesophyll cells of a plant have chloroplasts and therefore, this is where photosynthesis takes place.

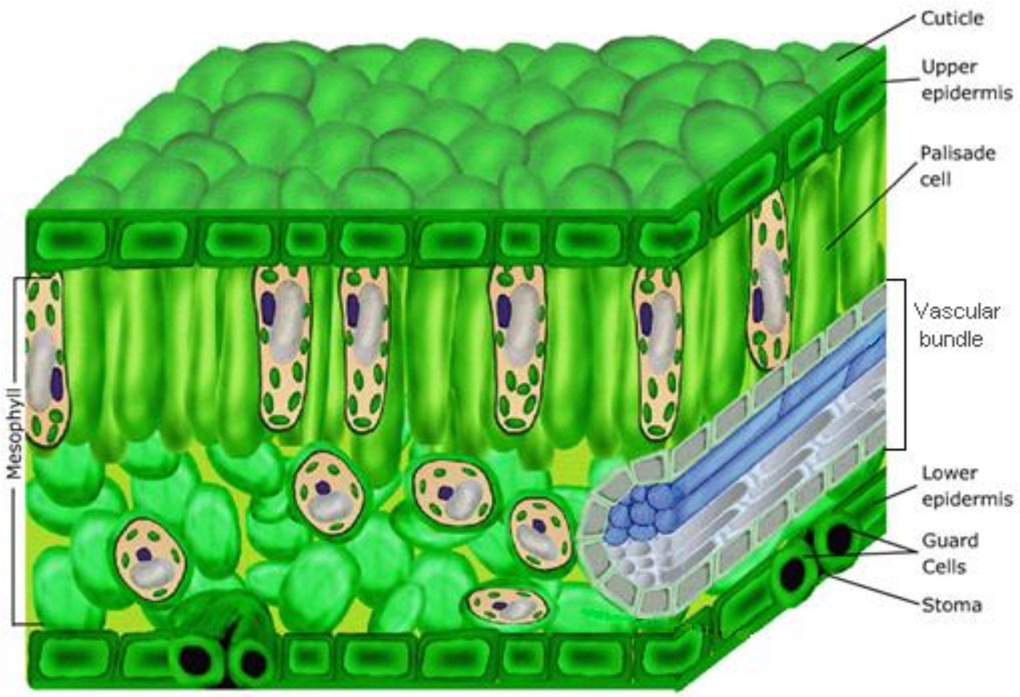

Figure 1. Cells in a cross section of a leaf
(Source: http://www.emc.maricopa.edu/faculty/farabee/biobk/biobookps.html)

A chloroplast (Figure 2) is made up of the following parts: the outer and inner membranes, intermembrane space, **stroma**, and **thylakoids** stacked in **grana** (singular granum). The chlorophyll molecules are located within the thycaloid membranes of chloroplasts.

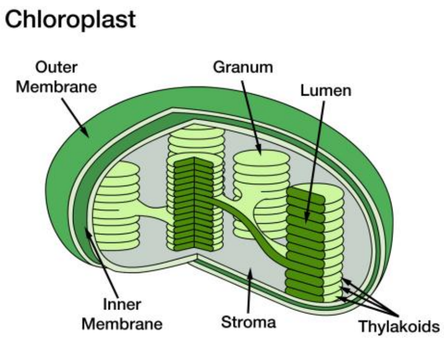

Figure 2. The structure of cloroplast
(Source: http://passscience.blogspot.com/2010/09/structure-of-cell-part-3.html)

The sunlight that reaches the Earth is made up of many different wavelengths of light. A wavelength of light corresponds to its colour and therefore, the mixture of wavelengths found in sunlight also includes those that we perceive as colours. The process of photosynthesis requires visible radiation. While various colours of light can be used for photosynthesis, not all the colours of visible light are equally good at helping the photosynthesis take place (Figure 3).

The green colour of chlorophyll comes from the fact that the clorophyll absorbs red and blue light and reflects green light. It is the energy of the red and blue light that is captured and used in the process of photosynthesis. (See Figure 3). The green light that makes the plant appear green is not absorbed by the plant, rather it is relfeced by the pant. Therefore, it cannot be used in photosynthesis

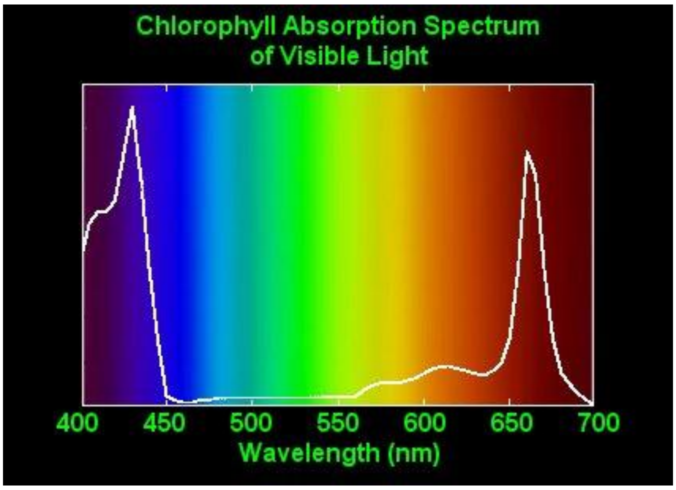

Figure 3. Chlorophyll absorption spectrum of visible light
(Source: http://facstaff.cbu.edu/~seisen/Photosynthesis.htm)

The overall chemical reaction of photosynthesis is:

$$6CO_2 + 6H_2O\ (+\ \text{light energy}) = C_6H_{12}O_6 + 6O_2$$

Photosynthesis, therefore, is the source of the O_2 that we breathe. The latter fact is an important consideration in a debate on deforestation[1].

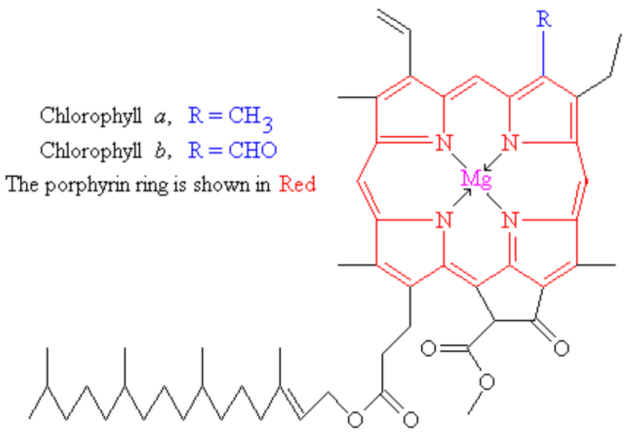

Figure 4. The structure of chlorophylls

Photosynthesis takes place in two parts. Namely, there are light reactions and light-independent reactions or dark reactions. Importantly, the light reactions capture and use light energy to produce high energy chemicals. These chemicals in turn are used to power light-independent reactions whereby carbohydrates are made.

The light reaction

The **light reaction** (Figure 5) takes place in the thylakoid membrane. Because the light reaction converts light energy to chemical energy, it must, therefore, take place in the light. The light reaction involves chlorophylls and a number of other pigments, such as **beta-carotene.** They are organised in clusters and situated in the thylakoid membrane. While clorophylls can exist in different forms, the most important ones are chlorophyll a and b shown in Figure 4.

As differently-coloured pigments are involved in the light reaction, each of these pigments can capture a slightly different colour of light. This light energy is then passed on to the central chlorophyll molecule to power photosynthesis. The main part of a chlorophyll molecule is a **porphyrin ring.** This consists of several rings of carbon and nitrogen atoms joined together with a magnesium ion in the centre of this main part.

[1] Only new plantations make a contribution to atmospheric oxygen. Old forests that have reached a steady state absorb as much oxygen as they produce.

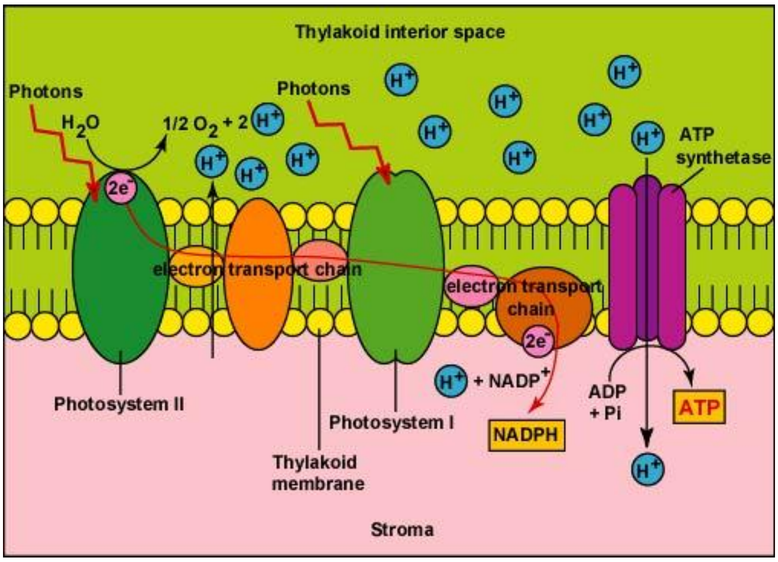

Figure 5. Light-dependent reactions of photosynthesis at the thylakoid membrane (Source: http://lilykid.wix.com/photosynthesis#!__inside-the-chloroplast)

1. As photons are absorbed by pigment molecules in the antenna complexes of **Photosystem II**, excited electrons from the reaction centre are picked up by the primary electron acceptor of the Photosystem II electron transport chain.

During this process, Photosystem II splits molecules of H_2O into 1/2 O_2, $2H^{+,}$ and 2 electrons. These electrons continuously replace the electrons being lost by the chlorophyll A molecules in the reaction centres of the Photosystem II complexes.

$$H_2O \rightarrow 1/2\ O_2 + 2H^+$$

2. During this process, ATP is generated by the Photosystem II electron transport chain and chemiosmosis. According to the chemiosmosis theory, as the electrons are transported down the electron transport chain, some of the energy released is used to pump protons across the thylakoid membrane from the stroma of the chloroplast to the thylakoid interior space producing a proton gradient or proton motive force. As the accumulating protons in the thylakoid interior space pass back across the thylakoid membrane to the stroma through ATP synthetase complexes, this proton motive force is used to generate ATP from ADP and Pi.

3. Meanwhile, photons are also being absorbed by pigment molecules in the antenna complex of **Photosystem I** and excited electrons from the reaction centre are picked up by the primary electron acceptor of the Photosystem I electron transport chain. The electrons being lost by the chlorophyll *a* molecules in the reaction centres of Photosystem I are replaced by the electrons traveling down the Photosystem II electron transport chain. The electrons transported down the Photosystem I electron transport chain combine with $2H^+$ from the surrounding medium and $NADP^+$ to produce NADPH + H^+.

The light-independent (dark) reaction

The **light-independent (dark) reaction** (Figure 6) occurs in the stroma of the chloroplast. During the dark reaction CO_2 is converted to carbohydrates. While light is not directly necessary for this reaction, it is the products of the light reaction (ATP and another chemical called NADPH) that are needed. In the light-independent reaction CO_2 and energy from ATP are used to form glycose. This process is called the **Calvin cycle.** In fact, the first product of photosynthesis is a three-carbon compound called **glyceraldehyde 3-phosphate**. Almost immediately, two such compoundsjoin to form a **glucose** molecule. The glucose molcule can then be transported to other cells, or packaged for storage as insoluble polysaccharides (e.g. starch).

$$3\ CO_2 + 6\ H^+ \rightarrow C_3H_6O_3\text{-phosphate} + 3\ H_2O$$

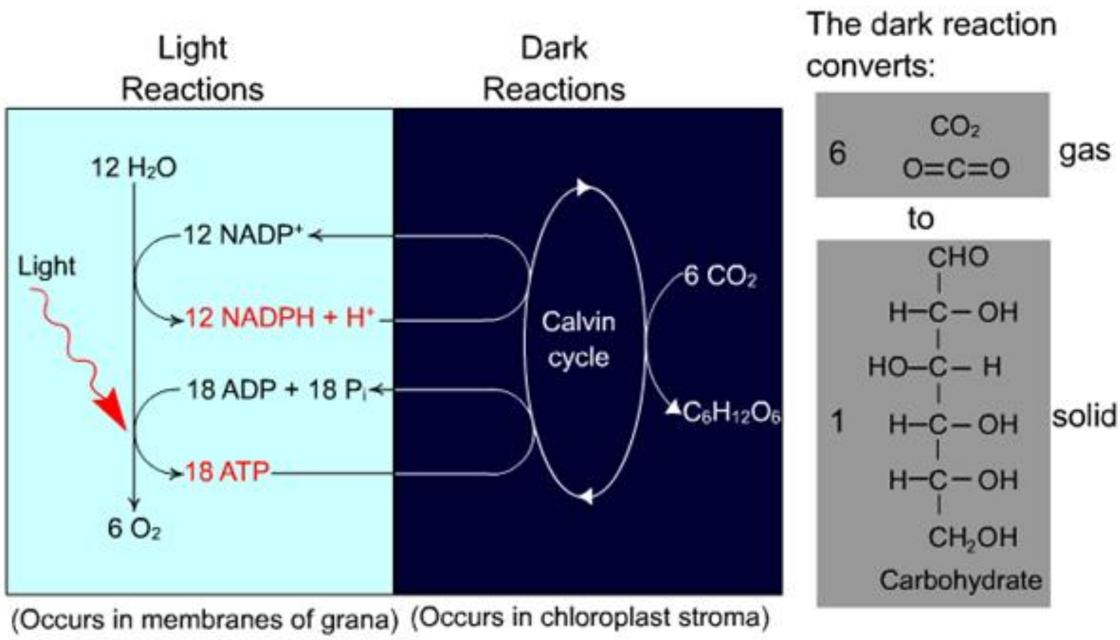

Figure 6. Relationship between light dependent and light independent reactions

Factors that affect photosynthesis

There are four main factors that affect the rate of photosynthesis. In addition to these these four factors, several other factors also impact the process. The main factors, however, are: (1) **light intensity and (2) wavelength, (3) carbon dioxide concentration, and (4) temperature.**

Light intensity

When the temperature is constant, the rate of photosynthesis varies with light intensity. Intially, as light intensity increases, the rate of photosynthesis also increases. However, at a higher level of light intensity this correlative relationship ceases and the rate of photosynthesis reaches a plateau (Figure 7).

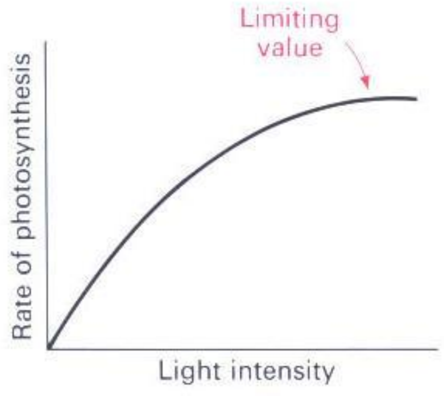

Figure 7. The dependency of rate of photosynthesis on light intensity

(Source: http://fhs-bio-wiki.pbworks.com/w/page/12145771/Factors%20effecting%20the%20rate%20of%20photosynthesis)

Wave length

Variations in the colour of light have impact the rate of photosynthesis. While the entire spectrum of light reaches the plant at the same time, there are certain colours that bring about higher amounts of photosynthesis than others. Because of chlorophyll each plant is of individual colouring. The clorophyll is created of four kinds of pigments: Chlorophyll A, Chlorophyll B, Xanthophyll, and Carotene. Some leaves contain more of certain colour pigments than of others, and as a consequence some leaves can appear yellow-green while others appear bright green, blue-green or even orange or red. With regard to photosynthesis, however, such pigmentation does not matter

As was exhibited in Figure 3, the colours that influence photosynthesis most are blue and red. Whereas, yellow light is the least helpful in the process of photosynthesis. It is important to bear in mind that, when testing the rate of photosynthesis in the case of various colours, the leaf used in such an experiment should not be exposed to natural light. It is important to use an absolutely dark room andany light that is not a part of the experiment itself should be carefully screened from the experimentation area. White light, also a part of the spectrum of light, should be used as a control element in the experiment.

Temperature

The rate of photosynthesis increases as the temperature is increased over a limited range. However, this relationship holds true only at high irradiance. At low intensity, increasing the temperature has little influence on the rate of photosynthesis.

Carbon dioxide concentration

The level of carbon dioxide in the atmosphere is relatively constant. Therefore, CO_2 concentration does not limit the rate of photosynthesis. Nevertheless, higher concentrations of CO_2 increase the rate of photosynthesis (the rate at which sugars are made by the light-independent reactions). Thus, in industrial greenhouses, this factor is used to encourage photosynthesis.

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IV. Pedagogical Content Knowledge

Content

The importance of photosynthesis for plants, other organisms and the biosphere. The mechanisms of light-dependent and light-independent reactions; and the factors influencing photosynthesis. Current and future applications of photosynthesis.

Learning/teaching objectives

The students are expected to:

- analyse the tasks, results and importance of photosynthesis;
- analyse the light dependent and light independent (dark) reactions of photosynthesis

- relate physical plant characteristics (chloroplasts, pigments, stomata, etc) to their functions
- understand the transfer of energy from light to usable chemical energy
- plan and perform an inquiry, use experimental data to make conclusions about the factors influencing photosynthesis
- communicate and present their ideas and results
- apply their knowledge to the topics related to the current and future applications of photosynthesis
- design a model of a space station
- seek relevant information from different sources
- conduct an experiment on planar chromatography of plant pigments, explain the results using scientific knowledge
- work successfully as a team
- develop their understanding of the nature of science aspects related to the knowledge of photosynthesis
- take a responsible attitude towards living organisms

Pre-required knowledge and skills

The energy needs of organisms and the methods of energy production used by autotrophic and heteroprophic organisms; general flow of substances and energy in organisms; ATP as the universal intermediary for energy storage and transfers; respiration as a mechanism providing organisms with energy.
Suggested: Basic knowledge in organic chemistry, chemical bond (hydrogen bond)
Students are familiar with independent inquiry, planning and carrying out experiments using safe and sustainable working methods.

Common misconception:

Students often misunderstand the basic process of photosynthesis. Rather than believing that plants make their own food internally using carbon dioxide, water, and sunlight, they think that plants take in their food from the outside environment using sources such as water and soil. They are missing the main principle of a process they have been taught in detail.

V. Industrial (technological) Content Knowledge

When designing their greenhouses for Mars, students must be introduced to the Martian conditions: the concept of gravity, the consistence of Mars' atmosphere and surface, length of the year and the day, temperature, etc. and what, therefore, the main problems are, that scientists are confronted with in designing a suitable green house.

The following information is adapted from the article

"Greenhouse design for the Mars environment: Development of a prototype, deployable dome"[2]

R.A. Bucklin, P.A. Fowler, V.Y. Rygalov, R.M. Wheeler, Y. Mu, I. Hublitz, E.G. Wilkerson

1. Atmospheric pressure and gravity

Atmospheric pressure measured on Mars varies widely with location and season from 0.69 kPa to 0.9 kPa. Atmospheric pressure is always extremely low compared with that on Earth and from a structural analysis viewpoint effectively zero. Martian gravity is 0.38 of the Earth's gravity (3.73 m/s^2) so one's weight will be less than on Earth. The Martian atmosphere has a density of about 0.01 of that of the Earth.

2. Wind and dust

Because of low atmospheric density, the wind load will be low. However, the dust carried by wind is important, as dust suspended in the air changes the overall quantity of light and the distribution of direct and diffuse radiation. It is suggested that it would be necessary to develop a method of dust removal from the exterior of the greenhouse.

3. Temperature

The average surface temperature on Mars is approximately –63°C with an average diurnal range of around –103°C to –5°C (Hiscox, 2000 as cited in Bucklin *et al.,2004*). The daily temperature range observed was –89° C to –32°C. Daytime temperatures in the summer at the equator may be suitable for plant growth, but nighttime temperatures are far below the temperature range where plants can survive.

4. Light Levels

Estimates of light levels vary and it is difficult to determine whether values are for the Martian surface or for the Martian orbit. The distribution of direct and diffuse light is needed. Ambient light levels on Mars are high enough to sustain plant growth. However, because of extremely low temperatures and pressures, any plant production must be conducted inside an enclosure. Even the best transparent wall materials reduce light levels. An ideal wall material would allow transmittance of the wavelengths above 400 nm at angles of incidence from zero to 90° and zero transmittance out of the structure for all thermal wavelengths beyond 3000 nm (Aldrich and Bartok, 1994; as cited in Bucklin, et al., 2004).
The wall materials with the highest light transmisivity are thin films that have low thermal resistance and low mechanical strength. Thin films can be reinforced by straps or frames, but these reinforcing elements reduce the amount of light. It may be

[2] http://www.marshome.org/files2/Bucklin2.pdf

necessary to supplement ambient light with artificial lighting to achieve satisfactory plant growth. The power requirements of artificial lighting are very high; however, in contrast to most situations on Earth, the waste heat from artificial lights would be very useful on Mars.

5. Structural needs
The main structural load on any configuration of Martian greenhouse will be imposed by internal pressure. Gravity loads and wind loads will be much smaller. The stresses in a curved shell are directly related to the internal pressure and the shell radius and are inversely related to the wall thickness. Stresses in flat sheets increase with pressure and sheet width. Bending stresses in flat sheets also increase as sheet thickness decreases. Walls must be as transparent as possible, which means walls should be as thin as possible. Most greenhouse films are less than 1 mm thick, so stresses can rapidly approach the film's failure strength. Reinforcing material can be added to films and sheets, but reinforcing material blocks or reduces light levels. A spherical shape gives the best strength to weight ratio for carrying pressure loads and curved shapes such as hemispherical domes or half cylinders have better strength to weight ratios than shapes with flat sides. Curved shapes also have lower surface area to volume ratios, which is an advantage when considering heat loss through the wall surfaces. However, the lower surface area to volume ratio can be a disadvantage when light collection is considered. Many film materials exhibit large thermal expansion and contraction. Large stresses are produced if the film is restrained from changing length as the temperature decreases and wrinkles can appear when the temperature increases. Cycles of expansion and contraction can also produce stresses at joints. Many clear materials are sensitive to ultraviolet radiation.

Environmental control
The dominant environmental parameter in a Mars deployable greenhouse will be **temperature**. A heating system will be a necessity at night. Solar collectors can be used to increase the amount of energy, but collectors will not be effective during times when light is diffuse because of dusty conditions or clouds. Even on the best days, supplemental heating will be required. If a transparent film is used for wall material, the heating system will consume major quantities of energy, so utilising as much solar energy as possible will be critical. Significant quantities of solar energy are available on the Martian surface, but as on Earth, solar energy on Mars is not always available when required and is never available at night. If **supplemental lighting** is used, cooling may be necessary because electrical lights produce very large quantities of waste heat. Because of the cold surroundings, cooling should consume much less energy than heating. The quantity of solar energy available to heat a greenhouse can be increased by the use of **solar collectors** and concentrators when direct sunlight is available. Thermal storage is necessary when using solar systems in order to provide a steady supply of energy throughout the day and night. **Glass** is transparent to visible wavelengths of light and opaque to infrared wavelength and is an ideal wall material for the greenhouse effect. Unfortunately, many plastic films are relatively transparent to infrared radiation. The radiation characteristics of wall materials must be carefully selected to optimise transmission of photo synthetically Active Radiation (PAR) and block as much radiation in the infrared range as possible. **Gas leakage** will occur from the greenhouse. All practical closed systems holding gas under pressure leak because of the pressure differential

across wall surfaces and the difficulties of maintaining tight seals of flexible materials. Heating of replacement gases will add to the energy load of the greenhouse. Carbon dioxide can be replaced from the Martian atmosphere, but water vapor and oxygen will be difficult to make up. The greenhouse will require a **ventilation system**. Plants will require some minimum air velocity over leaves for gas exchange. Plants transpire and release oxygen as a byproduct of photosynthesis. Even if the overall system is closed, the plant growth volume must be maintained within a certain range of relative humidities and at some point, surplus oxygen must to be removed from the system and carbon dioxide will need to be added.

Temperature and relative humidity must be constantly controlled to maintain a satisfactory environment for plant growth. An **overall environmental control system** will be required to manage the interactions between lighting, temperature, relative humidity, oxygen level, carbon dioxide level, pressure, the hydroponics system and plant growth.

Plant considerations

The plant consideration that has the largest impact on structural design is the internal **pressure** of the greenhouse. The absolute minimum internal pressure is the sum of the partial pressures of carbon dioxide, water vapor and oxygen inside the greenhouse. The partial pressure of carbon dioxide in Earth's atmosphere is 0.035 kPa. The partial pressure of carbon dioxide in the Martian atmosphere is about 0.57 kPa. The partial pressure of water vapor in Earth's atmosphere, referred to as the vapor pressure, varies with temperature and relative humidity. At comfortable room conditions of 25°C and 50% relative humidity, the vapor pressure for Earth's atmosphere is 1.6 kPa. The variation of humidity can be neglected in open systems operating at Earth atmospheric pressure, but the variation is important in closed systems operating at reduced pressures. Tests in the vacuum test chamber at Kennedy Space Center (KSC) (Fowler et al, 2000 as cited in Bucklin, et al., 2004) indicate that plants tolerate pressures down to 20 kPa without problem, but begin to wilt below this value. In other tests at KSC, plants survived below 10 kPa for short periods of time.

Plants have a region of **temperatures** in which they function best and also upper and lower limits beyond which they display heat or cold damage. Temperature also has a major influence on transpiration rate and on dissolved oxygen levels in root moisture.

The internal gas mix must contain minimum levels of carbon dioxide, water vapor and oxygen. The maximum desirable levels of these components will not total 10 kPa so some inert gas will be required to supply the remainder of the desired **pressure**. The pressure and the gas mix in the greenhouse will require monitoring and control. In a closed system, the carbon dioxide partial pressure will drop as carbon dioxide is consumed by photosynthesis. At the same time, oxygen is released by the plants and the oxygen partial pressure will increase. Water vapor partial pressure will increase as the plants transpire and add water to the gas mix. Excess water vapor will have to be removed from the gas mix and recycled into the soil media or the hydroponics system's water. Water vapor pressure will fluctuate by several kilopascals as relative humidity varies. Carbon dioxide will have to be replaced as it is consumed by photosynthesis and oxygen will have to be harvested and stored or discharged before it reaches undesirable levels. Just as with temperature, plants require a certain range of relative **humidity** to function. Relative humidity is the ratio of the ambient water vapor pressure to the water vapor pressure at saturation for the same temperature. For a given temperature, relative humidity is a function of ambient water vapor pressure. Vapor pressure increases as moisture is added to the air through transpiration or evaporation from leaks in the hydroponics system. Under Earth atmospheric pressure in an open system, the change in vapor pressure is not important, but in a totally closed system at low pressure, fluctuations in vapor pressure will significantly influence total pressure. Hydroponics systems will need to be as tight as possible to reduce the quantity of water that evaporates from leaks. At high relative humidities, condensation on interior wall surfaces will occur. Condensation by itself will reduce light levels and over time will promote dirt and mineral collection on wall surfaces that will further reduce light levels.

A minimum internal **air velocity** is needed for the gas exchanges required for photosynthesis to occur. Velocities in excess of this minimum should be produced by the ventilation system operating to remove moisture from the system, so maintaining the minimum required velocity is not expected to be a problem. The plant will also require some minimum volume for its canopy. The biggest challenge for the design of a deployable Martian greenhouse is to achieve maximum light transmittance while keeping heat loss to acceptable levels. Radiation heat transfer will dominate for Martian conditions. The low density atmosphere will reduce conductive and convective heat transfer through the atmosphere outside the greenhouse. Operating greenhouses at internal pressures as low as 0.1 Earth atmosphere has been discussed, but it appears that plants may not be productive at pressures below 0.2 or 0.3 Earth atmospheric.Conduction and natural convection inside the structure will be greatly reduced at 0.1 Earth atmosphere and hence a higher pressure may be required to maintain a good thermal and mass transfer balance. During the day, the greenhouse will receive direct radiation from the sun and some diffuse radiation. The greenhouse will lose radiant energy to all of the very cold surrounding objects and depending on sky conditions; it will lose radiant energy to cold portions of the sky away from the sun. At night, the surrounding objects will be even colder and the greenhouse will lose radiant heat to the cold sky. The presence of plants complicates the heat transfer analysis by adding latent heat transfer (evaporation and condensation) to sensible heat transfer (conduction, convection and radiation). The changing mix of carbon dioxide, oxygen and water vapor in the greenhouse must be accounted for in heat transfer analysis. Other factors of importance include leakage from the hydroponics plumbing and condensation on the inside of the greenhouse wall.

Laboratory tests

Several research groups are developing facilities to study the behaviour of plants at low pressure (Brown and Lacey, 2002; Chamberlian *et al*, 2003; Ferl *et al*, 2002; Goto *et al*, 2002; all cited in Bucklin *et al*., 2004). The tests described here are from preliminary studies with a 1 meter diameter dome shaped low pressure growth chamber developed as a prototype of a Mars Greenhouse by the Advanced Life Support group at KSC and the University of Florida. Tests conducted to clarify air and moisture relationships at low pressure have been conducted in a large vacuum chamber used to test space suits and several small chambers (Fowler et al, 2000; Fowler et al, 2002; Rygalov et al, 2002 as cited in Bucklin *et al*., 2004). An automated closed environmental growth chamber (see Figure 8) was developed at KSC that operates at pressures down to 25 kPa.

Figure 8. Mars Dome Greenhouse (Source: http://science.ksc.nasa.gov/biomed/marsdome/pictures.html)

The base of the dome is stainless steel and the dome is made of clear Lexan. Internally, a monitoring and control system regulates the atmosphere to predetermined set points. The system is controlled electronically by a microcontroller which interacts with sensors and appropriate relays and solenoids to enact systems for each parameter. Algorithms were developed to control each parameter. The main component of the system is a central tower, the Automated Tower Management System (ATMS).

The ATMS consists of a tube with a fan and heater at the top to create airflow in the system. Directly below the fan a cooling coil is used both for air temperature and humidity control. Underneath the cooling coil is a water collection pot that receives condensation from the cooling coil. This pot of water is then pumped back through a selective manifold that distributes the water back to the plants, thus completing the water cycle of the system. An outside PC is used to log data from the experiment. A regulated vacuum pump is used to maintain the desired pressure. The ability of the system to grow a crop was tested by growing nine plants of Waldmann's Green Lettuce at 25 kPa pressure, 0.2 kPa carbon dioxide and 5 kPa oxygen. Plants grown in arcillite medium with Osmocote time release fertiliser. An automated watering system was used. The watering system was based on scales continuously weighing each plant. Water and CO_2 were the only two outside inputs to the system. The experiment lasted 45 days with the first week (germination) done at regular pressure and then the plants were trans-planted and put into a 25 kPa environment. At the end of the experiment, the plants were harvested and analysed. One plant died and was removed from statistics. Six plants displayed tip burn, four plants had rusty spots on older leaves and there was mold on the soil surface under dead leaves of one plant. The system successfully grew a crop of lettuce past the typical harvest date.

VI. Learning Path(s)

This unit consists of 9 activities. The exemplary sequence of activities, in which all activities are used, is given in the table below.

Activity	***Inquiry Type***	***E-emphasis***
1. Capturing students' interests	Interactive discussion	Engagement

2. Exploring history of the development photosynthesis knowledge	Guided inquiry	Exploration
3. Exploring plant pigment	Guided inquiry	Exploration/Explanation /Elaborate
4. The processes of light-dependent and light-independent reactions	Interactive demonstration/ Guided inquiry	Exploration /Explanation
5. Inquiry on factors that influence the intensity of photosynthesis	Open inquiry	Engagement/Exploration /Explanation
6. Designing the model of a space station	Guided inquiry	Engagement/Exploration/ Elaborate

VII. Assessment

Students will be assessed in many different ways throughout the course, including science process skills, general competences, and topic-related content knowledge. The types of assessments will include formative assessments including observation, participation and quizzes and summative assessments such as a final project.

For computer simulated inquiry (see activity 5a) the following assessment criteria are suggested[3]:

	Poor	Satisfactory	Good
Introduction	Explanation of light dependent reaction lacking and/or hypothesis missing.	Offers explanation of the reaction, some parts vague or incorrect. Hypothesis unclear or does not answer the experimental question completely.	Offers good explanation of the light dependent reaction, includes how light is used to produce ATP and NADPH. Proposes a hypothesis to answer the experimental question.
Data	Variables not separated, data disorganised, trends not apparent.	Organised, though trends are not obvious from the layout. Hard to read, taking some time to figure out.	Well organised into tables, variables separated, data clearly shows trends
	Not enough data was collected to test variables	A fair amount of data was collected, enough to show trends	Enough data was collected to clearly show trends
	Graphs poorly	Graphs missing some labels	Graphs all labelled

[3] Suggestions are adapted from http://www.biologycorner.com/worksheets/photosynthesis_sim.html

	labelled, difficult to read.	or incorrectly set up	correctly, easy to read
Conclusion	Does not answer the experimental question. Erroneous conclusion.	Answers the experimental question, data used to support argument unclear, or partially incorrect analysis	Answers the experimental question, follows data, conclusions are not erred.
	Explanation attempted, but fails to explain data trends	Explanation is reasonable, but does not take into account important aspects of photosynthesis	Explanation for results is reasonable and takes into account principles of photosynthesis
Format	Not typed, not neat	Typed, neat	Total:

VIII. Student Learning Activities

Activity 1. Capturing students' interests

Learning aims:

Students are expected to

- express their previous knowledge, and
- generate and share ideas for further exploration about photosynthesis after discussing the idea of living in a space station on Mars with their group members.

Materials:

Overhead Projector

Suggestions for use:

After presenting the introduction, group discussion is carried out on how to create conditions for living in such a space station and on problems related to the management of a space station. The purpose of this activity is, among others, to assess the prior knowledge that the students have about photosynthesis and existing conditions on Mars compared to the Earth.

The topic itself may be related to a complex combination of problems related to food, living in an artificial environment, how to create psychological and physical comfort, etc. However, it is the teacher's task to address the themes more related to photosynthesis and conditions needed for that. All the other students' ideas may be developed further and be included in their final project (Activity 6).

Possible questions:

- *What are the conditions required for living in a space station? What are the main problems?*

Activity 2. Exploring history of the development of photosynthesis knowledge

Learning aims:

It is expected that students:

- seek relevant information from internet or library
- develop further an understanding of the nature of science, including how knowledge of photosynthesis has been developed.
- are able to give some examples representing the three aspects of the nature of science (that scientific ideas are subject to change; science demands evidence; and science is a complex social activity).

Supporting materials:

- Information from *World of Biology* (McGrath, 1999, p.600)
http://www.geocities.com/barefeetchild/history.html?200611
- Jeffery Kahn: Calvin Photosynthesis Group Subject of History Project
http://www.lbl.gov/Science-Articles/Archive/Calvin-history-project.html
- Discovery of Photosynthesis
http://www.biocrawler.com/encyclopedia/Photosynthesis

Suggestions for use:

During the first lesson, students hopefully put forward a range of ideas on what could be done in order to create proper conditions for living in space including growing plants or other organisms there for producing oxygen and absorbing carbon dioxide. The purpose of the following lesson is to encourage students to think about "how" do we know "what" we actually know about photosynthesis.

In other words, when students claim something related to photosynthesis, it is the right moment to ask "how do you (or we) know that?". This emphasis will nicely link activity 1 to activity 2 where discoveries as a result of human endeavour are revealed by introducing historical figures and experiments that contributed to the body of knowledge scientists have on the processes of photosynthesis.

Activity 2. 1 Writing activity

Groups (3-5 persons) are asked to use the Internet or library resources to research the experiments conducted by one of these scientists related to photosynthesis:

Jan van Helmont (1643)
After careful measurements of a plant's water intake and mass increase, van Helmont concludes that trees gain most of their mass from water.

Joseph Priestly (1771)
Using a bell jar, a candle, and a plant, Priestly finds that the plant releases a substance that keeps the candle burning – a substance that we know is oxygen.

Jan Ingenhousz (1779)
Ingenhousz finds that aquatic plants produce oxygen bubbles in the light but not in the dark. He concludes that plants need sunlight to produce oxygen.

Julius Robert Mayer (1845)
Mayer proposes that plants convert light energy into chemical energy

Samuel Ruben and Martin Kamen (1941)
Ruben and Kamen use isotopes to determine that the oxygen liberated in photosynthesis comes from water.

Melvin Calvin (1948)
Calvin traces the chemical path that carbon follows to form glycose. These light-independent reactions are known as the Calvin cycle.

Rudolph Marcus (1992)
Marcus wins the Nobel prize in chemistry for describing the process by which electrons are transferred from one molecule to another in the electron transport chain.

Based on their investigation, students write a summary (e.g. in the form of a poster) describing how the scientist contributed to the modern understanding of photosynthesis.

An alternative version of this stage may be that groups produce a PowerPoint presentation or even a video clip about the explored scientist and his discovery. In the last case the activity takes much more time (2-3 lessons + home work) as it involves both the process of setting and videotaping of a role-play.

Activity 2. 2 Compiling a flowchart

In this phase students put together the results of their group work, e.g. students present their posters on the classroom wall. Depending on the time sequence, groups introduce the ideas (~5 min.) that contributed to the development of photosynthesis-related knowledge.

Possible questions:

- What are the main stages in the development of knowledge about the photosynthesis?
- Which of those discoveries has contributed most to the current understanding of photosynthesis? Justify your choice!

Activity 3. Exploring plant pigment

Learning aims:

Student are expected to

- Identify where photosynthesis takes place
- Experiment to find pigmentation taking place in plant leaves
- Interpret, analyse, and describe the structure and function of chloroplasts
- Give some examples of photosynthetic pigments
- Understand the process of chromatography

Supporting materials:

Materials

50 mL graduated cylinder	pencil
chromatography (filter) paper	scissors
(spinach) leaves (e.g.)	solvent
coin	(1 part acetone with 1 part ethanol)
cork stopper	ruler
goggles	

Sources:

http://www.phschool.com/science/biology_place/labbench/lab4/intro.html

Suggestions for use:

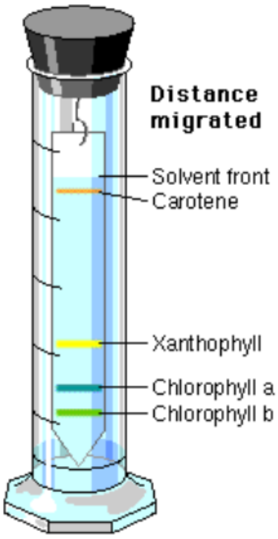
Activity 3.1 Independent reading exercise

In this part, students develop their understanding of the structure and functions of chloroplasts (students are provided with the relevant text), after what they answer the questions (individually). Questions are discussed afterwards in the class.

***Activity 3.2 Experiment: Plant pigment chromatography*[4]**

In this stage students conduct the experiment using paper chromatography technique in order to separate plant pigment substances in a mixture based on the movement of the different substances up a piece of paper by capillary action. Beta carotene is carried the furthest because it is highly soluble in the solvent and because it forms no hydrogen bonds with the chromatography paper fibers. Xanthophyll contains oxygen and does not travel quite as far with the solvent because it is less soluble than beta carotene and forms some hydrogen bonds with the paper. Chlorophylls are bound more tightly to the paper than the other two, so they travel the shortest distance. Spinach leaves are given only as an example. As a solvent, the mixture of acetone and ethanol (1:1) or petroleum ether and acetone (92:8) is used.

Expected results:



$$Rf = \frac{\text{distance pigment travels}}{\text{distance the solvent front travels}}$$

Attention: Students must be warned to keep the bottle tightly closed except when one is using it because the solvent is very volatile and produces fumes.

[4]This practical work is adapted from http://www.phschool.com/science/biology_place/labbench/lab4/design1.html

Possible questions:

- Experiment to find pigmentation taking place in plant leaves
- Interpret, analyse, and describe the structure and function of chloroplasts
- Give some examples of photosynthetic pigments
- Understand the process of chromatography

Activity 4. The processes of light-dependent and light-independent reactions

Students are expected to

- Identify the products of the light and dark phase
- Explain the roles of light, pigment, water, and the electron transport system in the light phase
- Understand the transfer of energy from light to usable chemical energy
- Explain the processes of dark phase

Supporting materials:

Supporting computer simulations:

http://filebox.vt.edu/users/dwilhelm/portfolio/biounitplan.pdf
http://www.pbs.org/wgbh/nova/nature/photosynthesis.html
http://www.wiley.com/legacy/college/boyer/0470003790/animations/photosynthesis/photosynthesis.htm
http://www.mhhe.com/biosci/genbio/biolink/j_explorations/ch09expl.htm

Suggestions for use:

In this part, it is suggested that the teacher uses direct teaching as it is considered the most difficult part within the unit for students to understand. After that students are asked to individually fill in the concept map, and then share it in pairs (or groups). In addition, students' work sheets are provided with short questions for student self-assessment.

Possible questions

What are the products of the light and dark phase of photosynthesis?

What are the roles of light, pigment, water, and the electron transport system in the light phase?

What happens with a plant which is: (a) always exposed to the light? (b) kept in dark for days?

Activity 5. Inquiry on factors that influence the intensity of photosynthesis

Learning aims:

Students are expected to

- develop a testable hypothesis
- design an experiment (whether virtually or a real) that will answer a question about photosynthesis
- present collected data in the form of tables and graphs
- explain results using scientific knowledge
- use data and observations to form a conclusion.

Materials:

digital data logger	ice cubes
CO_2 gas sensor	1 L beaker
O_2 gas sensor	thermometer
250 mL respiration chamber	lamp with adjustable light intensity
plant material	coloured films

Suggestions for use:

This part of learning is provided with alternative strategies and suggestions that the teacher can choose, depending on existing resources. Alternatives are given as activity 3a, 3b, 3c.

Students will be given the materials and asked to design an experiment to answer the question. When they have finished planning their experiment the students will be required to set up their experiment and record their hypothesis and rationale of what will happen in their experiment. Students will make observations and collect data from their experiment. They will record their results in a data table.The students will form conclusions based on their data and explain any anomalies. The results of students' inquiry will hopefully feed the ideas of students' space project.

http://www.biologycorner.com/worksheets/photosynthesis_sim.html

Activity 5a Using computer models to explore the factors controlling photosynthesis (effects of light intensity and wavelength on the rate of photosynthesis)

In this simulation, students will stimulate two variables: light intensity and light wavelength. The amount of ATP produced will change depending upon the set parameters. The simulation "Johnson Explorations: Photosynthesis" is located at http://www.mhhe.com/biosci/genbio/biolink/j_explorations/ch09expl.htm

The students' task is to use the simulation to determine how wavelength and intensity affect the rate of photosynthesis (and the production of ATP).

In addition, valuable animations of the processes can be found at the website: http://science.nhmccd.edu/biol/bio1int.htm#photo

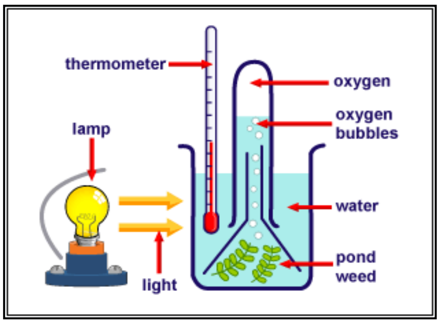
Technology in the classroom, when available, provides an ideal situation in which multiple representations of information can be disseminated to the students.

Activity 5b. Using digital sensors and data logger to explore the factors controlling photosynthesis (effects of light intensity and wavelength, temperature and on the rate of photosynthesis)

In this experiment, students will

- Plan and carry out an experiment on factors controlling photosynthesis
- Study the effect of at least one condition (light intensity, wavelength, plant, or temperature) on the rate of photosynthesis
- Use an O_2 Gas Sensor to measure concentrations of oxygen gas.
- Use a CO_2 Gas Sensor to measure concentrations of carbon dioxide gas

Activity 5c. Using pond weed to explore the factors controlling photosynthesis



(Source: http://9arevision.wikispaces.com/plants)

This alternative is given in case the other possibilities are unavailable. It takes more time to get visible results (oxygen displacing water), still, all the aforementioned variables are testable.

Possible questions:
• How do different factors influence the intensity of photosynthesis?

Activity 6. Designing the model of a greenhouse for space station

Learning aims:

Students are expected to:

- analyse critically the conditions people will encounter on Mars when designing a greenhouse,
- propose solutions to the possible problems and develop a model of a greenhouse.

Supporting materials:

Computers and internet

http://science.nasa.gov/science-news/science-at-nasa/2004/25feb_greenhouses/
http://en.wikipedia.org/wiki/Life_on_Mars_%28planet%29
http://hortist.blogspot.com/2009/09/greenhouse-on-mars.html

Sheet of paper (A3 or A2), coloured or felt-tip pencils.

Suggestions for use:

In this activity, it is expected that students will find relevant information themselves regarding the conditions on Mars (gravity, air pressure, consistence of atmosphere, temperature, mineral consistence of the ground, is it possible to use the existing ground for growing plants, level of radiation, length of the day and year) and fill in the table using 1) critical thinking to understand what the main problems related to greenhouse design are, and 2) creative thinking to offer possible design solutions.

When drawing the scheme, students may just use a pencil and paper (at least A3), but all other solutions (e.g. digital) are welcome as long as the picture is supplemented with relevant details and comments.

In the last lesson, all groups will present their models to the other groups where students can test their ideas with the help of the comments and questions of class mates.

Possible questions:

- Which wavelengths of radiation, temperatures, etc are needed to make the photosynthesis effective in artificial conditions?
- Is the existing ground on Mars suitable for growing plants?
- What are the most critical problems when growing plants on Mars?

WP3
Photosynthesis

European Science and Technology in Action Building Links with Industry, Schools and Home

Work Package 3
Photosynthesis
Classroom Materials

European Science and Technology in Action: Building Links with Industry, Schools and Home

Lead partner for deliverable: **University of Tartu**

The development of the package was made by Katrin Vaino, Miia Rannikmäe, and Jack Holbrook.

The ESTABLISH project has received funding form the European Community's Seventh Programme [FP7/2007-2013] under grant agreement n^{o} 244749
Start Date: 1st January 2010 Duration: 48 months

Greenhouses on Mars?!

Activity 1.

Introduction

To travel in space the basic requirements for human survival are exactly the same as those requirements on Earth - air, water and food. For short term missions into space the problem of maintaining a suitable atmosphere is solved simply by removing unwanted gases (by pumping the air through scavenging filters), and adding oxygen as required, then recirculating the air. All waste materials are simply discarded when the mission returns to Earth. For long term missions, especially when it is planned to build a space station on the next planet Mars, the problem is much harder to deal with, since one cannot easily travel with an unlimited supply of either gas filters, water, food, or oxygen. Water vapour also creates a problem. If the air is too dry it is uncomfortable to breathe for long periods. If the air is too moist, again, it may cause different problems. One possible solution to produce oxygen, food and, at the same time, absorb carbon dioxide, is considered to be greenhouses. Different projects are developed in different space centres, incl. NASA, to find ways to realise the idea of a number of science fiction books and movies to reside other planets.

Brainstorming session in groups:

- Discuss with your group members about living in a space station.
- Write down as many ideas, questions, problems as you can, regarding creating necessary conditions for short term as well as long term missions.
- Share your ideas with other groups.

Activity 2. Exploring history of the development of photosynthesis knowledge

Activity 2. 1. Writing activity

- Use the Internet or library resources to research the experiments conducted by one of these scientists related to photosynthesis:

Jan van Helmont (1643)
After careful measurements of a plant's water intake and mass increase, van Helmont concludes that trees gain most of their mass from water.

Joseph Priestly (1771)
Using a bell jar, a candle, and a plant, Priestly finds that the plant releases a substance that keeps the candle burning – a substance that we know is oxygen.

Jan Ingenhousz (1779)
Ingenhousz finds that aquatic plants produce oxygen bubbles in the light but not in the dark. He concludes that plants need sunlight to produce oxygen.

Julius Robert Mayer (1845)
Mayer proposes that plants convert light energy into chemical energy

Samuel Ruben and Martin Kamen (1941)
Ruben and Kamen use isotopes to determine that the oxygen liberated in photosynthesis comes from water.

Melvin Calvin (1948)
Calvin traces the chemical path that carbon follows to form glycose. These light-independent reactions are known as the Calvin cycle.

Rudolph Marcus (1992)
Marcus wins the Nobel prize in chemistry for describing the process by which electrons are transferred from one molecule to another in the electron transport chain.

Based on your investigation, write a summary (e.g. in the form of a poster) describing how the scientist contributed to the modern understanding of photosynthesis.

Activity 2. 2. Compiling a flowchart

According to the historical sequence, groups introduce the ideas (~5 min.) that contributed to the development of photosynthesis-related knowledge.

Activity 3. Exploring plant pigment

Activity 3.1. Independent reading exercise

In this part you are expected to develop your understanding of the structure of chloroplasts. Read the text given by your teacher and answer to the questions given below:

1. The photosynthetic pigment that is essential for the process to occur is:

a) chlorophyll *a;* b) chlorophyll *b;* c) beta carotene; d) xanthocyanin; e) fucoxanthin.

2. When a pigment reflects red light:

a) all colours of light are absorbed; b) all colours of light are reflected; c) green light is reflected, all others are absorbed; d) red light is reflected, all others are absorbed; e) red light is absorbed after it is reflected into the internal pigment molecules.

3. Chlorophyll *a* absorbs light energy in the colour range:

a) yellow-green; b) red-orange; c) blue violet; d) a and b; e) b and c.

4. The individual flattened stacks of membrane material inside the chloroplast are known as: a) grana; b) stroma; c) thylakoids; d) cristae; e) matrix.

5. The fluid-filled area of the chloroplast is the: a) grana; b) stroma; c) thylakoids; d) cristae; e) matrix

6. The chloroplasts of plants are closest in size to: a) unfertilised human eggs; b) human cheek cells; c) human nerve cells; d) bacteria in the human mouth; e) viruses.

Activity 3.2. Experiment: Plant pigment chromatography[1]

Paper chromatography is a technique used to separate substances in a mixture based on the movement of the different substances up a piece of paper by capillary action. Pigments extracted from plant cells contain a variety of molecules, such as chlorophylls, beta carotene, and xanthophyll, that can be separated using paper chromatography.

A small sample of plant pigment placed on chromatography paper travels up the paper due to capillary action.

The ratio of the distance moved by a pigment to the distance moved by the solvent is

[1] Adapted from http://www.phschool.com/science/biology_place/labbench/lab4/design1.html

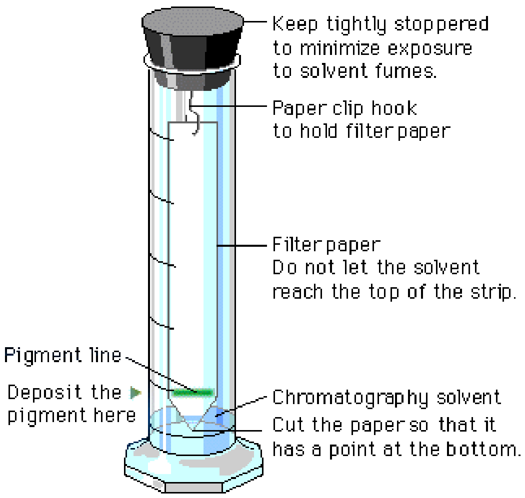
a constant, R_f. Each type of molecule has its own R_f value.

$$R_f = \frac{\text{distance travelled by pigment}}{\text{distance travelled by solvent}}$$

Materials

- 50 mL graduated cylinder
- chromatography paper
- (spinach) leaves
- coin
- cork stopper
- pencil
- scissors
- Solvent (1 part acetone with 1 part ethanol)
- Ruler

solvent, but keep the pigment line abo



Be sure the tip of the filter paper touches the solvent, but keep the pigment line above it.

Procedure

Obtain and wear goggles! ***Caution:*** *The solvent in this experiment is flammable and poisonous. Be sure there are no open flames in the lab during this experiment. Avoid inhaling fumes. Wear goggles at all times. Notify your teacher immediately if an accident occurs.*

1. Obtain a 50 mL graduated cylinder with 5 mL of solvent in the bottom.

2. Cut the chromatography paper so that it is long enough to reach the solvent. Cut one end of the paper into a point.

2. Draw a pencil line 2.0 cm above the pointed end of the paper.

3. Use the coin to extract the pigments from the spinach leaf. Place a small section of the leaf on top of the pencil line. Use the ribbed edge of the coin to push the plant cells into the chromatography paper. Repeat the procedure 10 times making sure to use a different part of the leaf each time.

4. Place the chromatography paper in the cylinder so the pointed end just touches the solvent. Make sure the pigment is not in the solvent.

5. Stopper the cylinder and wait until the solvent is approximately 1 cm from the top of the paper. Remove the chromatography paper and mark the solvent front before it evaporates.

6. Allow the paper to dry. Mark the bottom of each pigment band. Measure the distance each pigment moved from the starting line to the bottom of the pigment band. Record the distance that each of the pigments and the solvent moved, in millimetres.

7. Identify each of the bands and label them on the chromatography paper.

   - beta carotene: yellow to yellow orange
   - xanthophyll: yellow
   - chlorophyll *a*: bright green to blue green
   - chlorophyll *b*: yellow green to olive green

9. Staple the chromatogram to the front of your lab sheet.
10. Discard the solvent as directed by your teacher.

Band number	Distance travelled (mm)	Colour	Pigment
1			
2			
3			
4			
5*			
Distance solvent front moved =......................mm			

* The fifth band may not appear.

Processing the data
Calculate the R_f values and fill the Table 2.

Table 2	
Molecule	R_f
beta carotene	
xanthophyll	
chlorophyll *a*	
chlorophyll *b*	

1. What factors are involved in the separation of the pigments?

___

___

2. Why do the pigments become separated during the development of the chromatogram?

   ____

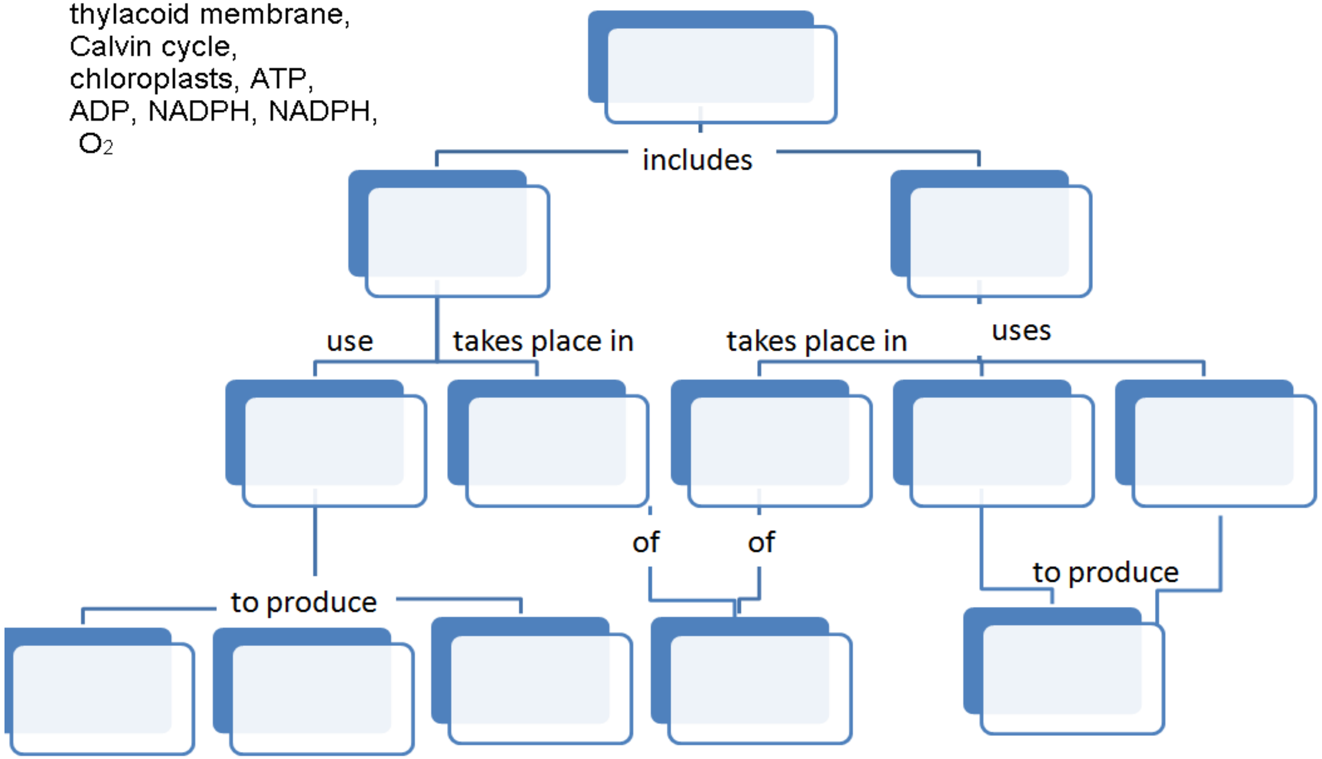
   ____

3. Look again at the chromatogram you completed in the previous exercise. Which of the following is true for your chromatogram?
    a. The R_f for carotene can be determined by dividing the distance the yellow-orange pigment (carotene) migrated by the distance the solvent front migrated.
    b. The R_f value of chlorophyll *b* will be higher than the R_f value for chlorophyll a.
    c. The molecules of xanthophyll are not easily dissolved in this solvent, and thus are probably larger in mass than the chlorophyll *b* molecules.
    d. If this same chromatogram were set up and run for twice as long, the R_f values would be twice as great for each pigment.
4. If a different solvent were used for the chlorophyll chromatography described earlier, what results would you expect?
    a. The distances travelled by each pigment will be different, but the R_f values will stay the same.
    b. The relative position of the bands will be different.
    c. The results will be the same if the time is held constant.
    d. The R_f values of some pigments might exceed 1.0

Activity 4. The processes of light-dependent and light-independent reactions

After teacher's presentation, please fill the following concept map:

Use the following:
Light dependant reactions,
energy from sun light,
stroma, sugars,
thylacoid membrane,
Calvin cycle,
chloroplasts, ATP,
ADP, NADPH, NADPH,
O_2



1. The organic molecule produced directly by photosynthesis is:
    a) lipids; b) sugar; c) amino acids; d) DNA[2]
2. The photosynthetic process removes ___ from the environment.
    a) water; b) sugar; c) oxygen; d) chlorophyll; e) carbon dioxide
3. The process of splitting water to release hydrogens and electrons occurs during the _____ process.
    a) light dependent; b) light independent; c) carbon fixation; d) carbon photophosphorylation; e) glycolysis
4. The process of fixing carbon dioxide into carbohydrates occurs in the ____ process.
    a) light dependent; b) light independent; c) ATP synthesis; d) carbon photophosphorylation; e) glycolysis
5. Carbon dioxide enters the leaf through ____.
    a) chloroplasts; b) stomata: c) cuticle; d) mesophyll cells; e) leaf veins
6. The cellular transport process by which carbon dioxide enters a leaf (and by which water vapour and oxygen exit) is ___.
    a) osmosis; b) active transport; c. co- transport; d) diffusion; e) bulk flow
7. Which of the following creatures would not be an autotroph?
    a) cactus; b) cyanobacteria; c) fish; d) palm tree; e) phytoplankton
8. The process by which most of the world's autotrophs make their food is known as:
    a) glycolysis; b) photosynthesis; c) chemosynthesis; d) herbivory; e) C-4 cycle
9. The process of ______ is how ADP + P are converted into ATP during the Light dependent process.
    a) glycolysis; b) Calvin Cycle; c) chemiosmosis; d) substrate-level phosphorylation; e) Kreb's Cycle

10. Many of the sun’s rays may be blocked by dust or clouds formed by volcanic eruptions or pollution. What are some possible short-term effects of this on photosynthesis?

11. Construct a flowchart that illustrates the steps of photosynthesis. Begin with the energy of sunlight and end with the production of glycose. Include as much detail as possible in the numerous steps.

[2] The questions above are adapted from http://www.phschool.com/science/biology_place/labbench/lab4/quiz1.html

Activity 5. Inquiry on the factors that influence the intensity of photosynthesis

Activity 5a. Using computer models to explore the factors controlling photosynthesis (effects of light intensity and wavelength on the rate of photosynthesis)

In this simulation, you will stimulate two variables: light intensity and light wavelength. The amount of ATP produced will change depending upon the set parameters. The simulation "Johnson Explorations: Photosynthesis" is located at http://www.mhhe.com/biosci/genbio/biolink/j_explorations/ch09expl.htm

Your report must include the following sections:

1. Propose a hypothesis to answer to the posed research question.

2. Provide a rationale to your hypothesis (Why do you think that?)

3. Define independent and control variables.

4. Data: Include data tables to your report. The tables must show clearly trends resulting from changes of intensity and changes of wavelength. Multiple data tables would probably be best here.

4. A graph showing how the percentage of ATP changed (Y axis) as a result of changes in wavelength and intensity (X axis). Two graphs would be best here. You may use Microsoft Excel to make your graphs, or use a spread sheet or graphing program of your choice.

5. Conclusion: Use your data to answer the experimental question. Offer an explanation of the results, taking into account the principles of photosynthesis and the light reaction.

Activity 5b. Using digital sensors and data logger to explore the factors controlling photosynthesis (effects of light intensity and wavelength, temperature and on the rate of photosynthesis)

In this experiment, you will

- Plan and carry out an experiment on factors controlling photosynthesis.
- Explore the effect of at least one condition (light intensity, wavelength or temperature, plant) on the rate of photosynthesis.
- Use an O_2 Gas Sensor to measure concentrations of oxygen gas.
- Use a CO_2 Gas Sensor to measure concentrations of carbon dioxide gas.

Your report must contain the following sections

1. Propose a hypothesis to answer the research question.
2. Provide a rationale to your hypothesis (Why do you think that?).
3. The list of materials.
4. Define independent and controlling variables.
5. Procedure: (Write a detailed account of how you will set up your experiment). Notes: (Write down any events that occurred during the lab set up that may affect your results).
6. Data: Construct a data chart that contains observations and results.
7. Compare your results to one other group's results. Make sure that you understand their procedure.
8. Conclusion: Write a conclusion that discusses what your results in your data chart mean. Also analyse your hypothesis and discuss future experiments that may be done to get a further understanding of the question.

NB: In this experiment, two parallel reactions, photosynthesis and cell respiration, take place simultaneously in the chamber. However, in light conditions, the first process is more intensive than the other, and therefore, we are able to control variables that influence the rate of photosynthesis.

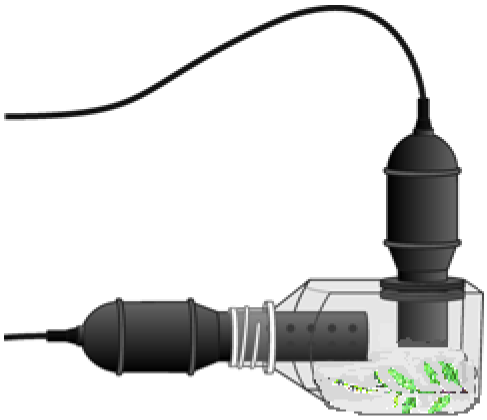


Figure x

Digital data logger
CO_2 gas sensor
O_2 Gas Sensor
250 mL respiration chamber

Plant material

ice cubes
1 L beaker
thermometer
lamp with adjustable light intensity
coloured films

1. Connect the CO_2 Gas Sensor to the data logger Channel 1 and the O_2 Gas Sensor to Channel

3. Obtain ~25 g plant material and put it into the respiration chamber.

5. Insert the CO_2 and O_2 sensors into the neck of the respiration chamber (Figure 1).

6. Wait four minutes for readings to stabilise, then begin collecting data

7. Record your data into the table whether manually or, depending on your technical equipment, by the data logger itself.

(Compile graphs of CO_2 concentration vs. time; O_2 concentration vs time)

7. When data collection has finished, remove sensors from the respiration chamber.

Activity 6. Designing a greenhouse for Mars

Supplying oxygen is only one of many life-support necessities for human spaceflight, but for long-term missions it is obviously the most vital. Now, you are invited to work in groups:

1. Using Internet, find out what are the conditions on Mars compared to the Earth (gravity, air pressure, consistence of atmosphere, temperature, mineral consistence of the ground, is it possible to use the existing ground for growing plants, level of radiation, length of the day and year). Record your findings to the Table 1.

2. What are the main problems caused by the specific conditions on Mars comparing to Earth scientists will encounter when planning a greenhouse for producing oxygen, food and absorbing carbon dioxide?

3. Based on the created list, propose possible solutions to the problems (record your solutions into Table 1).

4. Develop a visualised scheme of a greenhouse taking into account the considerations above. Provide your drawing with references to the conditions that are artificially created or, used as they exist on Mars.

5. Present your design to the other groups.

6. Discuss with your group members: What are the limitations of your model? What aspects of your model need further development?

Table 1.

Condition/Feature	Mars	Earth	Possible problems/affordances related to greenhouse design	Possible solution to the problem
Temperature				
Gravity				
Atmospheric pressure				
Type and level of radiation				
Consistence of atmosphere				
Consistence of ground (soil)				
Lenght of day/year				
Water				

WP3
Forensic Science

European Science and Technology in Action Building Links with Industry, Schools and Home

Work Package 3
Forensic Science

European Science and Technology in Action: Building Links with Industry, Schools and Home

Lead partner for deliverable: **C.M.A.**

Version: 1…

The ESTABLISH project has received funding form the European Community's Seventh Programme [FP7/2007-2013] under grant agreement n^{o} 244749
Start Date: 1st January 2010 Duration: 48 months

A: Teacher Information

I. Unit description

In this module we are going to look at forensic science from different points of view. There are two subunits, the first one focused on students aged 12 to 14/15 years old; the second focused on students aged 15 – 18.

In the first unit the students do research on fingerprints and on properties of human beings like length, mass and step distance. There are links with the classical school disciplines like biology and physics. Where possible, we introduce computer based measurement or educational games (for instance in identifying fingerprints).

In the subunit meant for older students, three different case studies are treated. The first is based on a real case in the Netherlands where a woman was found dead with a ballpoint in her head. Students do research to find out how likely it is that the woman had fallen and dropped on the pen or if it was possible that the pen was fired at her with the use of a crossbow. In the second case study the students try to do face recognition, they do several tests and try to solve a crime they have themselves witnessed. The third case is to study DNA as a way to identify criminals.

Subunit 1

Student level: lower secondary school, age 13 – 15 years
Discipline(s) involved: biology, physics, mathematics (statistics)
Estimated duration: five lessons of one hour approximately

Subunit 2

Student level: higher secondary school, age 15 – 18 years
Discipline(s) involved: biology, physics, chemistry, mathematics (statistics and geometry)
Estimated duration: seven lessons of one hour approximately

II. IBSE Character

Forensic science is developed outside the classroom as a tool to investigate crime scenes. It contains subjects related to chemistry, physics, biology and technology. The approach in forensic science is an inquiry based approach. Forensic scientists have to work with different types of investigation and gather and record data from different sources found on the crime scene (and on the victim). In many cases there is not directly a 100% solution available. With the use of different techniques and different types of evidence, the researcher can state how likely it is that a certain crime was committed by the suspect. The forensic researcher has to be open minded and be aware not to use a tunnel vision. All these aspects make forensic science very suitable to be used as an IBSE approach in education.

Subunit 1

Through the activities in this subunit students develop basic abilities to do and understand scientific inquiry.

- Asking and answering questions.
- Planning and conducting simple investigations.
- Employing tools to gather data (fingerprints, properties of human beings).
- Using data to construct reasonable explanations.
- Communicating investigations and explanations.

Subunit 2

The activities in this subunit address the same abilities as the former one, but at a higher level. The students also see that there are more possible solutions for one problem and that there are different ways to find this solution. Besides that, students have more opportunity to do open inquiry (compared to the first unit).

The abilities addressed in this unit are:

- Asking and answering questions.
- Planning and conducting simple investigations.
- Employing tools to gather data.
- Using data to construct reasonable explanations.
- Communicating investigations and explanations.
- Understanding that scientists use different kinds of investigations and tools to develop explanations using evidence and knowledge.

III. Science Content Knowledge

For both the subunits, basic knowledge on biology, physics, chemistry and mathematics is required at the level the module is written for. The activities in this subunit introduce students to the following concepts and ideas:

Subunit 1

- Properties of fingerprints and the fact that fingerprints are unique
- Techniques to identify fingerprints
- Techniques to take fingerprints (both from a suspect and from a crime scene)
- Properties of the human body and ways to use this in identifying a criminal
- Relation between step distance and length of a person
- Basic rules about statistics

Subunit 2

- Mechanics in collisions (impetus, kinetic energy, inertia).
- Working with models to simulate reality (it is not possible to do experiments on living people in the ballpoint case).
- Memory and the reliability of witnesses.

- Face recognition.
- Properties of DNA and the fact that DNA is unique.
- Techniques to isolate, multiply and analyse DNA
- Doing real and accurate measurements on pictures.
  - Gathering evidence from pictures of a crime scene
  - Inferring suspect features from the pictures

IV. Pedagogical Content Knowledge

This unit gives insight in many different concepts of forensic science. One of the common beliefs is that people in ordinary life expect a forensic scientist to solve any crime whatsoever. This unit puts the high expectations on forensics in proper perspective. On the one hand this will moderate the expectations on forensics, on the other hand it will show that a good mix of small clues will lead to a solution of a crime.

As far as moderating the expectations is concerned, students should be aware of the statistics involved. A lot of clues will lead to average values from which minor derogations are possible. For instance, based on footprints the suspect is identified as being around 1.88 m tall and having a mass of 90 kg. In this case it is still possible that the criminal has a mass of 85 kg and is 1.95 m tall. Students will have to learn to work with this. Students have to be flexible and versatile in using theories, keeping a good eye on the procedures.

Because forensics is built up from different sciences, some aspects of this module will be familiar to the students while other parts are completely new. It is important to the check these familiar subjects on misconceptions. Problems and misconceptions the teacher should be aware of might be:

- Fingerprints are the same for identical twins.
- Fingerprints change during time.
- Difficulties with statistic calculations.
- Problems with impetus, impulse, kinetic energy, gravity, inertia.
- DNA is different for identical twins.
- Difficulty with three-dimensional thinking

V. Industrial Content Knowledge

Forensic science can be seen as industrial content by itself. It is what's being done by professionals in their daily routine. With the use of scientific concepts, crime scenes are researched and hopefully crimes are solved. The forensic science has aspects of chemistry, biology, mathematics and physics. All these disciplines are combined.

VI. Learning Path(s)

Subunit 1

The activities in this subunit can at best be taught in the given sequence. However, it is possible to change a bit in this sequence. It is up to the teacher to decide which sequence will be used. In the table below the activities are given in the advised sequence. The type of inquiry and the E-emphasis is described (see 'Guide for developing ESTABLISH Teaching and Learning Units').

Activity	***Inquiry Type***	***E-emphasis***
1.1. How can fingerprints be categorized?	Guided discovery	Engagement
1.2. Fingerprints as a way to identify persons.	Guided Inquiry	Engagement/Exploration/
1.3 Take your own fingerprint.	Guided discovery	Exploration/Elaborate
1.4 Take fingerprints from an object	Guided Inquiry	
1.5 Identify the criminal	Guided Inquiry	Explanation
2.1 Solve another crime.	Interactive discussion / Guided discovery	Exploration
2.2. Crime solving game.	Guided discovery	Elaboration
3.1 Properties of human beings	Interactive discussion / Guided discovery	Exploration
3.2 Whodunit	Guided discovery	Explanation/Evaluate
3.3 Traces in the snow	Guided inquiry	Exploration/Elaboration/Evaluate
3.4 Can you use footprints to determine if a person was running or walking?	Open inquiry	Elaboration
3.5 Other indirect clues	Open inquiry	Elaboration

Subunit 2

The sequence of the activities in this unit is less important. The teacher can decide to change the sequence or even skip some of the items. The three main activities (ballpoint case, face recognition and DNA) are all independent of the other activities. However, to do the activity on face recognition in an appropriate way, it is necessary to use the introductory video to the ballpoint case. Parts of this introductory video (playing time 2:45 min) are used in the module on face recognition. Without knowing it in advance, the students witness a crime (ballpoint theft) in this clip.

In the table below the activities are given in the advised sequence (as said before, the sequence can easily be changed) The type of inquiry and the E-emphasis is described (see Guide for developing ESTABLISH Teaching and Learning Units).

Activity	***Inquiry Type***	***E-emphasis***
1.1 Introduction movie	Interactive demonstration*	Engage
1.2 Historical Trials	Guided inquiry	Explore
1.3 Modelling the ballpoint case	Bounded inquiry	Explore
1.4 Calculations on the ballpoint case	Guided discovery / Interactive discussion	Evaluate
1.5 Other effects of collisions	Bounded inquiry	Extend
1.6 Telescoping effect	Guided discovery / Interactive discussion	Extend
1.7 The trial	Open inquiry	Evaluate
2.1 Face recognition	Interactive demonstration	Engage
2.2 Ballpoint theft, cloths and glasses	Guided discovery	Evaluate
2.3 Awareness test and change blindness.	Open inquiry	Explore ->Extend
3.1 What is DNA?	Interactive discussion	Engage -> Explore
3.2 PCR technique	Guided discovery	Explore
3.3 Analyzing the DNA	Interactive discussion	Explain -> Evaluate
3.4 Identifying with the use of DNA	Open inquiry	Evaluate
4. Measuring on crime-scene pictures	Guided discovery	Engage, Explore, Explain

VII. *Assessment*

In the table below some ideas are given for assessment
For both subunits it is possible to take a questionnaire / knowledge test for the whole subunit.

Subunit 1

Activity	*Assessment*
1.1. How can fingerprints be categorized?	Poster presentation, log file or essay
1.2. Fingerprints as a way to identify persons.	
1.3 Take your own fingerprint.	
1.4 Take fingerprints from an object	Presentation, log file
1.5 Identify the criminal	Presentation (poster or powerpoint) All the activities on fingerprints can be assessed with a knowledge test.
2.1 Solve another crime.	Log file
2.2. Crime solving game.	Summary with screenshots from PC game.
3.1 Properties of human beings	Log file
3.2 Whodunit	Log file
3.3 Traces in the snow	Essay, presentation.
3.4 Can you use footprints to determine if a person was running or walking?	Essay, presentation.
3.5 Other indirect clues	Essay, presentation.

Activity	*Assessment*
1.1 Introduction movie	None
1.2 Historical Trials	Essay, knowledge test.
1.3 Modelling the ballpoint case	Essay, presentation (powerpoint, poster, video)
1.4 Calculations on the ballpoint case	Knowledge test with similar calculations.
1.5 Other effects of collisions	Presentation (powerpoint, poster, video)
1.6 Telescoping effect	Essay
1.7 The trial	Essay, log file.
2.1 Face recognition	Essay with screenshot from PC game.
2.2 Ballpoint theft, cloths and glasses	Log file.
2.3 Awareness test and change blindness.	Presentation (powerpoint, poster, video); log file of the process and planning.
3.1 What is DNA?	Essay, presentation.
3.2 PCR technique	Log file, essay.
3.3 Analyzing the DNA	Knowledge test with similar calculations.
3.4 Identifying with the use of DNA	Screenshot from PC game, essay or presentation.
4.1 Measuring on crime-scene pictures	Coach result file or short student report

WP3
Forensic Science

European Science and Technology in Action Building Links with Industry, Schools and Home

Work Package 3
Forensic Science

European Science and Technology in Action:
Building Links with Industry, Schools and Home

Lead partner for deliverable: **C.M.A.**

The ESTABLISH project has received funding form the European Community's Seventh Programme [FP7/2007-2013] under grant agreement n^{o} 244749
Start Date: 1st January 2010 Duration: 48 months

I. Student Learning Activities SUBUNIT 1

1.1 How can fingerprints be categorized?

Learning aims:

- Introduction to fingerprints.
- Develop a system to categorize fingerprints.
- Learn more about the different properties of fingerprints.
- Learn that an incomplete fingerprint is still very worthwhile evidence.

Materials:

- PC with internet connection:

http://www.trutv.com/shows/forensic_files/games/fingerprint/index.html

Screenshot from the fingerprint identification game.

Suggestions for use:

This introductory activity can be done without any pre-knowledge. In a playful and attractive way the students get introduced to the subject. However, it is more then just an appetizer, students have to reflect on the way they recognize the fingerprints. It might be that they discover some of he rules of the system to categorize fingerprints.

- Introduce the problem with the use of the fingerprint game.
- In the game, let students motivate why they choose the specific fingerprint.
- Let the students write down which properties of the fingerprint they use during the game.
- After playing the game, students do further research on how to categorize (and recognize) fingerprints.

Possible questions:

- Write down three properties that you might use to recognize (categorize) a fingerprint (see *http://www.fun-science-project-ideas.com/The-science-of-fingerprints.html* for a suggestion)
- After doing the research, play the game once more. Is it more easy now?

1.2 Finger prints as a way to identify persons

Learning aims:

- Building knowledge on finger prints
- Find out how unique fingerprints are
- The role of fingerprints in identifying a criminal

Materials:

- PC with internet connection, see these sources for example
  - http://www.cyberbee.com/whodunnit/fp.html
  - http://www.biometrics.gov/documents/fingerprintrec.pdf
  - http://www.exploreforensics.co.uk/Fingerprints.html
  - http://en.wikipedia.org/wiki/Fingerprint
  - http://onin.com/fp/fphistory.html
- Information in text files (print outs from some of the sources mentioned above)

- **Suggestions for use:**

In the previous activity, students were working more intuitive. In this part, they discover the theoretical framework behind the fingerprints. They discover how powerful fingerprints are in identifying criminals. The method chosen here is an essay, where a student writes a comment on a letter in a magazine or newspaper. The activity starts with a letter from a lawyer who argues that his client is wrongly accused on the basis of fingerprints. The students have to write an answer to this letter, defending the use of fingerprints.

- Students do literature review to gather knowledge on fingerprints.
- Let the students exchange the information they find to increase their knowledge on fingerprints.
- When internet is not available, the teacher can spread hard copies of the information.
- Based on the information they find, the students write an answer to the letter in the newspaper/magazine.
- The teacher can decide in which year the essay was written. It might be at the very beginning of the use of fingerprints, or in this time where one can imagine that technology is so sophisticated that fingerprints can be falsified.
- Be sure to focus on the scientific basis of the arguments.

Possible questions:

- How valuable (unique) are fingerprints in identify a criminal?
- Are fingerprints unique? Or do relatives have the same finger prints?
- When were finger prints used for the first time in solving a crime?
- How long and how can fingerprints be saved?
- Is it allowed to file a person's finger prints?

1.3 Take your own fingerprints

Learning aims:

- Ability to take own fingerprints (or in general fingerprints from a person).
- Learning about different methods to take fingerprints.
- Learning about which materials easily show fingerprints and which do not.

Materials:

- Pencil, paper, stamp pad.

Suggestions for use:

- Experiment in groups.
- See http://youtu.be/to6NYRgM184 or http://makefingerprintjewelry.com/tutorials/taking-fingerprints-easily-found-materials/
- As it is presented here, these experiments are rather straightforward. That is mainly to save time and to give the students a good example of how fingerprints work. Besides that, the fingerprints taken will be used to identify persons in a later part of the subunit.
- The next part (1.4) will give more freedom to the students.

In the picture on the right you see a screenshot from the youtube tutorial.

Possible questions:

- Discuss (and write down) which method to take fingerprints from a person you prefer. Explain why you prefer your method.
- Describe a way to file the fingerprints from the students in your classroom.

1.4 Take fingerprints from an object

Learning aims:

- Compare different methods to take fingerprints from an object

- Ability to decide which method serves the best for which circumstances

Materials:

- Magnifying glass, tape, cacao powder, hair brush, etc..

Suggestions for use:

- Students work in groups to decide which method is the best to collect fingerprints from objects.
- The objects examined might be: glasses, letters, door handle, knife.
- Students have to write a tutorial (manual) to take fingerprints from the suggested objects.
- They present their results in a poster presentation.

Setting to take fingerprints with the use of cacao and a brush. On the right a print taken with this method.

Possible questions:

- Which method serves the best for which object?
- Make a list of tools that are needed to take fingerprints from an object.

1.5 Identify the criminal

Learning aims:

- Ability to identify a criminal based on fingerprints found on objects.

Materials:

- Magnifying glass, pencil, transparent tape.

- Suggestions for use:

- Experiment in groups.
- See background material named in the student material.
- Depending on the students, the teacher can make a contest out of this: which team is the quickest to identify the criminal.

Possible questions:

- What might criminals do to avoid that they can be identified by fingerprints?

2.1 Other clues to solve a crime

Learning aims:

- Reflection on which other types of evidence there might be, besides fingerprints.
- Comparing pros and cons of different types of evidence.

Materials:

- Pen and paper

Suggestions for use:

- At first, students think for themselves which clues there might be.
- In a classroom discussion students exchange their clues and discuss which are the most valuable.
- How valuable a clue is, depends on the circumstances (if a crime takes place outside in muddy garden, it can be very useful to look for footprints).
- The teacher can emphasize that it is not possible that in a crime scene all the things are investigated, depending on the severity of the crime. It is a bit out of balance if the police will take fingerprints, footprints, DNA-profiles, etc. in case of a bicycle theft.
- Answers of the students (in the classroom discussion) might look like:

Clue	*Easy to collect and use?*	*Unique way to identify criminals?*
Fingerprints	**+ -**	**++**
Footprints (shoe size)	**+ -**	-
Footprints (profile)	**-**	**+**
DNA from blood	**-**	**++**

- Let the students give valid arguments to decide which five clues are the most powerful.

Possible questions:

- Students can make a flow chart or table, where the evidence to collect depends on the circumstances. Part of this table might look like this:

	Yes	**No**
Is it raining outside or is it muddy?	Look for footprints.	Do not look for footprints.
Was there a struggle on the crime scene?	Look for blood traces.	Do not look for blood traces.

2.2 Solving another crime

Learning aims:

- Matching the different types of evidence.
- Work systematically, write down results systematically.

Materials:

- PC with internet connection.
- Pen and paper.

Suggestions for use:

- Be sure that the students do not look at the results from one another; it is always the same person who kidnaps the bird.
- This can be done as homework as well.
- The different types of evidence each eliminate another suspect. When in doubt if the students were working serious on their activity, the teacher can check the table. See below for the different clues of the criminal as they match the different suspects.

	Karen	*Aileen*	*David*	*Sam*
Blood	*match*	*match*	*no match*	*no match*
Fibre	*match*	*match*	*match*	*match*
Footstep	*match*	*match*	*no match*	*match*
Fingerprint	*match*	*no match*	*match*	*match*

Possible questions:

Be sure to ask these questions before finishing the game (the part where the police visits the house of the suspect).

- How sure are you about your answer?
- If it is a set up, how could one of the other suspects falsify the clues?

3.1 Properties of human beings, properties of a suspect.

Learning aims:

- Develop a list with ten properties that can be used to identify a person.
- Compare the different properties; decide which properties are the most useful.
- Write down for each property how easy it is, as a criminal, to cheat on this property.

Materials:

- Pen and paper.

Suggestions for use:

- Start this as a classroom discussion.
- The first list with properties might look like this:

Property	**Easy to cheat on**
Mass	*No, however one can go in disguise to pretend to be a lot fatter than in reality.*
Length	*No, also difficult to pretend to be shorter or taller than in real life.*
Age	*No, however by going in disguise one can seem to be of a different age.*
Gender	*No, however by going in disguise a woman may look like a man and vice versa.*

- The second list, filled in for the students, might look like this.

Name	*Age (year)*	*Gender (M/F)*	*Length (m)*	*Mass (kg)*	*Eye color*
John	***16***	***M***	***178***	***75***	***Brown***
Susan	***17***	***F***	***164***	***58***	***Blue***
Omar	***16***	***M***	***168***	***79***	***Green***
Britt	***15***	***F***	***169***	***67***	***Green***
Holger	***17***	***M***	***183***	***79***	***Blue***

Possible questions:

- Which properties are the most distinctive in this class?

- How precise do you need to know certain properties?

For this specific case, all the suspects are part of the class and thus have similar age and background.

- Would the same list be useful for the police in general, when the group of suspects is more divers?
- Which properties (that are not important inside the group of students) might be important for general purposes, when the group of suspects is more divers?

3.2 Whodunit?

Learning aims:

- Decide on the basis of evidence who committed a crime.

Materials:

- List as it was filled in in the previous activity.

Suggestions for use:

- Make a contest to find the suspect with as few questions as possible. Make teams to compete with each other.
- Give penalty points if someone is falsely accused.

Possible questions:

- How sure are you when this list is used?
- How many students would be found guilty if one of the clues appears to be false (in other words: how many students match with all but one of the given clues).
- What properties might be investigated to be more sure that the suspect is the criminal indeed?

3.3 Traces in the snow (or in the mud)

Learning aims:

- Using a related clue to identify a criminal.
- Performing an experiment, work precisely.
- Register, analyze and present the results from your experiments.

Materials:

- Tape-measure, video or photo camera (optional).

Suggestions for use:

- Information on stride length is available for example at: http://walking.about.com/cs/pedometers/a/pedometerset.htm or http://moon.ouhsc.edu/dthompso/gait/knmatics/stride.htm
- With the use of video it is very easy to collect data for different persons.

Possible questions:

- What else can be deduced from a footprint?
- How useful (valuable) can this be in a legal process?
- Suppose you are a lawyer who defends a suspect. What arguments would you use to prohibit the use of footprints in a legal case?

3.4 Can you use footprints to determine if a person was running or walking?

Learning aims:

- Develop a scientific experiment.
- Use prior knowledge in a new setting.

Materials:

- To be decided by the students.

Suggestions for use:

- This is an open inquiry, the students have to take the initiative to develop their own experiment.
- Depending on the time available, the teacher can skip one of the activities 3.4 and 3.5. However, it is highly recommended to do at least one of these.
- In supporting the students, also give attention to the process (how to plan the experiment etc.).
- Check the experiment plans from the students before they can do their experiment.

3.5 Other indirect clues

Learning aims:

- Develop a scientific experiment.
- Use prior knowledge in a new setting.

Materials:

- To be decided by the students.

Suggestions for use:

- This is an open inquiry, the students have to take the initiative to develop their own experiment.
- Depending on the time available, the teacher can skip one of the activities 3.4 and 3.5. However, it is highly recommended to do at least one of these.
- In supporting the students, also give attention to the process (how to plan the experiment etc.).
- Check the experiment plans from the students before they can do their experiment.

STUDENT MATERIAL subunit 1

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Introduction
This module is about forensic science. In forensic science, a team of scientists does research on a crime scene to find information and evidence about the suspect and the victim. The forensic scientist is not a judge but he or she advices the judge on how likely it is that something has happened. The next lessons, you are going to work as a forensic scientist. You will do research on fingerprints, you will do research on other human properties and you will find out about footsteps. To start with, take a look at the fingerprints in the next item.

1.1 How can fingerprints be categorized?

In police files, fingerprints are complete but in a crime scene you rarely find a complete finger print. In this game you have to match an incomplete finger print with one of five complete prints from the police files.
You can find this fingerprint game here:
http://www.trutv.com/shows/forensic_files/games/fingerprint/index.html

- Play this game three times, write down for each trail how many attempts you needed to find a match.
- Write down for each attempt on the basis of which properties you decide that the fingerprint found on the crime scene matches that of one of the suspects.
- How many attempts do you need in total to find the three fingerprints?
- What is the record in your class?

You have used different properties of a fingerprint to match with the filed prints.

- Write down at least three properties of fingerprints that can be used to identify a specific fingerprint (for the specific game you have written down some properties in the second question of this activity).
- Discuss these properties with your fellow students and build a system to categorize fingerprints.
- Compare the categories from your system with information you can find on internet, see for example: http://www.fun-science-project-ideas.com/The-science-of-fingerprints.html

1.2 An essay in a magazine or newspaper

You are no working as a prosecutor. In a newspaper or magazine, you see a letter published, written by a lawyer. In this letter, the validity of fingerprints is marked as dubious. You are very engaged in this subject and you want to write a reply on this letter.

- Read the letter.
- Find information from different sources to have your arguments to reply to this letter.
- You can ask your teacher to help you collect different sources.
- Write an essay, giving a reaction on the letter. Focus on the use of fingerprints in general, you can decide for yourself if you also want to react on this specific case.
- Be sure to address all the arguments that the lawyer gives in his letter.

The letter as it was printed in the newspaper:

In two weeks time, the appeal will take place for the trial in the so called taxi-murder. In the original trial, a suspect was convicted only on the basis of fingerprints. There are no witnesses, there is no confession, there is no real evidence, there are only the so called fingerprints. The scientific basis for the use of fingerprints is very limited. Different people can have the same fingerprints, while collecting the fingerprints the police can make mistakes, in the time between crime and trial the fingerprints can change. As a whole, the use of fingerprints as basis for 'guilty' or 'not guilty' is very doubtful. However, the judge seems to be deaf for this argument. I hope that the judge responsible for the appeal will use his common sense. If not, a person that is not guilty will go in jail for a long time. That would be a big shame, not only for this judge but also for the whole legal system and every man and woman in this country.

Lou Tiger, Lawyer

1.3 Take your own fingerprints

Fingerprints can be found on objects at a crime scene. These prints have to be matched with the fingerprints from the suspect. In this part, you will take your own fingerprints. Everybody has heard of fingerprints and of course you have seen in television series how these prints were taken. However, you can not always believe things you see on you see on television.

- Discuss in your group what might be a proper method to take fingerprints from a person.

There are different ways to take your fingerprints. For this moment, we start with two methods that are not difficult to do with easily available material. We will do this in a step by step way.

1.3.1 Method 1: pencil dust

- Rub a small dark area with a pencil point on a sheet of white paper.
- Press and rub your right index finger in the pencil-lead dust.
- Place the sticky side of a piece of transparent tape on the dusted finger.
- Take the tape with the fingerprint and tape it to in the box below.
- Repeat this process for the thumb of your right hand.
- If you are not satisfied with one of the fingerprints, use the spare box to take another fingerprint. Be sure to write down which fingerprint this is.

The method above is demonstrated on youtube. You might want to watch it before taking the fingerprints.
http://www.youtube.com/watch?v=to6NYRgM184

Index finger right hand	Thumb right hand	Spare box: index finger right hand / thumb right hand

1.3.2. Method 2: inkpad

For the left hand, we are going to use a stamp pad (inkpad).

- Press your index finger of your left hand to an inkpad.
- Carefully press and roll your finger on a piece of white paper.
- Be careful to protect your clothes and not to slide your finger across the paper.
- If you are satisfied with the result, make a new print of your finger in the box below.
- Repeat this process for the thumb of your left hand.
- If you are not satisfied with one of the fingerprints, use the spare box to take another fingerprint. Be sure to write down which fingerprint this is.

Index finger left hand	Thumb left hand	Spare box: index finger left hand / thumb left hand

- Discuss which method to take fingerprints from a person you prefer.
- Explain what the pro's and cons are of these two methods.

1.4 Take fingerprints from an object.
At this stage you have some experience on fingerprints. However, there is one thing we have not discussed yet. That is the method to take fingerprints from an object. It is your task to do research on this and to find out what is the best way to do so. You have to describe the method you prefer in a manual for forensic scientist. There are several methods to take fingerprints from an object. These methods have a lot in common but differ in the materials used. Here we describe two methods.

- **Method 1: Cocoa powder**
  See: http://www.cyberbee.com/whodunnit/dusting.html

Dusting a Glass

1. When fingers are oily or sticky you get better fingerprints. So press an oily or sticky finger on the side of a drinking glass.
2. Coat the fingerprints with a dusting of cocoa powder.
3. Brush gently with either a camelhair or fiberglass brush. The fingerprints remain.
4. Place the sticky side of the tape on the dusted fingerprint. Lift on the tape and place on light colored construction paper.

Materials used are:
- Drinking glass
- Cocoa powder
- Brush: camelhair or fiberglass
- Transparent tape

Step 1
Press an oily or sticky finger on the side of a drinking glass.
Step 2
Coat the fingerprints with a dusting of cocoa powder
Step 3
Brush gently with either a camelhair or a fiberglass brush. The fingerprints remain.
Step 4
Place the sticky side of the tape on the dusted fingerprint. Lift the tape and place it on light colored construction paper.

- **Method 2: graphite powder (or pencil dust)**

See http://www.ehow.com/how_2096229_take-fingerprints.html

Materials used are:

- Pencil
- Knife
- Coin
- Feather of fine brush hair
- Transparent tape

Step 1
Look for objects that can potentially carry fingerprints. Fingerprints leave better impressions on smooth objects. These items hold the best prints: glass, painted surfaces, metal, linoleum, varnished woods and paper.

Step 2

Grind some graphite powder from a pencil. Using a knife, break the lead from a pencil into tiny pieces. Use a coin on a flat surface to grind the pieces into a fine powder.

Step 3

Sprinkle the powder onto your object. Lay the object on a flat table and gently coat the surface of the object with a fine layer of graphite powder.

Step 4

Reveal the fingerprint. Lightly dust the powder off the surface with a feather. The powder will stay attached to the oils from the suspect's skin, and a fingerprint should take shape. Be sure to dust very lightly, or you may dust away the fingerprint.

Step 5

Transfer the fingerprint. Holding a small strip of transparent tape at both ends, place the tape over the fingerprint. Press it down for a moment, then carefully pull the tape up from one end. The fingerprint will transfer onto the tape.

Step 6

Place the tape face down on an index card. Repeat the process for each fingerprint you can find on the object, and place them on the same card.

- Try out both methods to take fingerprints from an object
- Discuss which method you prefer, explain why
- Discuss which other materials might be used.
- Write a manual to take fingerprints form an object inspired by the methods described here and other sources you found.

1.5 Identify the criminal
For this part, you work in a group with four students. One of you will take a glass in her or his hand thus leaving a finger print. You give the glass to your teacher (make sure to leave no other marks) and the teacher will give the glass to another group. You will get another glass from the teacher with a finger print from a student form another group.

- Leave a clear finger print from one of your group on the glass given to your group
- Give this glass and the finger print files from every member of the group to your teacher

You will get a glass touched by someone from the other group and the finger print files from the members of this group.

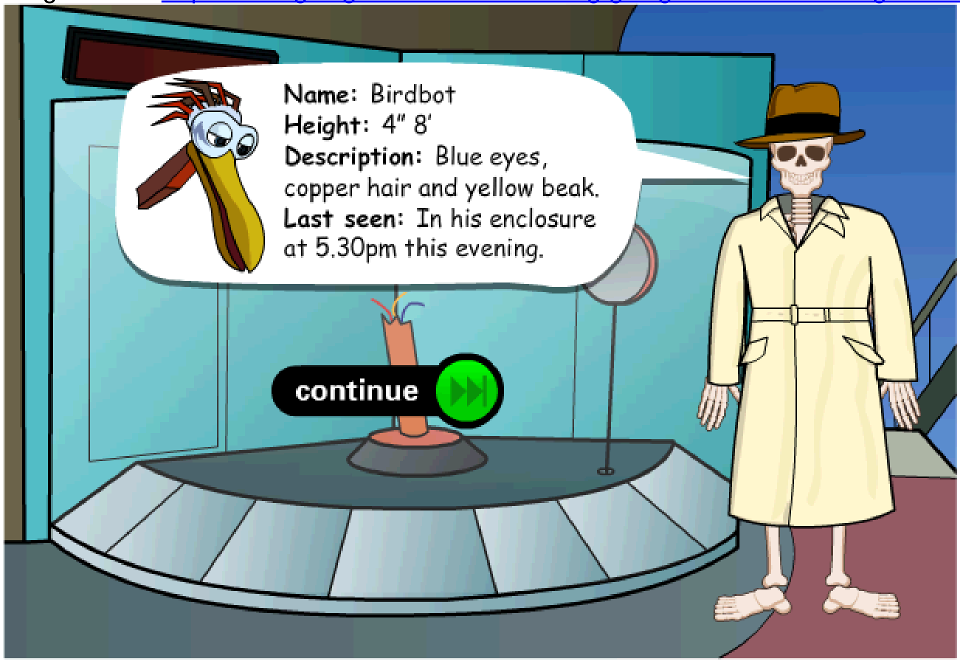
- Identify the person from the other group who touched the glass. Use your favorite method to take these fingerprints.
- Write a report on how you identified the criminal and how sure you are about your findings.

2.1 Solve another crime
In the former case, you only worked with finger prints. In many cases, there is also other information about the suspect available. When investigating a crime scene, police officers and forensic scientists have to check for as many types of evidence as possible.

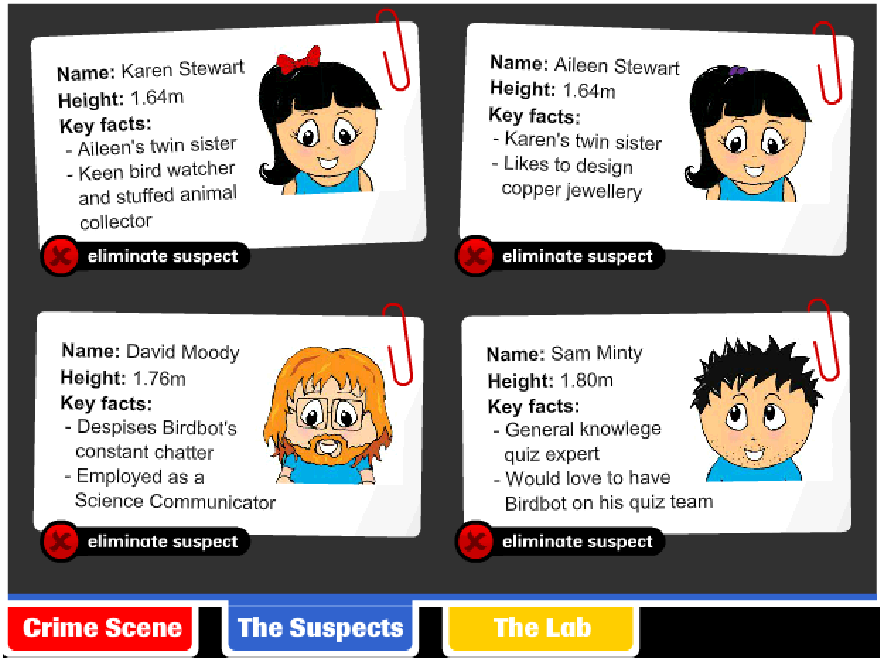
- Write down three other clues (besides fingerprints) that might be useful to solve a crime.
- Discuss this with your classmates which other clues there are, discuss how useful each clue might be. Are different clues easy to collect? How unique are the clues in identifying the criminal?
- Make a list (or table) of the clues and their pros and cons.
- Choose which five clues you would recommend to collect as a standard procedure in a crime scene.

2.2 Crime solving game
In the Glasgow Science Centre, the mascot Birdbot has been kidnapped. This is a serious crime that needs to be solved. Hopefully you can help to solve this crime. Play the game and find out if you are a good detective.

You can find this game on: http://www.glasgowsciencecentre.org/glasgowscienceinvestigation.aspx



Detective Bones at the crime scene, asking for your help.



The four suspects to this crime.

In the crime in this case, as in a lot of other crimes, you use elimination to find the criminal.

- Explain what is meant with elimination.

In the game, you find different types of evidence

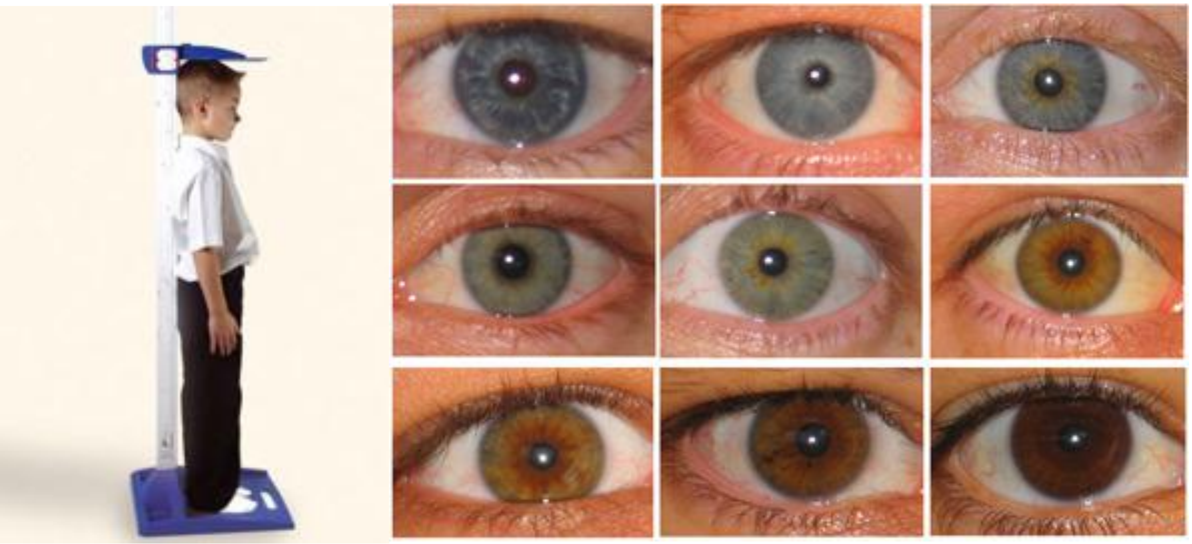
- The clues presented in this game, do they match the clues you advised in the previous activity? (write down which clues are used in this game that you yourself did not mentioned before)?

- Play the game and write down which clues eliminate which person.
- How long did it take you to solve the crime?
- Did everybody in the class accuse the same suspect?

3.1 Properties of human beings, properties of a suspect

In crime scenes, the traces and witnesses lead to a description of the suspect. The more details there are in a description, the higher the chance to find the criminal. A lot of descriptions start with simple and easily to recognize properties like length, gender and hair color. In this part we are going to measure and analyze a couple of properties from the students in your classroom. Some of these properties can be directly measured, other properties need to be deduced from other measurements (for instance step distance is related to the length of a person).

- Make a list of ten properties that can be easily be determined for the students in your class. For example: eye color, length, hair color, gender, weight, if you are left handed or right handed, shoe size, etcetera.
- Discuss how easy it is to change these properties as a person. That is: can a criminal disguise himself by changing this property.
- Make a table of these properties and fill in the data for each student in the group.



- Now it should be possible to answer the following questions:
    - How many male students do you have in your class?
    - What are the chances that a student from your class has brown eyes?
    - How many students are longer than 1.65 m?
    - How many students are shorter than 1.55 m?

3.2 Whodunit?

With the list of all the properties of the students you can take one person in mind. Then another student then has to ask straightforward questions to find out who you have in mind. The goal is to be sure who it is by asking only a few questions. Ascertain that you have all properties correct.

- Identify the selected person with as few questions as possible.
- Make sure to use only objectively verifiable questions.

- Possible questions are the ones that have a definitive and objective answer, answers that are independent of whom you ask it.
  - Is it a boy or a girl?
  - What is the color of his/her eyes?
  - The length of the person, is it between 1.50 m and 1.65 m?

- Questions that are not suited for this case:
  - Do you like the person you have in mind?
  - Is he or she tall?

3.3 Traces in the snow or mud.
Besides primary properties that can be directly measured there are also related clues hat follow from these properties. For instance when a student has a length of 1.50 m, it seems impossible that he or she can reach a shelf that is 2.10 m high (without help). Whereas a student with a length of 1.90 m should be able to reach this (stretching the arm).
Another example is the distance between your footprints. It seems reasonable to expect that the footprints of a taller person are farther apart than those of a smaller person. So the distance between the footprints can give a clue about the length of a suspect. It might as well be possible to decide, based on the footprints, if a person was running or walking.

- Without doing any research or searching in literature, what do you think is the distance between two steps for a person with a length of 1.75 m?
- Measure the distance you cover when you walk normally a few steps (for instance ten meter).
- Calculate the distance you cover with one step. Explain how you did it.
- Put the results for the whole class in a diagram. Show step distance as a function of the body length. Make two different graphs, one for the boys and one for the girls.
- Find out in literature what is known about this so called 'stride length'
- Discuss the results of your measurement and the literature research. Do they match?

On a crime scene, footprints in the mud (or in the snow) are 70 cm apart from each other. These traces are from the same shoe and they seem to belong to the suspect.

- What might be the length of the suspect (give a reasonable estimation)?

3.4 Can you use the footprints to determine if a person was running or walking?

- Find out if there is a difference in the footprints if a person is running or walking.
- Is there a difference in the step distance?
- Is there a difference in the type of the footprint?
- Make a presentation (poster, powerpoint, movie or a combination) to present your conclusions.

3.5 Other indirect clues.
As the step distance is related to the length of a person, there are other clues that can be deduced from properties of a suspect.

- Name as many deduced clues as possible in a classroom discussion.

- Make your choice:
  - Choose one of these deduced clues and write a manual to use this clue in solving a crime.
  - Choose one of these clues and write a crime story where the clue is used to solve the crime.

II. Student Learning Activities SUBUNIT 2

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1.1 *Introduction movie*

Learning aims:

- To give an overview of this activity
- To prepare the students for activity 2.2

Materials:

- PC with internet, projector

Suggestions for use:

- Be sure that all students see this movie, it is crucial for activity 2.2

Possible questions:

- Ask the students after seeing this video if they did see something strange on the video.
- If so, what did they see?

1.2 *Write an article in the series 'Historical trials'*

Learning aims:

- Gather information on the ballpoint case.
- Judge which information is most important.
- Write the information in own words.

Materials:

- PC with internet connection
- Different articles in hardcopy (made available by the teacher)

Suggestions for use:

- Though it is more time consuming, students might as well make a documentary on this subject, using the video camera en editing tools.
- Students can write down some questions they have about this case (questions that can not be answered with the information they have found so far).

Possible questions:

- Design your own cover of a magazine with information on the ballpoint case

1.3 Modeling the Ballpoint case

Learning aims:

- Using experiments to see if both mentioned scenarios are possible: scenario 1: accident: the victim falls in the pen; scenario 2: murder: a pen is shot into the victim.
- Use creativity to model this case.
- Find out that here are limits to a model.

Materials:

- Ballpoint, materials to simulate a head (fruit, clay, cotton cushion, ….)
- Stand material
- Optional video camera (preferably with high-speed possibilities)
- Program Coach (optional)

Suggestions for use:

- Students have to simulate both scenarios (accident and murder) by means of an experiment and have to discuss which of these scenarios is possible. In two experiments it can be made clear what the impact of the pen is: in the accident scenario the students let the object fall on the pen, in the murder scenario they let the pen fall on the object. They investigate the differences.
- Be aware of the differences and the similarities between experiment and the ballpoint case.

Possible questions:

- Students take the role of the CSI-investigator. There job is to argue which of the scenarios is most likely.
- Discuss which materials are suitable to model the head of the victim. Make sure to address both the practical use and the ethical aspects and physical properties of the head.

1.4 Calculations on the modeling of the ballpoint case.

Learning aims:

- Students use calculations to be able to decide better which of the scenarios are possible.

Materials:

- Pen, paper, calculator
- Program Coach (optional)

Suggestions for use:

- Introduce the physics concepts necessary for this calculation in a classroom discussion.
- In order to prepare the students for the next activity, focus on inertia.
- The first part of this activity is a rather ‘closed’ activity to make sure that all the students are at the same level.
- In the second part the students have to discuss the probability of both the scenarios. They have to compare the results from different experiments with each other.
- Let the students discuss how valuable, objective and discerning their results are.

Example of a calculation:

Pen dropping on a mandarin

- The height from which the pen starts is 100 cm, the mass of the pen is 11 g, the pen penetrates the mandarin for 0,5 cm. Calculate the force between pen and mandarin during the collision.
    - First put all the data in SI-units: h = 1.00 m ; m = 0.011 kg ; d = 0.005 m
    - The speed that the pen has when making first contact with the mandarin (we neglect friction) can be derived from: $E = mgh = ½ m v^2$
    - $v^2 = 2 * g * h = 2 * 9.8 * 1 = 19.6 (m/s)^2$
    - v = 4.4 m / s
    - The starting velocity is v = 4.4 m / s, the stopping distance is 0.005 m. We use W = F * s for the work done, this work is equal to the kinetic energy of the ballpoint at the beginning of the collision.
    - $Ek = ½ m * v^2 = 0.5 * 0.011 * 19.6 = 0.108$ J
    - F = W / s = 0.108 / 0.005 = 21.6 N

Mandarin dropping on a pen

- We now take a mandarin (100 g) and assume that the force between mandarin and pen is a constant 21.6 N. We then calculate how far the pen would penetrate the mandarin when the mandarin would drop from a height of 1.00 m.

- The starting velocity is $v = 4.4$ m / s (as follows from the previous calculation), the force is 21.6 N. We use $W = F * s$ to calculate the stopping distance.
- The kinetic energy of the mandarin is $Ek = ½ m * v^2 = 0.5 * 0.100 * 19.6 = 0.98$ J
- The stopping distance s is $s = W / F = 0.98 / 21.6 = 0.045$ m

Possible questions:

- Calculations with other data (height, weight).
- Derive a general formula for two objects (with masses m_1 and m_2) falling from the same height, to calculate the penetration distance s.
  - Using the same steps as in the former calculation, we find
    $m_1 * g * h_1 = F * s_1$ and for the other case $m_2 * g * h_2 = F * s_2$

    We can write $F = (m_1 * g * h_1) / s_1$
    and thus find: $m_2 * g * h_2 = \{(m_1 * g * h_1) / s_1 \}* s_2$

    In this specific question $h_1 = h_2$ and g is also the same in both cases. This means:

    $m_2 = \{ m_1 / s_1 \}* s_2$ and this can be written as: $m_2 / s_2 = m_1 / s_1$ or $m_1 * s_2 = m_2 * s_1$

- Derive a general formula for two objects (with equal masses) colliding with different velocities, to calculate the penetration distance s.
  - This time we calculate the kinetic energy, this is equal to the work done while stopping the object. $½ m v^2 = F * s$
  - $½ m_1 v_1^2 = F * s_1$ and $½ m_2 v_2^2 = F * s_2$
  - Since F is equal for both cases, we find: $½ m_1 v_1^2 / s_1 = ½ m_2 v_2^2 / s_2$
  - For equal objects ($m_1 = m_2$) we then find:
    $v_1^2 / s_1 = v_2^2 / s_2$

1.5 Other effects of collisions

Learning aims:

- Further experiments to find out which of both scenarios is most likely
- Reflecting on the students' knowledge of physics to apply to this case.

Materials:
• To be decided by the students.
Suggestions for use:
• Classroom discussion as introduction to the subject. • Emphasize that further research is needed when the research thus far is not sufficient to draw a definitive conclusion. • Address the fact that there are still doubts in this case, sometimes this is inevitable. • Which other effects might occur in this case? How can this be demonstrated? • If it is difficult for the students to plan the experiments, activity 1.6 might be done first, followed by activity 1.5 . In that case it is a more guided inquiry: find an experiment that demonstrates the telescoping effect.
Possible questions:
• Are there other facts that might be investigated further?

1.6 Telescoping effect
Learning aims:
• Further literature research on the case to find out which of both scenarios is most likely.
Materials:
• Article: Cause celebre – Ballpoint Murder', see http://library-resources.cqu.edu.au/JFS/PDF/vol_45/iss_5/JFS4551144.pdf……
Suggestions for use:
• Give the students (part of) the article 'Cause celebre – Ballpoint Murder' and pay special attention to the telescoping (page 2, paragraph 'results'). • Depending on the results of activity 1.5 students might come up with the telescoping effect themselves. In that case the teacher can start a classroom discussion and the students can discuss what will have to be investigated by the forensic scientist.
Possible questions:
• Can you make a better decision now if the suspect is guilty? Discuss why or why not.

1.7 The trial
Learning aims:
• Come to a verdict: is the suspect guilty or not guilty?

Materials:

- Presentation tools (this activity is a classroom discussion based on the facts and the information available).

Suggestions for use:

- Make three groups (not necessary the same size):
  - Judge and jury (independent)

    This group will organize the trial, and will give the verdict about the suspect
  - Group that argues that the suspect is guilty

    This group will look in literature and forensic research for evidence to accuse the suspect. They prepare their part of the trial and give a plea where they will plead guilty for the suspect.
  - Group that argues that the suspect is not guilty

    This group will look in literature and forensic research for evidence to clear the suspect. They prepare their part of the trial and give a plea where they will plead not guilty for the suspect.
- Leave the rest as open as possible, let the students from group one decide how the trial is organized.
- Make sure that the physics used in the arguments of the students is correct.

Possible questions:

- Decide with the group if the suspect is guilty or not.
- How sure are you about your verdict?

2.1 Face recognition

Learning aims:

- Knowledge on face recognition.
- Reflection on reliability of witnesses.

Materials:

- PC with internet connection, website http://www.bbc.co.uk/science/humanbody/sleep/tmt/instructions_1.shtml
- Pen and paper.

Suggestions for use:

In this game there are twelve pictures shown to the user. In a second round another twelve pictures are shown. After these two rounds, users see another series of pictures. They have to declare for each picture in this series if they have seen the picture before, and if so in which round. It seems that the game has an archive of about fifty pictures to choose from, each round there are randomly chosen some pictures from this archive.

- Make a contest of this.
- Make sure that the students take their rest between each round of the game.
- Let each student make a screen capture of the results.

Possible questions:

- Is it possible to find differences depending on gender? For instance, do male students recognize other males better than females (or the other way around)?
- How sure are you about your answers?
- Make for each picture that is used in the game a data sheet: how often was this picture used, how often was it recognized?

2.2 Ballpoint theft - With clothes and glasses

Learning aims:

- Reflection on reliability of witnesses.
- Reflection on your own reliability.

Materials:

- PC with internet connection, projector.

Suggestions for use:

- Individual students can be mixed in groups to try to match and discuss their answers.
- Teacher can choose some students and instruct them to give (on purpose) false information in a very convincing way. This will influence the other students.
- In a classroom discussion the value of eye witnesses as part of the evidence might be discussed.

Possible questions:

- Further research on the way witnesses can be influenced during a trial. See for example ***https://www.ncjrs.gov/nij/eyewitness/procedures_intrv.html***
- Further research on how witnesses (and suspects) may be questioned when they give a statement.

2.3 Awareness test, change blindness

Learning aims:

- Applying the new knowledge in a case study.

Materials:

- Video camera, photo camera.
- Further to be decided by students.

Suggestions for use:
• Open inquiry
Possible questions:
• What would you change if you could do this experiment again? • What other experiments could you do to treat change blindness?

3.1 DNA
Learning aims:
• Gathering basic information on DNA • Be able to find out which information is the most valuable • Write down the information in your own words.
Materials:
• PC with internet connection. • See for information http://www.ipn.uni-kiel.de/eibe/ENGLISH/U2.HTM (also available in German and Danish) • Teacher can take care of hardcopies of the information by EIBE (see previous bullet).
Suggestions for use:
•
Possible questions:
•

3.2 PCR technique
Learning aims:
• Gather information on PCR technique. • Compare and evaluate information from different sources. • Discuss information with other students.
Materials:
• PC with internet connection. • Text files (see sources).
Suggestions for use:
• In this activity a specific method is being used to divide the work between different groups of students. The steps of this method are described here: ○ At the first step, students work on different sources individually.

- In the second step, students exchange information and discuss this with fellow students who have studied the same source. Each student then will become an expert in this particular source. Students write down their own questions about the PCR-technique, these might be questions that can be found in their source but also questions they have themselves.
- In the last step, the student mix again and now exchange information with the experts from the other sources. In the group, the questions of the individual students have to be answered.

This method is highly recommended but of course the teacher can decide to use another method.

- The teacher divides the students in several groups and gives each student the proper sources. Each group (A, B and C) has to study two sources: a text file and a animation on youtube. The sources are as stated below:
  - Group A
    http://www.ipn.uni-kiel.de/eibe/UNIT02EN.PDF (page 16 and 17)
    http://youtu.be/2KoLnIwoZKU
  - Group B
    http://en.wikipedia.org/wiki/Polymerase_chain_reaction
    http://youtu.be/JRAA4C2OPwg
  - Group C
    http://www.dnalc.org/resources/animations/pcr.html
    http://youtu.be/vmlLj1aLZ7s

  Another source, only available in Dutch is http://www.bioplek.org/animaties/moleculaire_genetica/PCR.html (for those who speak Dutch)

3.3 Analyzing the DNA

Learning aims:

- Applying information on DNA to find out if a suspect is guilty or not guilty.

Materials:

- Pen and paper.

Suggestions for use:

- Students have to answer some questions on DNA profiles.
- Evaluate this in a classroom discussion, use this to check if the information so far is

clear to the students.

- Give extra information for those students who do not master the topic so far.

Example of an answer:

- The frequency of feature 19 on locus D18S51 is 0.039. This means that from 100 persons, 3.9 will have this specific property.
- The sum of all the possibilities has to be 1.0 (or 100%).
- For the individual properties, the probability is
  p = 0.067 (VWA 14)
  p = 0.141 (D18S51 17) and
  p = 0.011 (D21S11 32)

  This means the probability of this mix is 0.067 * 0.141 * 0.011 = 0.000104
  (that is 0.0104 %)

Possible questions:

- Students can make similar questions (with answers) based on the profiles given to them.

3.4 Identifying with use of DNA

Learning aims:

- Apply knowledge on DNA in solving a case (game and real life).
- Develop an own DNA-profiling experiment.

Materials:

- PC with internet connection.
- Online game: http://www.biotechnologyonline.gov.au/popups/int_dnaprofiling.html
- Up to the students to decide.

Suggestions for use:

The game is a good method to check if the students have enough knowledge on DNA and if they are able to apply this. A weak point in this game is that they can click what they want without knowing anything. The teacher has to be aware that students can clarify why they click on certain choices.

The DNA experiment in real life is a difficult part. It would be very interesting for students to do their own DNA-experiment. However, proper DNA-kits are very expensive. These DNA-kits cost € 20.000,- or more. There are some affordable (but still not cheap) alternatives but these are not reliable. In many countries however, there are institutions that promote DNA research and it is often possible to hire or rent a DNA kit here. Another possibility is to contact these partners for an excursion. It is up to the teacher to do research in the own region to contact these institutions. When the materials are available, the students can do their own experiments.

- Open inquiry.
- Depending on the available materials, students can perform their own experiment.
- Find connections to industry, this topic is very suitable for an excursion.

Possible questions:

- Do research on the historical use of DNA profiling.

4 Measuring on crime-scene pictures

Learning aims:

- Understand why crime scene photography is so important in forensic science.
- Do accurate distance measurements on a picture, even when taken from a point of view
- Learn about perspective deformation
- Use different methods to correct for perspective distortion

Materials:

- PC with the program Coach or pen and paper for the first part if Coach is not available.

Suggestions for use:

- In this part, the students work individually or in pairs first on the introduction, then on two or three Coach activities for measurements of distances between objects on a few pictures of crime scenes. They learn why it is so important that there are pictures available of crime scenes, and how perspective distortion in the pictures can be overcome such that accurate distance measurements between objects on the picture is possible.
  The first activity offers instructions how to do perspective correction and come to correct scaling in the software. In the second and third activities the students have to perform the measurement (and perspective correction) on their own. These activities have some assignments. In the third activity students are asked to find some features of the suspect. From the stride length, an estimate can be made of the suspects length, using the same website as activity 3.3 of Subunit 1. Moreover the footsteps on the picture are rotated to the inside, which may be an indication that the suspect suffers from knock-knees (which happens more in adult women than in men).
- Reasons for photography of a crime scene are a.o.:
  - the crime scene cannot stay as it is e.g. when it is in a public place. Then pictures are the only way to retain images of it.
  - By walking in the scene evidence may be destroyed
  - The pictures can be used for future reference
  - The pictures give an unprejudiced image of the scene
  - for evidence a picture may be used to do measurements of distances between objects.
- Students may come up with the fact that nowadays digital pictures are easy to manipulate. So it is important that they are not manipulated. If this comes up, you can

let students look for clues of digital manipulation of the three pictures used in this part. Are the pictures original to their opinion?
Possible questions:
• Questions are in the student material and in the Coach activities. • How can the police or forensic scientist make sure that the pictures are not manipulated?

Student material

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1. The ballpoint case

1.1 Introduction movie

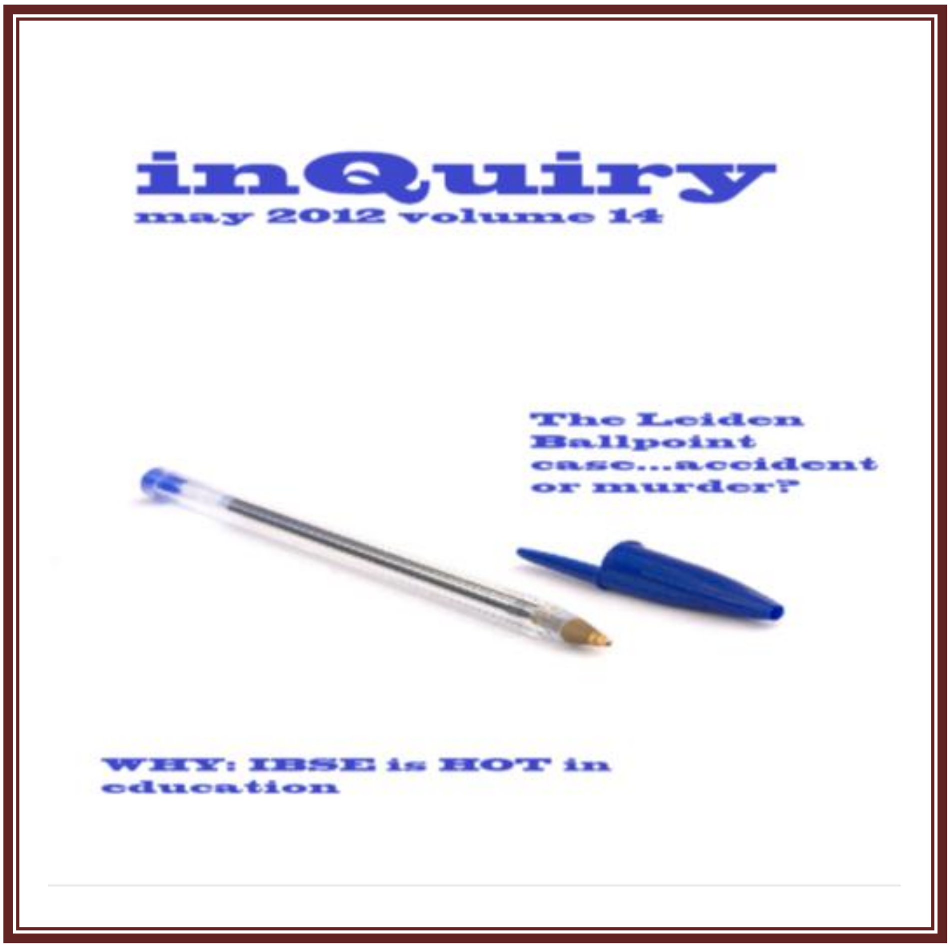
Watch the movie that introduces this module. It contains crucial information for this module.

- See http://youtu.be/VOgyHjMBSOA

In 1991 in the Netherlands, a woman died because of injuries caused by a pen that was in her head. The police investigated this case and there were two possible scenario's. The first scenario is that it was an accident. The woman had a pen in her hand and then dropped, thus falling with her head on the pen. The second scenario is that the pen was shot with the use of a crossbow, thus hitting the woman in the eye. In this case it was no accident but murder.

We are going to discuss these two scenarios from the point of view of a forensic scientist. As a forensic scientist we do scientific research to analyze the available evidence. Based on this, we make a statement about the probability of the two scenarios. We start by doing some literature research and then perform some experiments.

1.2 Write an article in the fictitious series 'Historical Trials'
Imagine you are a reporter working for a monthly magazine. In the series 'Historical Trials' you are going to write an article about the ballpoint case. You have to find information first and then write an article describing all the aspects of the case.



- Find information on internet about this case. Search with words like 'Leiden ballpoint case' or 'ballpoint murder'.
- Write down in your own words, based on the information found, what has happened.

1.3 Modeling the ballpoint case
There are two possible scenarios for the ballpoint case: it can be an unfortunate fall of the victim with her eye exactly on the pen she held in her hand or the victim could have been murdered by someone who fired a pen with a crossbow. It is up to you to find as much as possible evidence to be able to advice the judge if these scenarios are possible or not. The

first task is to set up two different experiments that can simulate these scenarios. Of course you can not do this experiment with real human beings so you have two think of alternatives. Which objects or materials will give reliable results?

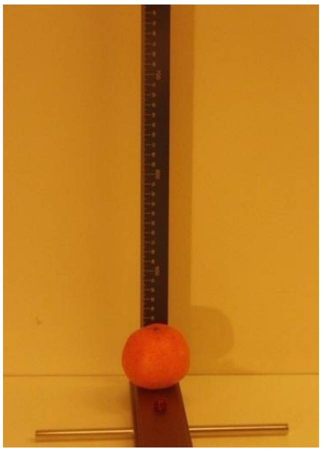
- Set up two experiments to model both scenarios. You can choose the materials that you want. Be sure to use materials that are easily available. Keep in mind what is moving and what is stable in both scenarios. While preparing, doing and discussing the experiment, think about the following points:
    - Which materials are suitable to use?
    - What are the similarities and what are the differences between model and reality?
- Discuss this with your group, discuss also with your teacher
- Perform these experiments and report about your experiment. Be sure to address the questions stated above and also pay attention to the following questions:
    - What are the outcomes of the experiment?
    - Is it possible that someone dies because of an accident with a ballpoint?
    - Is it possible that someone dies because he (or she) gets shot with a crossbow?
    - Where possible, support your findings with quantitative data.

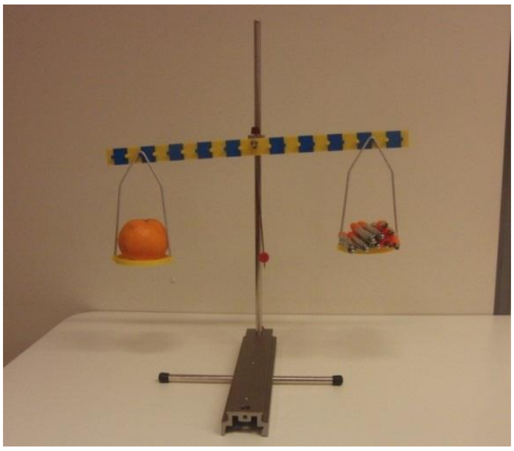
1.4 Calculations on the ballpoint case

In the former activity, a lot of experiments were possible to simulate the ballpoint case.

One way to simulate this is to use mandarins and pens. In this activity we discuss the results of an experiment with these items.

- What are the similarities and what are the differences between model and reality in this experiment?
- What are the similarities and what are the differences between your model (previous activity) and this mandarin model?





A mandarin weighs just about as much as nine pens. In a certain attempt of this experiment, a student drops a mandarin from exactly 100 cm on the pen and finds out that the pen penetrates the mandarin for 5.0 cm.

- Calculate the speed that the mandarin had just before making contact with the pen.
- Calculate the average force between mandarin and ballpoint in this collision.

To simulate the murder scenario the experiment can be done the other way around: let a ballpoint collide with the mandarin. You are going to calculate which speed the ballpoint needs to penetrate the mandarinCalculate the speed that a ballpoint would need to penetrate the mandarin for 5.0 cm.

- What can you say about this speed? Is it possible to obtain this speed with a crossbow?

You can see some attempts of this experiment, filmed at different framerates at http://youtu.be/ANc14s6OUT4

You can use basic mechanics to make these calculations. If necessary, check your physics book for the theory or take a look at one of the following sources on the hyperphysics website:
http://hyperphysics.phy-astr.gsu.edu/hbase/flobj.html#c2
http://hyperphysics.phy-astr.gsu.edu/hbase/work.html#wepr

You now have done some experiments and calculations to model the ballpoint case. You can say more about the possibillities for both scenario's.

- In case of scenario 1 (an accident), estimate the speed that the head would have when falling on the pen.

- Based on the former step, calculate what the speed of the pen should be in scenario 2 (murder with a crossbow). How fast would the pen have to move to cause the same damage.

- Make clear in your calculations which data you use, are this measured data or estimations? Assume that the head behaves like the mandarin and make sure to use the mass of the head in your calculations.

- Discuss with your fellow students (and report about this) if
    - The accident scenario of the person dropping on the pan (scenario 1) is possible at all.
    - The murder scenario of the pen fired by a crossbow (scenario 2) is possible at all.
    - How likely it is for each of the scenarios to happen.

1.5 Other effects of collisions

The shot of the crossbow and the penetration of the head may have effects on the ballpoint. The two pictures below give examples of an effect that is meant here.


- Describe what you see in these pictures.
- Explain the physics behind these pictures, this phenomenon is called ‘inertia’.
- Discuss what the inertia effects in the ballpoint case might be.
- Give some examples of circumstances where you experienced the effect of inertia yourself.

1.6 Telescoping effect

- Find in literature about the ballpoint case what is stated about inertia in the ballpoint case.
- See http://library-resources.cqu.edu.au/JFS/PDF/vol_45/iss_5/JFS4551144.pdf (pay special attention to the paragraph 'results')
- Set up and perform an experiment where you explain what the telescoping effect is. You have to demonstrate the effect itself, you are not obliged to use a balllpoint in this experiment.
- Present your experiment to your fellow students (use video, ppt, poster, liver experiment, etc.).
- Explain if this 'telescoping' is an argument for the suspect to be guilty or not guilty.

1.7 The trial

You have now gathered enough information to set up a trial in the classroom. There are three groups (not necessary the same size) with each a specific task.

- Group A: Judge and jury (independent)

  This group will organize the trial, and will give the verdict about the suspect. The rules for the trial will be set by this group.

  During the process, members of this group have to ask B and C to explain their arguments.

- Group B: Accusers.

  This is the group that argues that the suspect is guilty

  This group will find arguments to convict the suspect. They prepare their part of the trial and give a plea where they will plead guilty for the suspect.

- Group C: Defenders.

  This group argues that the suspect is not guilty

  This group will find arguments to clear the suspect. They prepare their part of the trial and give a plea where they will plead not guilty for the suspect.

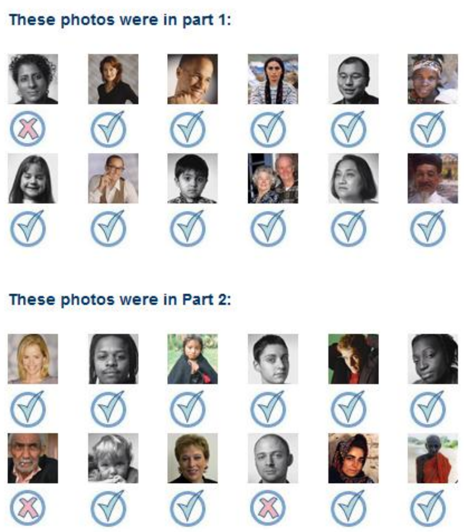
The groups B and C will give their pleas in the process, according to the rules set by group A. Then group A will decide if the suspect is guilty or not.

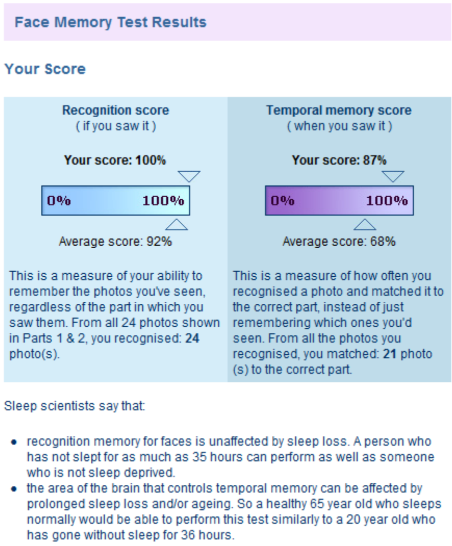
- Is the suspect guilty or not?

2.1 Face recognition

In this part of the series, we are going to look at faces. We start with a introductory game, where you can test how good you can remember faces.

- Visit http://www.bbc.co.uk/science/humanbody/sleep/tmt/ and play the game (be sure to take the breaks between the different rounds of this game)





Answers and score from the BBC face recognition game

- Write down your score and make a screenshot from your results.
- Compare your results with these of your classmates.
- How do the results in class relate to the average scores given by the game itself?
- Discuss in class these results, which factors influence your memory? Which faces are easy to recognize?

2.2.1 Look back at the introduction movie

As introduction to this module, you saw a movie where one of the authors of this module told you something about forensics and about the experiments in this module. This movie was also meant to test your reliability as a witness. To start with, we would like you to answer the following questions:

- Did you notice anything strange about the cloths of the presenter?
- Did you notice any other remarkable things happening (besides the experiment)?

2.2.2 Ballpoint theft

Without being aware of it, you were witness of a crime in the video in the previous lesson. It turns out that at CMA, a lot of ballpoints disappear. It is almost certain that it is an inside job. One of the people you saw on the movie is the suspect. Can you identify who was the one that steals ballpoints?
Here are four pictures from the suspects, one of them is almost certainly the thief of the ballpoints. Take note that the cloths worn might differ from that in the movie.

A

B

C

D

- Identify the ballpoint thief.
- How sure are you about your answer?
- Describe what you remember about the theft in the video (make a statement as a witness).
- Make a table of the persons above, how often was each of them accused?

2.2.3 Which clothes and glasses?

All the four suspects played a role in the movie. Here below you see them once again, wearing different clothes and with or without glasses. Can you tell which clothes they wore in the movie?

- Write down the character (A1,A2, B3, etc.) of the picture where the different person wear exactly the same clothes and glasses as in the video.


A1

A2

A3

A4

B1

B2

B3

B4

C1

C2

C3

C4

D1

D2

D3

D4

2.3 Awareness tests and change blindness

As you have seen in the previous activity, you are not always aware of things happening until you are warned to pay special attention to it. In this activity we give to other examples of what might be called 'change blindness'. There are some classical experiments on this subject. First you look at both these examples and answer some questions about it. Then it is up to you to make your own version of one of the given experiments.

2.3.1. Roadmap experiment

http://youtu.be/4-HxtKgKrL8



- Watch this movie from beginning to at least the first 1.5 minutes (it is allowed to watch this movie longer but to answer these questions it is enough if you stop at t = 1 m 30 s).
- Describe what is happening here.
- For this setting, estimate the percentage of people that would not know the change.

2.3.2. Murder case

http://youtu.be/ubNF9QNEQLA

- Watch this movie from beginning to t = 55 s. Please stop the movie at this point and answer the next questions

- Did you notice anything strange in this movie?

Depending on the answers to the question above, you might want to take a second look at the first 55 seconds of this movie.

- Make a list of all the changes you see.
- Discuss your answers and complete the list with your classmates.
- Check your list, watching the second part of the movie.

2.3.3. Your own experiment

Based on the examples from both the video clips, you know can make our own experiment. Choose one of the activities below:

- Write an essay about one of the experiments in the videos. Explain what is happening, give scientific information on the classical experiment the movie is related to, give historical information on this classical experiment.
- Make your own copy of this experiment, try to give it your personal flavor. Present your experiment (it is up to you what to do: a quiz for your fellow students, a movie of people in the street, a website with a test, etc.).

3. DNA profiling

Nowadays, DNA plays a very powerful role in forensics. The use of DNA in crime scene investigations has grown rapidly over the past years. What exactly is DNA and how is it used in forensics?

3.1 What is DNA?

There are a lot of sources on DNA to find on the internet. An important source for information is a guide developed by the European Initiative for Biotechnology Education. Your teacher can give you (part of) the guide that this organization has developed. You can also download it yourself at
http://www.ipn.uni-kiel.de/eibe/UNIT02EN.PDF

- Find in literature (the given source but also other sources) information about DNA
- Write an essay (400 – 500 words)on this. Be sure to address the following questions:
    - What are short tandem repeats?
    - What is a 'locus'?
    - How can DNA be damaged?
    - How can DNA be multiplied?

3.2 PCR technique

When DNA is found on a crime scene, it has to be copied a lot of times before you have enough to do research on. The technique used to copy DNA is called 'polymerase chain reaction' or in short PCR. There is a lot of information on PCR available.

In the list below you find different sources on PCR. Different students from your class each study two different sources and afterwards exchange information. Your teacher will tell you what sources you need to study. The sources we want to use here are (as you can see all these sources consist of a text and an animation on youtube):

A http://www.ipn.uni-kiel.de/eibe/UNIT02EN.PDF (page 16 and further) and http://youtu.be/2KoLnIwoZKU

B http://en.wikipedia.org/wiki/Polymerase_chain_reaction and http://youtu.be/JRAA4C2OPwg

C http://www.dnalc.org/resources/animations/pcr.html and http://youtu.be/vmlLj1aLZ7s

- Study the sources the teacher tells you to, write down a brief description of the main concepts involved in PCR.
- Discuss your findings with your fellow students who studied the same source.
    - Write with this group a summary on how PCR works.
    - Write down with this group three questions about PCR (these might be questions that can be found in your source but also questions you still have yourself).

Now you mix with other students who studied another source (and who discussed this source in a team).

- With your new group, discuss and answer the questions you had.
- Improve your summary that you wrote in the first part.

- By now, you should be able to answer the following questions.
    - Make a list of the equipment and sources you need to do a PCR.
    - Name two reasons why you have to use the PCR technique to make a DNA profile.
    - In a certain case, starting with the source DNA, it takes twenty minutes to make a copy. Calculate how long it will take before you have 1000 copies.

3.3 Analyzing the DNA

For each DNA feature the frequency to occur is known. When several features are combined, it is easy to calculate the frequency of this specific combination. In the next table, we see some features with frequencies for inhabitants of the Netherlands.

VWA	frequency	D16S539	frequency	D18S51	frequency	D19S433	frequency	D21S11	frequency
11	0,000	8	0,015	9	0,000	9	0,000	27	0,017
13	0,000	9	0,123	10	0,011	10	0,002	28	0,180
14	0,067	10	0,067	11	0,006	11	0,004	29	0,223
15	0,076	11	0,340	12	0,134	12	0,061	29.2	0,000
16	0,203	12	0,279	13	0,108	12.2	0,000	30	0,271
17	0,303	13	0,162	14	0,182	13	0,255	30.2	0,030
18	0,223	13.3	0,000	15	0,117	13.2	0,011	31	0,078
19	0,110	14	0,013	16	0,152	14	0,359	31.2	0,074
20	0,013	15	0,000	17	0,141	14.2	0,032	32	0,011
21	0,004			18	0,071	15	0,165	32.2	0,091
				19	0,039	15.2	0,037	33	0,002
				20	0,026	16	0,037	33.1	0,000
				21	0,006	16.2	0,026	33.2	0,022
				22	0,004	17	0,002	34	0,000
				23	0,000	17.2	0,006	34.2	0,000
				25	0,002	18.2	0,002	35	0,000
								35.2	0,002
								36	0,000

- What is the frequency for feature 19 on locus D18S51?
- What is the sum of all the possibilities for the feature D 16S539?
- What would you expect as an outcome of this calculation?

- A trace found on a crime scene has the following features: VWA 14; D18S51 17 and D21S11 32. Calculate the frequency for this combination.

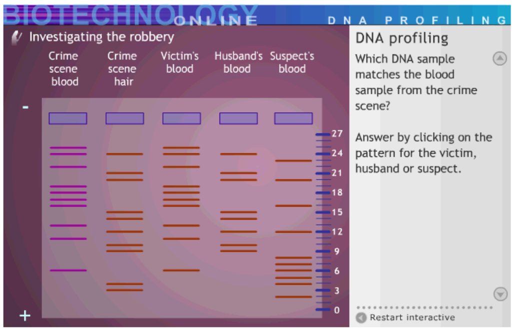
3.4 Identifying with use of DNA

3.4.1. To check once again the process of DNA-identification, you can play this online game.

http://www.biotechnologyonline.gov.au/popups/int_dnaprofiling.html

In this game you can choose to investigate a will or to investigate a robbery.

- Play the game and try to solve both cases.
- Explain in your own words why you have to turn on the electric current in this game.
- Explain in your own words what the vertical stripes in the picture below mean.



- Did you succeed to solve the robbery? Explain what were the difficult steps in this research.
- Did you succeed to solve the problem with the will? Explain what were the difficult steps in this research.

3.4.2. Identifying with the use of DNA in real life

It is difficult to do your own DNA analysis. Materials to do this experiment are very expensive, for schools it is not possible to buy reliable DNA-kits. However, in many countries there are companies that can support schools. For example with excursions, visiting lecturer or making equipment available. You will hear from your teacher what the possibilities are for your situation.

4. Measuring on crime-scene pictures

A crime scene is often meticuously recorded by pictures.

- Why would it be so important to record the whole crime scene in pictures?

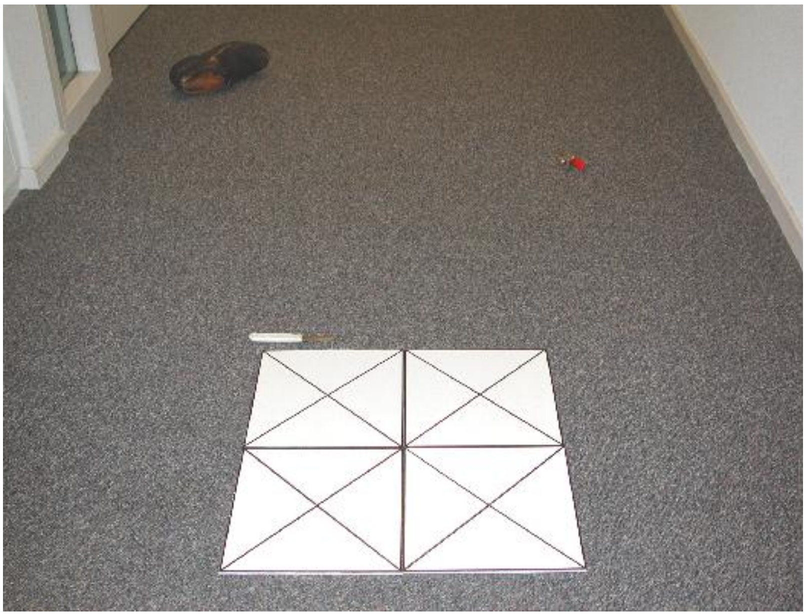
4.1 Introduction

In the picture above, you see a police officer in training taking a picture from a fake crime scene.

- Look at the picture above and describe the items that might be important in this scene.
- To the left of the pistol is a ruler. Do you think this is also an object from the crime? Explain your answer.
- Why do you think does the police officer take the picture from right above?
- If you need to know the distance between the objects from the picture can you tell for sure which distance between the three marked objects is largest and which is smallest? 1-2, 2-3 and 1-3? Why or why not?
- Can you say for sure that the distance of the photographer's right foot to object 2 is larger than to object 3? Why or why not?
- What can you say about the shape of the tile on which object '2' is placed? Compare the shape on the picture with the real shape you know from every-day life. Explain the difference.

4.2 Measuring distances on pictures

As a forensic scientist you cannot always walk through the crime scene, because you may destroy evidence. Or you are called in at the moment the crime scene is already cleared for a long time. Then the pictures may be the only way to know what the crime scene did look like. If you need to collect information e.g. about distances between objects you have only the picture at your disposal. But, it is usually impossible that an overview picture of a crime scene is taken directly from above. Therefore there is perspective distortion.



- Explain in your own words what you think is meant with perspective distortion? If you do not know, find some information about perspective distortion.
- What evidence can you give that there is perspective distortion in the above picture?

The pictures of a crime scene will be analyzed. An important thing to do is determining distances between different objects.

- Give some reasons why it can be important for you as a forensic scientist to know the real distance between objects in a crime scene
- Find out what is meant by perspective deformation and write a summary in which is explained how this can occur.

Look at the photograph above from a crime scene. We see a shoe, some keys (with a red label) and a knife (with a white handle). There are also four square tiles placed on the scene to use as a reference. These tiles are 25 cm wide and 25 cm high.

- Estimate from the picture the distances between:
    - Keys – shoe
    - Keys – knife
    - Knife – shoe
- Explain how you can see that the picture has a perspective deformation.
- Which two items are closest to each other?
- Use the software package *Coach* to determine the distance between the three objects.
- Start Coach activity 'Measuring on crime scene pictures – Instruction'. Follow the included instructions.
- After this activity, there are two more activities in which you can measure distances on pictures:

- ‘Measuring on crime scene pictures 2’ in which you will measure the distance between the objects on the picture shown in 4.1 and
- ‘Measuring on crime scene pictures 3’ in which you measure stride length and come to an estimation of the suspect’s length and possibly some other body features.

WP3
Unit Medical Imaging

European Science and Technology in Action Building Links with Industry, Schools and Home

Work Package 3
UNIT MEDICAL IMAGING

European Science and Technology in Action: Building Links with Industry, Schools and Home

Lead partner for deliverable: **C.M.A.**

Version: 1.0

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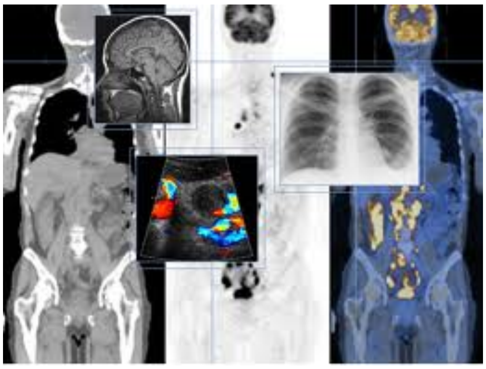
A. Teacher Information

I. Unit description



Medical imaging is the technique used to create images of internal parts of the human body for clinical purposes. Many of us have had some experience with the techniques and practices of medical imaging.

It began with the discovery of X-ray photos. During the 20th century other medical imaging techniques were developed: X-rays images, CT, MRI and ultrasound scan. Each of these techniques has advantages and disadvantages that make them useful for different conditions and different parts of the body.

The goal of this unit is to introduce students into fascinating areas of imaging techniques used in modern medicine and to make them familiar with scientific principles underlying these techniques.

The unit is divided into 3 subunits. The subunit 1 focuses on ultrasound imaging and is meant for lower secondary level. The subunits 2 and 3 focus on X-rays and nuclear imaging and are meant for higher secondary level.

The Medical Imaging unit is enriched with ICT activities. The following ICT tools are used here data logging, modelling, on-line simulations, on-line movies.

Subunit 1: Ultrasound imaging

Despite today's sophisticated, high-tech systems, ultrasound imaging remains a science built upon the simple sound wave. By beaming high-frequency sound waves into the body, physicians can translate the "echoes" that bounce off body tissues and organs into "sound you can see" - visual images that provide valuable medical information.

In this subunit students get familiar with basic physics concept needed to understand ultrasound imaging.

Student level: Lower secondary school level, students of age 12-15

Discipline involved: Physics

Estimated duration: 5-6 class periods

Subunit 2: X-rays imaging

X-ray imaging is the oldest and probably the most used imaging technique in medicine. X-ray imaging is a transmission-based technique in which X-rays from a source pass through the patient and are detected either by film or an ionization chamber on the opposite side of the body. Contrast in the image between different tissues arises from differential attenuation of X-rays in the body.

Planar X-ray radiography of overlapping layers of soft tissue or complex bone structures can often be difficult to interpret, even for a skilled radiologist. In these cases, X-ray computed tomography (CT) is used. This technique allows producing images, which show sections through a human body.

Student level: Higher secondary school level, students of age 15-18

Discipline involved: Physics

Estimated duration: 5-8 class periods

Subunit 3: Nuclear imaging

Nuclear medicine addresses the body's physiological processes rather than the anatomical structure. In nuclear imaging, short-lived radioactive materials that emit gamma rays (radiopharmaceuticals) are injected into a patient's bloodstream and are attracted to the particular organ being analysed. A gamma camera then takes a time-exposure image of the pharmaceutical as it concentrates in the tissues or organs or enters the bloodstream.

Nuclear medicine is used also in medical treatment; the radiopharmaceuticals go directly to the organ being treated. This subunit focuses only on medical imaging.

Student level: Higher secondary school level, students of age 15-18.

Discipline involved: Physics

Estimated duration: 5-8 class periods

II. IBSE character

Subunit 1

The main IBSE approaches employed in this subunit are interactive demonstration, guided discovery and guided inquiry. Inquiry based skills developed in this unit are amongst others:

- Asking and answering questions.
- Planning and conducting simple investigations.
- Performing experiments.
- Employing tools to gather data.
- Analysing results obtained with experiments.
- Communicating results with the use of graphs.
- Using data to construct reasonable explanations.
- Communicating investigations and explanations.
- Understanding that scientists use different kinds of investigations and tools to develop explanations using evidence and knowledge.

The activity 5 is an open inquiry; students have to prepare questions to ask during a visit to a hospital to be able to make a leaflet for patients having an ultrasound examination.

Some activities in this subunit make use of ICT tools:

- Data logging - measurements with a sound sensor
- On-line simulations
- Computer as source of information.

Subunit 2/3

This subunit is meant for higher levels of secondary education. The main IBSE approaches employed in this subunit are interactive demonstration, guided discovery and guided inquiry. Inquiry based skills developed in these subunits are amongst others:

- Designing experiment
- Planning scientific investigations
- Using tools and techniques to gather data
- Analysing and describing data
- Explaining results and drawing conclusions.
- Constructing models
- Comparing models with experimental results
- Debating with peers
- Forming coherent arguments
- Communication scientific procedure and explanations.

The activity 5 in the subunit X-ray imaging is an open inquiry type of activity. Students have to collect the evidence, construct their logical proofs and defend their point of view in a class debate.

The activity 3 in the subunit Nuclear imaging can be enriched with an open type of inquiry – an excursion to a hospital, which has a nuclear imaging department or inviting to school a person working at such department. Students should prepare their interview questions and after the excursion reports their findings.

III. Science Content Knowledge

In this unit students learn scientific principles underlying the major medical imaging techniques. Since a lot of activities in this unit go beyond school textbooks a lot of extra information has been included in the student worksheets.

Subunit 1.

This subunit goes beyond a school curriculum. It links to basic sound concepts and shows application of ultrasound in medicine.

For this subunit students should have prior knowledge about sound, for example a good background gives ESTABLISH Unit ‘Sound’, ‘Subunit 1. Sound exploration’.

Students should be familiar with concepts like wave nature of sound (propagation, reflection), sound echo, sound speed, they should know that the speed of sound waves depends on the medium. Student should be able to calculate the distance covered by a sound wave based on a given time interval and speed of sound.

The activities in this subunit introduce students to the following physic concepts and ideas:

- ultrasonic sound
- echolocation
- sound reflection
- the speed of sound varies in different media
- ultrasound can be used to make images of inside
- ultrasound A-scan and B-scan
- advantages and disadvantages of ultrasound imaging.

Subunit 2

As pre-requisite knowledge, students are supposed to be familiar with the concepts: radiation, electromagnetic wave, wavelength, wave frequency, structure of the atom (Bohr model, energy levels), electron, photon, energy of photon etc.

To recall the knowledge about the atom a Phet simulation can be used: http://phet.colorado.edu/en/simulation/build-an-atom

At the end of this subunit the student is able to:

- describe properties of X-rays (electromagnetic wave, ionisation, penetration)
- explain how the X-rays are produced and detected
- explain the absorption law and half-value layer concept
- explain how X-ray images are created
- explain how CT scans are created
- specify the value of X-rays and CT scans in medicine

Unfortunately there are not many suitable lab experiments, which can be performed in school.

Subunit 3

As pre-requisite knowledge, students are supposed to be familiar with the concepts from subunit 2 and with the structure of nucleus, radioactive isotopes, nuclear force.

The activities in this subunit introduce students into nuclear medicine. At the end of this subunit the student is able to:

- describe the nature and properties of the alpha, beta and gamma radiation
- explain the radioactive decay law
- explain the concepts of decay constant and half-life
- explain how radioactive materials are used in nuclear medicine
- explain why Technetium 99m is suitable as the radioactive tracer
- explain how gamma camera works
- measure background radiation
- explain the health hazards in use ionising radiations
- specify ways of protection from ionising radiation.

This unit does not explain the principles of a detector of ionising radiation. This subject should be treated separately.

Experiments with radioactive sources may be difficult to perform in schools.
In such cases virtual labs can be used, below few Internet examples:

1. Virtual Physics lab http://www.polyhedronlearning.com/cengage/
   Lab 45: Geiger Counter Measurement of the Half-Life of 137Ba”
   Lab 47: Absorption of Beta and Gamma Rays
2. Radioactive decay simulation:
   http://www.7stones.com/Homepage/Publisher/halfLife.html
3. Applets:
   http://lectureonline.cl.msu.edu/~mmp/applist/decay/decay.htm
   http://www.walter-fendt.de/ph14e/lawdecay.htm
   http://www.7stones.com/Homepage/Publisher/halfLife.html

IV. Pedagogical Content Knowledge

Medical imaging is a topic in which students might have some preconceived ideas and models because of their own or somebody from their family's medical experience. They will almost certainly have heard something about it.

General common students' difficulties identified by Science Education Research around Sound are:

- Sounds can travel through empty space (a vacuum).
- Sounds cannot travel through liquids and solids.
- Sound moves faster in air than in solids (air is "thinner" and forms less of a barrier).
- Ultrasounds are extremely loud sounds.

It is quite difficult to find research on students' understanding of ultrasound, X-rays and CT scans. This is probably because these topics are not covered in regular physics curricula. Almost all of the students either have undergone some ultrasound of X-ray procedure in their lives or know of someone who has.

The studies by Kalita and Zollman [1] showed in their research that

"… students transfer pieces of knowledge from very different sources such as their own X-ray experience, previous physics and other science courses and mass media. This transfer results in mental models that are not necessary stable, consistent or coherent."

These models should be taken into account.

General common students' difficulties identified around Radioactivity are:

- Atoms cannot be changed from one element to another
- Radiation causes a cancer, thus it cannot be used to cure cancer
- Once material is radioactive it is radioactive forever.

1. S.Kalita, D.Zollman, *Investigating Students' Ideas About X-rays While Developing Teaching Materials for a Medical Course*

V. Industrial Content Knowledge

The traditional physics curriculum rarely relates physics to other fields of science and neither shows its relevance industry and professions. This unit tries to do it.

Another goal of this unit is to link basic physics knowledge to applications of physics in contemporary medicine.

To show the relevance of physics in medical imaging making a link with different professions is very effective. For example: nuclear medicine is practised only by licensed physicians who are assisted by certified technologists and supported by specially trained physicists, pharmacists and radio-chemists.

It is very valuable for students to bring them into hospital departments of medical imaging (ultrasound, radiology and nuclear medicine).

In this unit students analyse the main products of medical imaging such X-ray machines, CT-scan machines, gamma cameras.

VI. Learning paths

The topic of medical imaging consists of 3 subunits. Subunit 1 can be used independently. Subunit 2 and 3 can be used independent, but if you like to use subunit 3 it is advice to start with subunit 2. Each unit is made up of series activities. The order and flow of activities are presented below. The activities are created in this way that they offer a complete learning cycle.

Subunit 1

Activity	*Inquiry Type*	*E-emphasis*
1.1. Can we use sound to "see"?	Guided discovery Guided inquiry	1. Engagement 2. Exploration 3. Explanation 4. Elaboration/Evaluation
1.2. Do muscle, fat and bone sound the same?	Guided discovery Guided inquiry Bounded inquiry	2.1. Engagement 2.2&2.3. Explanation 2.4. Elaboration 2.5. Evaluation
1.3. Make an A-scan.	Guided discovery	3.1. Engagement/Exploration 3.2. Explanation 3.3. Elaboration/Evaluation
1.4. Make a B-scan.	Guided inquiry	4.1. Engagement/Exploration 4.2. Explanation 4.3. Elaboration/Evaluation
1.5. Ultrasound imaging	Guided inquiry Open inquiry	5.1. Engagement/Exploration 5.2. Explanation 5.3. Elaboration/Evaluation

Subunit 2

Activity	**Inquiry Type**	**E-emphasis**
2.1. X the unknown	Guided discovery	1. Engagement 2. Exploration 3. Explanation 4. Elaboration/Evaluation
2.2. Interaction with matter	Bounded inquiry Guided inquiry	1. Engagement 2. Exploration 3. Explanation 4. Elaboration/Evaluation
2.3. X-ray medical machine	Guided discovery	1. Engagement/Exploration 2. Explanation 3. Elaboration/Evaluation

2.4. CT scans	Guided inquiry	1. Engagement 2. Exploration 3. Explanation 4. Elaboration 5. Evaluation
2.5. Are X-rays bad for you?	Open inquiry	Elaboration/Evaluation

Subunit 3

Activity	Inquiry Type	E-emphasis
3.1. α, β, and γ	Guided discovery Bounded inquiry	1. Engagement 2. Exploration 3. Explanation 4. Elaboration/Evaluation
3.2. Radioactive decay	Guided inquiry Bounded inquiry	1. Engagement 2. Exploration 3. Explanation 4. Elaboration/Evaluation
3.3. Tracing substances in the human body	Guided discovery	1. Engagement 2. Exploration 3. Explanation 4. Elaboration 5. Evaluation
3.4. Radiation exposure	Guided inquiry	1. Engagement 2. Exploration 3. Explanation 4. Elaboration 5. Evaluation
3.5. Radiation protection	Bounded inquiry Open inquiry (5)	1. Engagement 2. Exploration/ 3. Explanation 4. Elaboration 5. Evaluation

VII. Assessment

Preferably, the students' assessment includes both a theoretical test (basic concepts and laws) as a practical assignment (skills).

Teachers can assess practical skills also during the lessons, from students' reports and presentations.

VIII. Student learning activities

Subunit 1 – ULTRASOUND IMAGING

Activity 1.1. Can we use sound to "see"?

Learning aims:

- To explain the concept of echolocation
- To explain how sound can be used to measure distance
- To determine an unknown length of a tube by using the echo method

Materials:

- A computer, a sound sensor, interface and software that displays sound waveforms (e.g. CMA Coach 6), a cartoon or plastic hollow tube

Suggestions for use:

Start by giving the students the worksheet with activity 1. Let them first discuss the questions with their classmates and then write their answers on a paper.

Let them read the explanation given in activity 2 and discuss with the whole class what echolocation is, how bats use it to navigate and find their food. Discuss other applications of echolocation. At the end of the discussion ask the question 'Can blind people use echolocation to "see"?' Let them formulate their hypothesis.

To check their hypothesis show students discovery channel movie 'Real-life Bat Man" http://dsc.discovery.com/videos/is-it-possible-real-life-bat-man.html. Discuss the movie with students. Rise questions and act as a facilitator.

The activity is an Explanation activity. Students realise how to calculate the distance covered by sound waves, based on the measured interval time of echo and speed of sound (echo time covers double distance).

In activity 4 students apply learned concepts. Based on the echo time method they have to determine an unknown length of a tube. In this experiment a sound sensor, data-logger and computer are used. Students record sound signal of the initial sound and echoes. They read the echo time from a graph. Based on the echo time and speed of sound in air they calculate the length of the tube.

The final conclusion at the end of this lesson should be that (ultra)sound can be used to measure distances.

Another nice application of this idea is a motion detector. If you have such device you can show it and let student measure different distances in class. Again discuss how computer knows what the measured distance is.

Possible questions:

- Do you know other animals than bats, which make use of echolocation?
- Do you know other applications of echolocation?
- What is ultrasound?
- What is the speed of sound in air? In water?
- Does the speed of sound depend on the medium (air, water, etc..)?

Activity 1.2. Do muscle, fat and bone sound the same?

Learning aims:

- To explain when an echo occurs
- To define the concept of reflection interface
- To be able to interpret the recorded sound graphs
- To identify on what the strength of reflection depends
- To apply the concept of reflection interface for ultrasound and human body tissues

Materials:

- A computer, a sound sensor, data-logger and software that displays sound waveforms (e.g. CMA Coach 6), a cartoon hollow tube or plastic tube.

Suggestions for use:

Hand out the activity 1 worksheet. Let students work in small groups of 2 or 3. Summarize their answer in a class discussion.

In the activity students are introduced to the concept of reflection interface and are asked to answer the research question: *Does the strength of the reflection, in other words strength of echo, depend on the material which reflects sound?* Let the students formulate their hypotheses.

To test their hypotheses let them perform the experiment in which two different reflection media are compared: hard (e.g. plastic) and soft (e.g. foam) material. They should find out that hard material reflects sound better than soft material. The evidence for this is that the first echo pulse is stronger for hard material than for soft material (in each trial the initial sound should be the same and have similar intensity).

In activity 3 students have to answer the next research question: *Does sound travel with the same speed in different media?*

To answer this question the students perform investigation in which they compare the speed of mechanical waves in water and in vegetable oil. Each student group is provided with the following materials: two plastic droppers, a metric ruler, a stopwatch that measures tenths of seconds, water and vegetable oil in plastic bottles, two ripple tanks (e.g. aluminium foil lasagne pans with mirrors at the bottom).

The students have to design their experiment. Check their plans before they begin their experiments. The ripple tanks should be filled one with water, one with vegetable oil, to the same depth of 1-2 cm. In the most likely setup a student will release a drop of medium into one end of a ripple tank and start a stopwatch at the same time. In each trial, the drop should be released from the same height and distance from the edge of the tank. When the first wave produced by the drop reaches the opposite side of the tank, the second student will call out to stop the watch. The students should record this time in their data table. They should also measure and record the distance from the point where the drop hit the liquid to the opposite side of the ripple tank. The speed of wave can be calculated by dividing the distance by the time measured on the stopwatch. Students will find that, under similar conditions, waves travel faster in water than in oil.

In activities 4 and 5 students apply the concepts and realise how ultrasound pulses reflect from human body tissues.

Possible questions:

- Why echo occurs?

- In what kind of place would you expect to hear echoes?
- Does the strength of the sound reflection depend on the material which reflects sound?
- Give examples of good sound reflectors
- Does sound travel with the same speed in different media? Give examples.
- How do ultrasound waves reflect from human body tissues?

Activity 1.3. Make an A-scan

Learning aims:

- To explain how ultrasound pulses are used to measure a distance
- To describe how an ultrasound A-scan is created
- To interpret a simple ultrasound A-scan

Suggestions for use:

In this activity students learn what an ultrasound A-scan is and how it is created. They start with activity 1 (exploration) in which they once more analyse the experiment with the sound reflection in the cartoon tube. This time they get a recorded sound graph and they have to predict how the graph will look when a tube is 50% longer and when there is another barrier inside the tube. There is a small step from the graph of the sound signal versus time to a graph of the sound signal versus position - an A-scan.

The explanation of the A-scan concept is given in activity 2.

In activity 3, an A-scan of the human eye is presented. Let the students analyse the given A-scan. Discuss with them the scan, let students identify which eye parts generate respective ultrasound peaks.

Based on the given photo discuss how the A-scan is taken by a doctor.

Possible questions:

- What would you assume the speed of sound in the human?
- Which parts of the eye generate the ultrasound spikes?

Activity 1.4. Make a B-scan

Learning aims:

- To describe how an ultrasound B-scan is created
- To be interpret a simple ultrasound B-scan

Materials:

- A computer with internet connection

Suggestions for use:

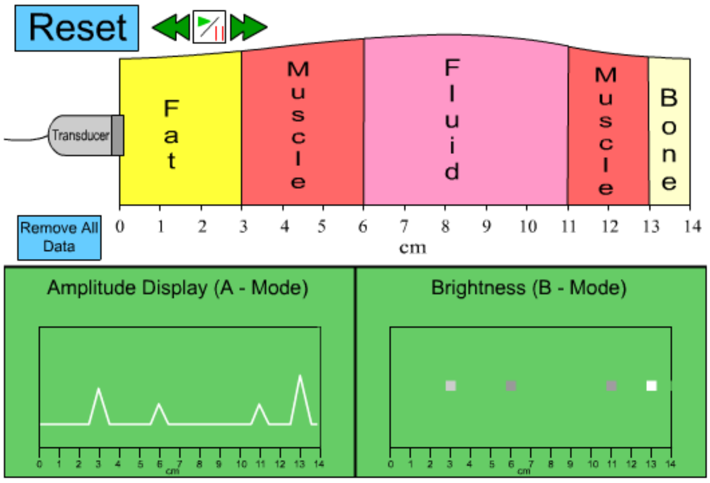
In this activity students learn how an ultrasound B-scan is created.

In exploration activity 1 students use the simulation *Ultrasound Imaging without Object*.

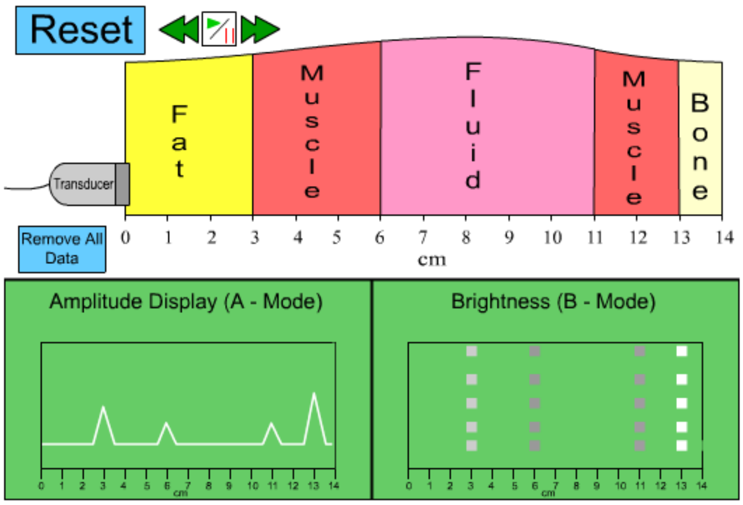
(http://physics.doane.edu/hpp/Resources/Media/Flash/UltraSoundImagingwithoutObject2.html).

In this simulation a transducer generates an ultrasound pulse, which is transmitted into a patient body built from layers pf fat, muscle, fluid, muscle and bone. The transmitter also records reflected from the “human layers” pulses. Students should first analyse and explain how the ultrasound pulses travel through the body.

The two graphs show created scans, the A-scan (left) and B-scan (right). Students should be able to discover that small squares in the B-scan respond to the strength of the reflected ultrasound. The strongest (white square) for the muscle-bone transition, The less strong (light grey) for the fat-muscle transition, the weakest (dark grey) for the muscle-fluid and fluid-muscle transitions.

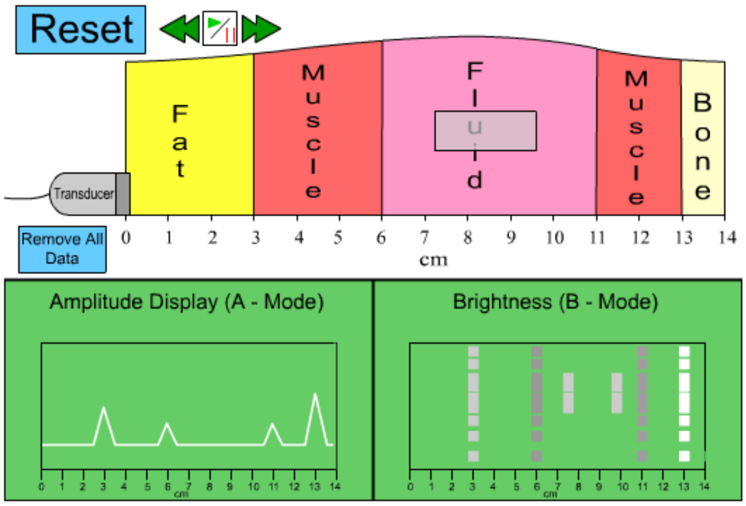


In activity 2 the explanation of a B-scan is given. Students continue to work with the simulation but now they move the transducer to get a complete scan.



Then by using the simulation *Ultrasound Imaging with Object*

http://physics.doane.edu/hpp/Resources/Media/Flash/UltraSoundImagingwithObject2.html students create a new scan. This time there is an extra object inside the body.



Students should explain how they can see on the B-scan that there is an extra object inside the body.

In activity 3, an example of the ultrasound B-scan is given. The scan shows a human fetus. Students should be able to distinguish and indicate on the scan the baby head, neck, torso.

Both simulations origin from *The Humanized Physics Project* http://physics.doane.edu/hpp.

Possible questions:

- What are differences between an ultrasound A-scan and B-scan?
- How is an ultrasound B-scan created?

Activity 1.5. Ultrasound imaging

Learning aims:

- To identify advantages and disadvantages of ultrasound imaging for humans
- To explain how an ultrasound machine works
- To explain how an ultrasound examination is done
- To establish an informational folder for patients having an ultrasound examination

Materials:

- Computer with internet connection for finding information

Suggestions for use:

This activity is an excursion to a hospital department where ultrasounds are taken and ian nterview with a sonographer.

Students should prepare their visit by first exploring ultrasound safety and ultrasound advantages and disadvantages of ultrasound (activity 1) and by preparing interview questions (activity 2). During the visit they should understand what the sonographer profession is. If an excursion to a hospital is not possible then at least a sonographer should be invited for an interview at school.

Based on information collected during the excursion students have to prepare a folder for patients who will have to undergo an ultrasound examination.

Advantages of ultrasound:

1. Ultrasound examinations are non-invasive i.e. they do not require the body to be opened up, or anything to be inserted into the body. This is a major advantage compared to fibreoptic endoscopy, for example, which may involve much more patient discomfort as the probe is inserted.
2. Ultrasound methods are relatively inexpensive, quick and convenient, compared to techniques such as X-rays or MRI scans. The equipment can be made portable, and the images can be stored electronically.
3. No harmful effects have been detected, at the intensity levels used for examinations and imaging. This contrasts with methods based on X-rays or on radioactive isotopes, which have known risks associated with them, and ultrasound methods are preferred whenever possible. This is particularly relevant to examination of expectant mothers.
4. Ultrasound is particularly suited to imaging soft tissues such as the eye, heart and other internal organs, and examining blood vessels.

Disadvantages of ultrasound:

1. The major disadvantage is that the resolution of the images is often limited. This is being overcome as time passes, but there are still many situations where X-rays produce a much higher resolution.
2. Ultrasound is reflected very strong on passing from tissue to gas, or vice versa. This means that ultrasound cannot be used for examinations of areas of the body containing gas, such as the lung and the digestive system.
3. Ultrasound also does not pass well through bone, so that the method is of limited use in diagnosing fractures.

Possible questions:

- Is ultrasound safe?
- Does ultrasound hurt?
- How does an ultrasound machine work?
- What are the main parts of an ultrasound machine?
- How is an ultrasound examination performed?

Subunit 2 – X-RAY IMAGING

Activity 1.1. X the unknown

Learning aims:

- To be able to describe how X-rays were discovered
- To be able to explain what X-rays are and how they are produced

Materials:

- A computer with internet connection

Suggestions for use:

Let student watch the Science Channel's movie (2.5 min): Discovery of X-rays (play via http://videos.howstuffworks.com/science-channel/29105-100-greatest-discoveries-discovery-of-x-rays-video.htm).

This short movie gives background information about the discovery of X-rays. Let students answer questions given in 1.

Activity 2, is an Exploration activity. Based on the given picture discuss with the students what X-rays are. Listen carefully to students, act as facilitator, ask questions if needed.

In activity 3, an Explanation activity, students learn how X-rays are produced. To be able to understand the theory students need to have some pre-knowledge about Bohr's model of the atom, photons, energy levels of electrons, etc.

Activity 4, an Extension activity, goes deeper into the theory. By watching the YouTube movie 'How does an X-ray Tube Work' (http://www.youtube.com/watch?v=Bc0eOjWkxpU) students learn more about atom interactions which cause the X-ray radiation. Encourage the students to explain their findings in own words.

Possible questions:

- In which experiment X-rays were discovered?
- What are X-rays?
- What is the energy of X-rays?
- What is the wavelength of X-rays?
- How X-rays are produced?

Activity 1.2. Interaction with matter

Learning aims:

- To introduce the students into the field of X-ray imaging
- To interpret an X-ray image
- To design experiments to determine how the degree of absorption of radiation depends on the material used and on the thickness of the absorbing material
- To define the law of attenuation and the concept Half Value Layer (HVL) and apply these to human tissues

Materials:

- A computer with internet connection

- gamma source e.g. Cobalt-60. This isotope emits photons with energies 1332 keV and 1173 keV. In comparison to an X-ray generator, cobalt-60 produces energies comparable to a 1250 keV X-ray system
- a device to detect the radiation e.g. a Geiger-Mueller tube or a radiation sensor with computer and data collection software (e.g. Coach 6)
- a set of absorption plates of the same thickness made from different materials e.g. Plexiglas, aluminium, steel, lead.
- a set of absorption plates of the same thickness made from lead.

Suggestions for use:

Activity 1 engages students into the field of X-ray images and their interpretations. Let the students answer the given questions and discuss their answers with the whole class. Act as facilitator of the discussion.

In activity 2 students explore the process of attenuation. They have to design experiments to answer two research questions:

a) How does the degree of absorption depend on the material?
b) How does the degree of absorption depend on the thickness of absorber?

Experiment A.

In order to demonstrate how the degree of absorption depends on the material, 2 mm plates of Plexiglas, aluminium, steel and lead can be used.

Exemplary data: Co-60 gamma radiation, measurement time: t = 10 s

Absorber	**Count**
Without absorber	172
2 mm Plexiglas	163
2 mm aluminium	161
2 mm steel	154
2 mm lead	140

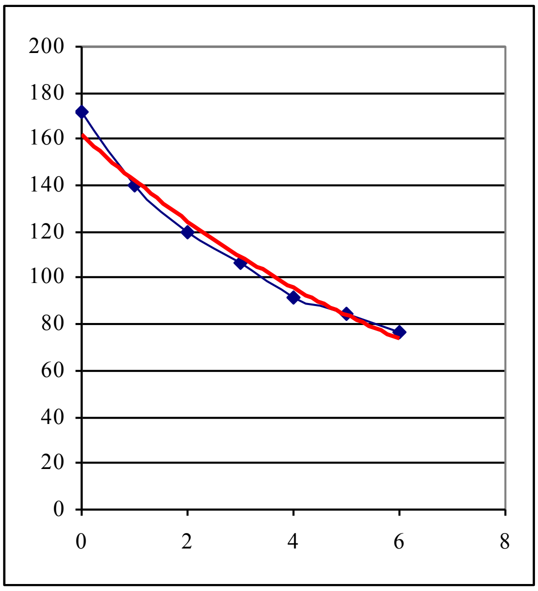
The measurements show that substances having a higher atomic number (“heavy elements”) are better able to attenuate gamma radiation than substances with a lower number. It can be clearly seen that lead shields gamma radiation. Yet high-energy gamma radiation is able to penetrate even a 2 mm layer of lead without any noticeable amount of attenuation.

Experiment B.

The thicker the material, the more the gamma radiation attenuated. This effect may be demonstrated by using lead plates, since the thickness of lead needed for a half-value layer can be easily achieved in an experiment.

Exemplary data: Co-60 gamma radiation; t = 10 s

The resulting graph (blue: measurement, red: function-fit) shows the exponential decrease. The half-value layer for lead when used to shield Co-60 gamma radiation can be found. During a nuclear decay, Co-60 emits two consecutive photons having energies of 1332 keV and 1173 keV respectively. This makes it impossible to determine an exact curve describing the absorption behaviour of lead or to accurately determine the half-value layer.



The HVL for lead is approximately 12 mm.

Activity 3 explains the law of attenuation and gives definition of the concept Half Value Layer.

Activity 4 encourages students to apply the learned concepts to human tissues.

Calculated HVLs for soft tissue and bone at 30 and 60 keV are:

Material	30 keV	60 keV
Soft Tissue HLV (cm)	1.82	3.3
Bone HLV (cm)	0.43	1.54

Possible questions:

- Which material is the best absorber of gamma radiation?
- What is the function, which describes the relationship between the intensity of the radiation and the thickness of the absorber for lead?
- What is the thickness of lead for which radiation is reduced to 50% of the original radiation?
- What would you expect if you would use X-rays instead of gamma rays?

Activity 2.3. X-ray medical machine

Learning aims:

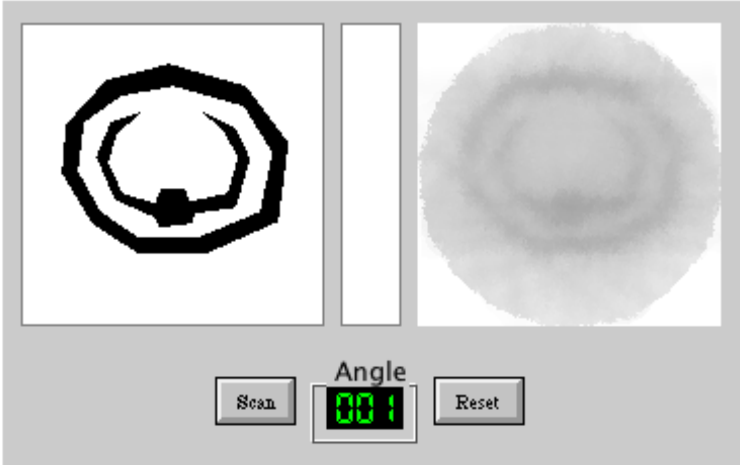
- To explain how an X-ray machine works
- To examine the different medical applications of X-rays

Materials:

- A computer with internet connection

Suggestions for use:
In this activity students learn how X-machine used in medicine works. In activity 1 students explore the X-ray source device. In activity 2 further explanations of the parts of the X-ray machine are given. In activity 3 students extend their knowledge about X-ray machines by looking into different applications of X-ray images in medicine. Discuss in what types of medical examinations X-rays are used and how an X-ray machine may differ depending on the aim of photo. Act as a facilitator of this discussion. Medical x-rays are used in many types of examinations like: • radiography - to find orthopaedic damage, tumours, pneumonias, foreign objects, • dental photos – to image the internal structures of teeth, • mammography - to image the internal structures of breasts.
Possible questions:
• How are X-rays produced in an X-ray source? • What are the basic parts of an X-ray machine? • What are applications of X-rays in medicine?

Activity 2.4. CT scans
Learning aims:
• To explain how a CT scan is created • To explain how a modern CT scan machine works
Materials:
• A computer with internet connection
Suggestions for use:
In activity 1 students are faced with a problem that conventional X-ray shadow images are only two-dimensional flat images and they do not provide complete information. In activity 2 they explore how several shadow images can be combined to create a more complete picture. In activity 3 they use simulation available at http://www.colorado.edu/physics/2000/tomography/final_rib_cage.html and learn how the CT scan is created. In the simulation a simple model of a rib cage is shown. The model can be scanned with an X-ray beam. By turning the model around and scanning it for each selected position (angle) a CT scan of the model is created.

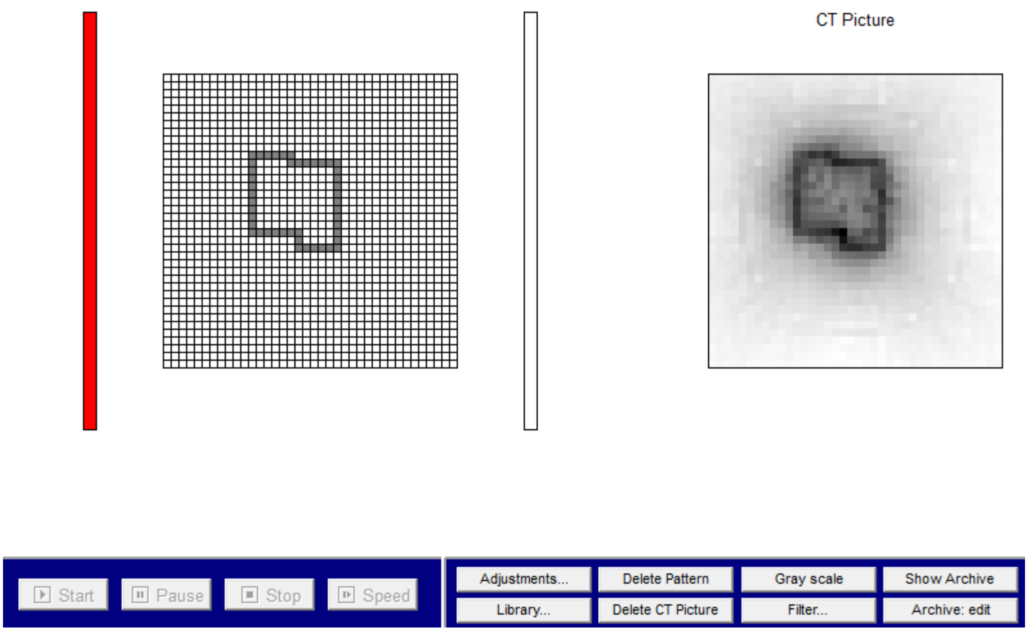


After playing with the simulation encourage the students to explain in their own words the principles of this technique. Raise extra questions, for example about the attenuation of the X-rays, the grey scale of the image, ideas of improving the quality of the scan.

Another nice simulation of creating a CT scan is included in the program called CTSim available at Kansas State University Physics Education Research Group

http://web.phys.ksu.edu/mmmm/software/CTSim/

Here the user can create an own model to scan and after pressing the Start button the computer produces its CT scan.



This program also provides an extended and more advanced explanation of the CT scan technique.

In activity 4 students learn how this principle is applied in CT scan machines and get a basic explanation how a CT scan machine works.

The ‘Analog slices’ movie shows analogue representations of tomography, using everything from horned melons to violins and hairdryers. http://videos.howstuffworks.com/discovery/45162-the-ge-show-presents-analog-slices-video.htm

Additionally students can watch the YouTube movie ‘CT Scans How it works’. http://www.youtube.com/watch?v=rN4E8Y5loAs&feature=related.

Possible questions:

- Why conventional X-ray machines cannot provide a complete image of the inside body?
- How is the image of a slice of the body created?
- What is the basic principle of a CT scan machine?
- What are the vasic parts of a CT scan machine?

Activity 2.5. Are X-rays bad for you?

Learning aims:

- To understand the health risks of X-rays and CT scans
- To establish inquiry based skills like: identifying problems to investigate, analysing and evaluating scientific arguments, constructing logical proofs, communicating and defending scientific arguments,

Materials:

- A computer with internet connection

Suggestions for use:

In this activity students investigate the health risks of X-rays. They research the problem to be able to defend a statement in which they believe.

The statement is:

Many people are concerned about the risks to their health from getting medical X-rays and CT scans. In my opinion X-rays and CT scans may be important in medicine but they are also very harming, I think they are not good for me.

They should realise:

- advantages and disadvantages of X-rays and CT-scans
- health risks connected to both techniques
- how much benefit is needed to accept certain health risks.

This is an open inquiry type of activity. Students have to collect the evidence, construct logical proof and defend their point of view in a class debate.

The best approach is to divide students in smaller groups and let them divide the tasks in the group themselves.

A nice addition would be to organize a visit to a radiology department in a hospital or to invite a radiologist into the class.

Possible questions:

- What are advantages and disadvantages of X-rays and CT scans?
- What are biological effects of X-rays?
- How much radiation is exposed in X-ray image? CT scan?
- Is there a minimal radiation dose, which is not harmful? What are results of too large dose?
- Can modern medicine miss X-ray and CT medical imaging?

Subunit 3 – NUCLEAR DIAGNOSTIC

Activity 1. α, β, and γ

Learning aims:

- To identify three kinds of radiation and their properties
- To measure the absorption properties by matter for alpha, beta, and gamma radiation

Materials:

- A computer with internet connection
- Radiation sources: Alpha source (e.g. Po-210), Beta source (e.g. Sr-90) and Gamma source (e.g. Co-60)
- A detection device: a Geiger-Müller counter or radiation sensor with a data-logger and software (Coach 6)
- A set of absorbers e.g. paper, aluminium and lead of varying thicknesses

Suggestions for use:

Here students get familiar with different types of natural radiation.

In activity 1 they recall their knowledge about gamma radiation.

In activity 2 they explore alpha, beta, and gamma radiation properties, their behaviour in an electric and magnetic field and penetration properties.

Alpha particles are attracted to the negatively charged plate and are deflected by a magnetic field. This confirms that they must be positively charged. Alpha particles are helium nuclei; they contain 2 protons, which gives them their positive charge.

Beta particles are attracted to the positively charged plate and are deflected by a magnetic field in the opposite direction of alpha particles. This confirms that they are negatively charged. Beta particles are fast moving electrons. They are deflected much more than the heavier alpha particles.

Gamma rays are unaffected by an electric field and are also unaffected by a magnetic field. Gamma rays are highly energetic waves with no charge associated with them.

In their investigation of penetrating properties students use sources of different radiation. They measure the effect of absorbers put between the source and the detecting device.

Alpha particles should be stopped by anything except the very thinnest piece of paper or foil. If you do not have a pure alpha source, you need to be careful about trying to show the properties of alpha using a Geiger-Müller tube. The radiation from a mixed source like ^{241}Am can penetrate aluminium and has a long range. This is because it gives out gamma as well as alpha radiation. Beta radiation can be stopped by a sheet of Perspex, an exercise book, or thin aluminium. Gamma radiation is very penetrating and needs thick layer of lead to reduce it to a low level.

It can be easily showed that alpha radiation has a very short range (between 3-10 cm), beta has a range of about 10 cm, and gamma gets weaker with distance but doesn't come to a stop at any particular distance.

If there is no equipment for student investigations then a teacher demonstration should be performed in which students should be actively involved.

Also students can perform these experiments in a virtual lab, for example:

1. Virtual Physics lab http://www.polyhedronlearning.com/cengage/
Lab 47: Absorption of Beta and Gamma Rays

or

2. http://visualsimulations.co.uk/software.php?program=radiationlab
Radiation lab program

In activity 4 students evaluate why radioactive materials emitting alpha and beta radiation are not suitable for nuclear medicine.

Possible questions:

- What are alpha, beta and gamma radiations?
- What are properties of alpha, beta and gamma radiation?
- Which material stops alpha radiation? Beta radiation? Gamma radiation?
- Which radiation, alpha, beta or gamma has the longest range? How do you know?
- Why alpha and beta radioactive materials are not suitable for nuclear medicine?

Activity 2. Radioactive decay

Learning aims:

- To measure radioactive decay
- To determine the decay constant
- To calculate the half-life time

Materials:

- A computer with internet connection
- A radioactive isotope generator
- A detection device: a Geiger-Müller counter or data-logger with a radiation sensor and software (Coach 6)

Suggestions for use:

Here students focus on the process of radioactive decay.

In activity 1 students simulate the process of radioactive decay and learn that it is a random process.

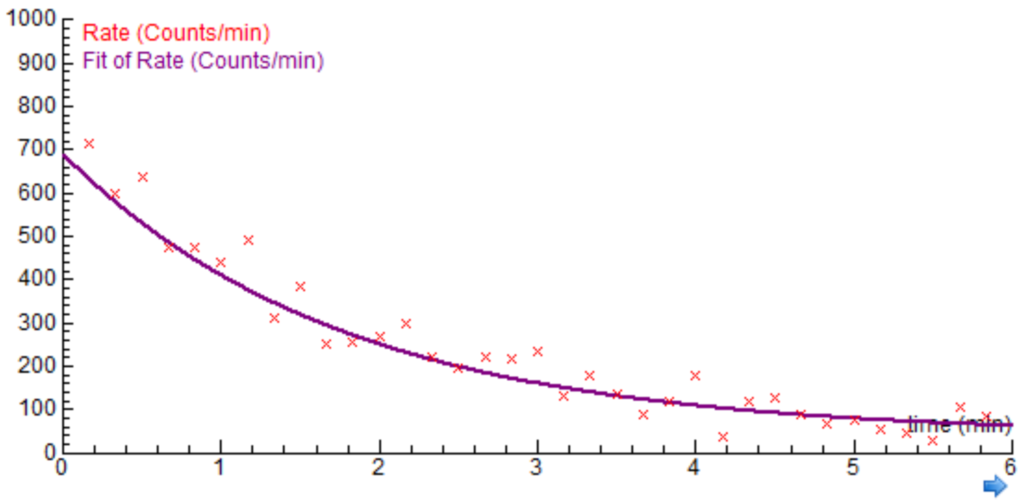
In activity 2 they explore a given radioactive decay model and determine the function, which describes the radioactive decay.

In activity 3 the radioactive decay law, the decay constant and the half-life time are introduced.

In activity 4 students measure the activity of a radioactive isotope. Based on the measured results they determine the decay constant and calculate the half-life value. In this experiment a Protactinium Pa-234m generator or Barium 137m generator can be used. A Protactinium generator consists of a small plastic container hermetically sealed by a thin-walled plastic cap. A container consists of an aqueous solution of uranyl nitrate in the lower layer and an organic phase (ketton) in the upper layer. By shaking the generator is activated: the two phases are mixed together and slowly separate again. Due to the better solubility of the short-lived Protactinium in organic solvents, the isotope is enriched in the ketton phase. The fade away of the nuclide can be followed using a radiation sensor. Protactinium decays with a half-life of about 70 seconds.

The isotope generator Barium 137m contains cesium-137 as the long parent nuclide which has a half-life of 30.25 years. Cs137 decays, by emission of beta radiation, into stable isotope Ba137. This transition is partly affected (approx. 5%) by direct conversion into stable isotope Ba137 and partly (95%) via the metastable energy state of Ba137m. In the experiment Ba is "milked" out of the Isotope Generator by pressing eluting solution through the generator. The half-life of Barium137m is 2.55 minutes.

Exemplary data: Radioactive decay of Protactinium, the coefficient of exponential function is λ = 0.563, the half-time $t_{1/2}$= $\ln 2/\lambda$=0.6931/0.5633=1.23 min



In activity 5, students modify the model of activity 2 to create a model of radioactive decay of the isotope used in their experiment and compare the model data with the experimental results.

Possible questions:

- Which function describes the radioactive decay?
- What is the decay constant?
- What is the half-life?
- What does it mean that radioactive decay is a random process?
- How do you measure radioactive decay?
- How do you model radioactive decay?

Activity 3. Tracing substances in the human body

Learning aims:

- To explain which type of radioactive materials can be used in nuclear imaging
- To explain why Technetium 99m is suitable for nuclear imaging
- To specify the main elements of a gamma camera

Materials:

- A computer with internet connection

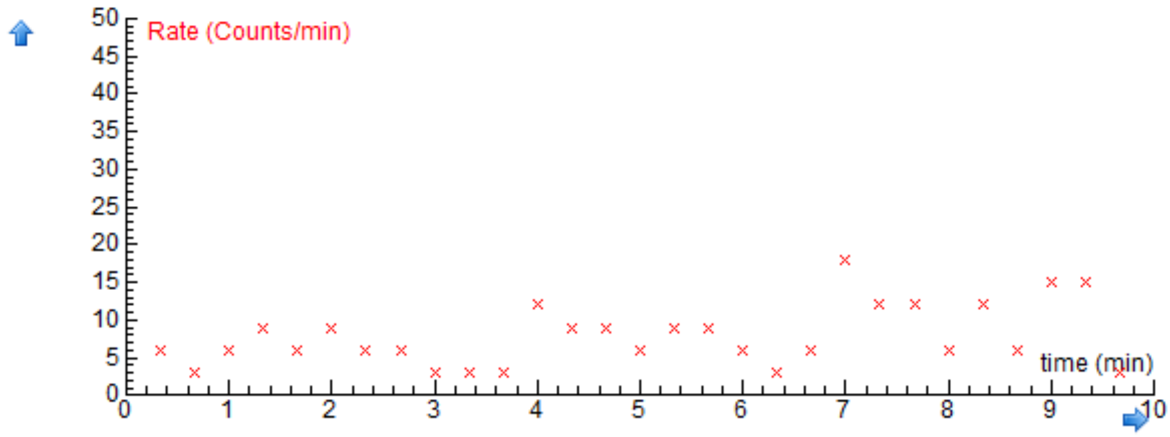
Suggestions for use:
Here students learn how radioactive materials are used in nuclear imaging and how they are detected. In activity 1 students identify properties of radioactive materials suitable for nuclear tracing. In activity 2 they explore Technetium 99m, a radioactive material often used in nuclear tracing. In activity 3 they learn more about Technetium 99m, about its decay, the way of producing and preparing for use in medicine. In activity 4 they learn the basic ideas of gamma cameras and PET scans. This activity is quite full of facts and inquiry based approach is here quite limited. On the other side this activity gives a good opportunity to link to the medical industry. A good addition here, activity 5, would be an excursion to a hospital, which has a nuclear imaging department or inviting to school a person working at such department (there are few professions involved). In both cases students should prepare interview questions and after the excursion/visit write a report. (A worksheet for this activity is not provided).
Possible questions:
• What kind of radioactive materials can be suitable for nuclear imaging? • What are radiopharmaceuticals? • What is Technetium 99m? • How is Technetium 99m produced? • How is Technetium 99m stored? • How are radiopharmaceuticals injected into a body detected? • What is a PET scan?

Activity 4. Radiation exposure
Learning aims:
• To understand that radiation origins from natural and from artificial (man-made) sources • To give examples of radiation from natural and man-made source • To measure the radiation background and the radiation from naturally occurring radioactive substances. • To observe the random nature of the radiation process • To explain the way the effective exposure dose is calculated • To calculate a personal annual radiation dose • To explain effects of radiation
Materials:
• A computer with internet connection • Sources of natural radiation • A detection device: a Geiger-Müller counter or data-logger with a radiation sensor and software (Coach 6)
Suggestions for use:
Here students learn to which radiations people are exposed, how an annual radiation dose

is calculated and what are effects of radiation on humans.

In activity 1 students analyse the sources of ionising radiation on Earth. Ionising radiation in our direct environment arises from natural processes (e.g. cosmic radiation, radioactivity in the body, inhalation of radon gas, radionuclides in food and drink) and from artificial process (such as medical X-rays, fallout from nuclear weapons tests, and discharges of radioactive waste).

In activity 2 students investigate the radiation of their environment, they measure background radiation in different places and measure the radiation of some natural materials. In this activity they observe the random nature of the radiation process.
Exemplary data:
Background radiation, Number of measurements: 30, Max: 18.00, Min: 3.00, Average: 8.00, Standard deviation: 3.97



In activity 3 they learn how absorbed radiation doses by the human body are calculated and in which units they are measured.
In activity 4 students realise that the personal annual radiation dose exposure depends on many factors (the amount of natural radioactivity depends on the location on earth, the amount of artificial radiation depends on the dose of medical radiation, etc.). They calculate the annual personal radiation dose. For this they use the provided chart (origin American Nuclear Society).

Such an annual personal dose can also be calculated via computer for example at:
http://firstyear.chem.usyd.edu.au/calculators/radiation_dose.shtml, or
http://www.epa.gov/rpdweb00/understand/calculate.html
In activity 5 the students find out and discuss the effects of radiation on the human body and cells.

Possible questions:

- What are natural sources of radiation?
- What are man-made sources of radiation?
- What is the most significant natural source of radiation?
- What is the background radiation in your environment?
- How do you measure the background radiation?
- What does it mean that background radiation has a random nature?
- What is the absorbed radiation dose and in which units is it measured?
- What is the equivalent radiation dose and in which units is it measured?
- What is the effective radiation dose and in which units is it measured?

- What is your personal annual radiation dose and how is it calculated?
- What are the biological effects of radiation?

Activity 5. Radiation protection

Learning aims:

- To measure how radiation changes with the distance to the radiation source
- To measure how beta radiation is absorbed
- To describe methods of protection against ionising radiation
- To compare the health risks of an ionising radiation dose to other risks

Materials:

- A computer with internet connection
- Radiation sources of alpha, beta and gamma radiation
- A detection device: a Geiger-Müller counter or a radiation sensor with data-logger and software (Coach 6)

Suggestions for use:

This activity is about radiation protection.

In activity 1 students analyse the health risks associated with ionising radiation.

In activity 2 they investigate:

1. how the radiation changes with the distance from the source, and
2. how beta radiation is absorbed by cardboard or aluminium foils.

In activity 3 they learn three factors of minimising the radiation: minimising exposure time, maximising distance, and the use of shielding.

In activity 4 students find out how film badges are used for monitoring the radiation exposure.

Possible questions:

- What is a health risk of an X-ray dental image?
- How to minimise the radiation dose?
- What is the ALARA principle?
- How is the radiation exposure of health care staff involved in radiology or nuclear medicine monitored?

WP3
Eco Biology

European Science and Technology in Action Building Links with Industry, Schools and Home

Work Package 3
Eco Biology
Teacher Information

European Science and Technology in Action: Building Links with Industry, Schools and Home

Lead partner for deliverable: University of Cyprus (UCY)

Version 1.0

University of Cyprus / Frederick University: Nicos Valanides (nichri@ucy.ac.cy)

Cyprus Ministry of Education and Culture: Constantinos Phanis (phanis.c@cytanet.com.cy)

The ESTABLISH project has received funding form the European Community's Seventh Programme [FP7/2007-2013] under grant agreement n^{o} 244749
Start Date: 1st January 2010 Duration: 48 months

UNIT TITLE: ECO BIOLOGY

I. Unit description

The proposed activities are designed for an inductive or 'inquiry' field work approach that incorporates the processes of field research. Issues are introduced, key questions raised, and students select methods to investigate and develop possible solutions to these. The teachers act as supervisors and advisors, providing equipment, advice and ensuring safe working.

Student level: Secondary school
Discipline level: Biology, Chemistry, Physics and Technology
Estimated duration:
10-15 lessons

<u>Learning objectives</u>

At the completion of this unit, pupils should be able to:

1. Develop observation and interpretation skills
2. Formulate their own questions and hypothesis
3. Plan, carry out and report on an investigation that can answer their question/ hypothesis
4. Specify the dependent, independent and control variables of their designed experiment
5. Learn how to record and present data in a table and graph format
6. Consider the limitations of the methodology
7. Discuss and evaluate both the validity and the reliability of the outcomes of their designed experiments
8. Consider conservation of endangered plant species
9. Learn relevant ecological terminology
10. Consider safety and ethical issues
11. Estimate the density of an endangered plant species in a named ecosystem
12. Suggest how conservation of specific endangered species can take place.
13. Become able to design and perform an experiment for investigating the effect of temperature or any other specifically selected abiotic factor on the development of seeds of a selected plant or its seedlings that can be find in the ecosystem under investigation
14. Inquire about the construction of a greenhouse
15. Identify living organisms in the local ecosystem
16. Construct keys using common features of organisms
17. Inquire about scientific classification –taxonomy- of organisms
18. Inquire about the life cycle of a living organism

19. Inquire about the role of an organism in the ecosystem
20. Use genetics to identify common features of organisms
21. Discuss the theory of evolution based on DNA homologies
22. Learn how to draw a biological diagram using a flower from their local ecosystem
23. Understand the significance of biological magnification
24. Relate the structure of a flower to seed production, whilst learning relevant terminology, such as, pollination, fertilization. To identify pollen grains using microscopy
25. Understand the structure of seeds
26. Evaluate the methods used by seed banks in the conservation of endangered plants
27. Inquire about the life cycle of a named insect and its role in pollination
28. Collect pollen from flowers and observe it under a microscope
29. Inquire about the effects of Global warming in seasonal flowering, pollination and seed biology
30. Design and perform an experiment to investigate the time that they can store selected seeds
31. Implement an appropriate methodology for safely obtaining a plant extract
32. Investigate the effect of different plant extracts/ antibiotics on bacteria

It is not the intention that pupils should work on each learning objective in turn, but that the pupils should develop their basic skills in science by carrying out an inquiry-based project.

II. IBSE-Inquiry-Based Science Education

The activities elaborate on observations from the European Union Science Olympiad (EUSO), which was organised in Cyprus and took place in May 2008. The proposed activities focus on a low secondary biology level (student age 12-15), but can be also adapted to higher secondary-level school. The field activities have been carefully planned in order to enhance students' abilities and skills resulting from class and laboratory investigations. From this perspective, field activities put emphasis on stimulating students' curiosity and interest to provide answers to either their own questions or to questions initiated by their teacher. Students are encouraged to be involved in activities targeting the development of their understanding of how science works and on social, moral and ethical issues. Specific attention is drawn to recent technological advances and students have the opportunity to become familiar with new science applications. Students are also guided to gain an appreciation of the ecosystem which is selected for investigation and correctly conceptualize the potential of integrated science and technology for solving or alleviating contemporary environmental issues. The students are guided to record their experimental observations and draw from them tentative generalizations and conclusions that can be verified through continuous experimentation. At the same time, they can also gain an appreciation of the limitations that apply when designing an experiment whilst gaining technical experience.

In an educational context, where there is an increasing need to encourage students to enjoy science, so that they become interested, curious and develop knowledge-building skills, field investigation approaches can be very useful. The field work activities that are presented attempt to promote science, mathematics, and technology and put emphasis on the 7E learning cycle, namely:

- elicit
- engage
- explore
- explain
- elaborate
- evaluate
- extend

"What do you think?" questions can elicit students' prior conceptions, and an ecosystem engages and motivates students by arousing their interest. The students explore the environment under investigation identify a problem as a result of their observations and make predictions or formulate a hypothesis, design a research methodology, collect, record and analyze data, draw conclusions that result in the acceptance or rejection of the original hypothesis. Various degrees of teacher and student ownership and control are possible. New concepts are introduced and new terms are explained.

III. Pedagogical Content Knowledge

The field study inquiry-based activities are designed, so that students who collaborate as a team:

- Are intrigued by field activity.
- Appreciate their experimental observations in order to describe and explain scientific phenomena.
- Appreciate the limitations, which apply when designing an experiment
- Gain technical experience, develop skills of handling simple apparatus through team cooperation and develop initiative
- Gain an appreciation of the ecosystem, which is under investigation.
- Become intrigued to ask and solve questions that arise from their investigations in order to gain knowledge, understanding and critical thinking.
- Plan, carry out and report on investigations
- Develop scientific attitudes and habits of mind that are extremely useful even in usual everyday activities
- Promote their epistemological development life-long learning abilities.

IV. Industrial Content Knowledge

In the study of ecology there is now major focus on the increased use of resources and on the impact of humans on the Earth. Classical biology can explain biological phenomena but modern biology must now find new innovative ways to stimulate the intelligent mind and encourage science inquisitiveness. Is it possible to understand human effects on the environment without knowledge of physics, chemistry, mathematics, technology and biology? Eco biology involves industries, businesses, research and educational institutions as well as the activities of municipal and county government. We therefore recommend study visits and the involvement of experts A study visit and field-work will probably give rise to many questions. Some of these can be answered by doing Internet searches and email contact with various businesses, researchers and others. Another alternative is to invite an expert to work in the field or to talk to the class

V. Assessment

When working with a unit of this type, it is important that its associated assessment is in line with the stated learning objectives, and of course also with relevant policies. It is also important that the pupils are informed at the beginning of the unit about how they are to report on their work and how they are to be assessed. Assessment can also take place in the field when the students are interacting as a group.

WP3
Eco Biology

European Science and Technology in Action Building Links with Industry, Schools and Home

Work Package 3
Eco Biology
Classroom Materials

European Science and Technology in Action: Building Links with Industry, Schools and Home

Lead partner for deliverable: University of Cyprus (UCY)

Version 1.0

University of Cyprus / Frederick University: Nicos Valanides
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The ESTABLISH project has received funding form the European Community's Seventh Programme [FP7/2007-2013] under grant agreement n° 244749
Start Date: 1st January 2010 Duration: 48 months

Student learning activities

Activity	Subject	Connection to the syllabus and main contents
1. ESTIMATING THE DENSITY OF AN ENDANGERED PLANT SPECIES IN A NAMED ECOSYSTEM	Biology Physics Maths Technology	
2. PLANT ADAPTATIONS AND EFFECTS OF GLOBAL WARMING ON ENDANGERED AND/OR FARMED PLANT SPECIES	Biology Physics Technology Chemistry	
3. THE SCIENCE OF TAXONOMY	Biology Chemistry Physics Technology	
4. FLOWERING PLANT REPRODUCTION	Biology Chemistry Technology	
5. PLANT EXTRACTS AND ANTIBIOTICS	Biology Technology	

Student learning activities

Activity 1

ESTIMATING THE DENSITY OF AN ENDANGERED PLANT SPECIES IN A NAMED ECOSYSTEM

Stages of learning cycle	Activity
Elicit-Engagement	X
Exploration	X
Explanation	X
Extend – Elaborate	X

Learning aims:

1. To learn relevant ecological terminology, such as: ecosystem, habitat, abiotic factor, species, population, community, density, endemic organism, adaptation
2. To estimate the density of an endangered plant species in a named ecosystem
3. To learn how to record and present data in a table and graph format
4. To consider the limitations of the methodology
5. To consider conservation of endangered plant species
6. To consider safety and ethical issues
7. To suggest how conservation of specific endangered species can take place.

Subjects: Biology, physics and technology

Materials:

Calculator

Tape measures

Thermometer

Hygrometer

pH meter

Light meter

Quadrants (1 m^2 or 0.25 m^2)

Suggestions for use: Introduce the topic: Humans are dependent upon plant life. Plants provide fuel, food, clothing, paper, shelter and yield important medicinal compounds. The International Union for Conservation of Nature and Natural resources (IUCN) report a combined total of 35,319 endangered plant species. Human impact has been the main cause of the rapid destruction of unique ecosystems, thus threatening plant species.

Exercise 1

To learn relevant ecological terminology, such as: ecosystem, habitat, abiotic factors, species, population, community, density, endemic organism and adaptation.
To consider conservation of endangered plant species

The students will be asked to explore a local ecosystem and to select an endangered plant species for their field study. This inquiry-based activity will take place in the field, aiming to stimulate students' interest to raise and investigate relevant scientific questions and connect learning with everyday life and human interest. A class of 20-30 students can be organized by the teacher in 4-6 teams, each team consisting of 5 students. There are many examples of local ecosystems that can be investigated—a pond, a school garden, a forest, an estuary and a grassland. Each team of students can suggest and inquire about a specific plant, which is present in the selected ecosystem. At the end of the field-work the students must search the web in order to find information so that they can write a short passage about the ecosystem under investigation highlighting and/or introducing relevant ecological terminology, such as, ecosystem, habitat, abiotic factor, species, population, community, density, endemic organism, adaptation.

For example in Cyprus, the Athalassa National Park can be the selected ecosystem.

As an example, a short passage follows introducing a Cypriot ecosystem:

The Cyprus National Park of Athalassa (**ecosystem)** is the result of afforestation (deliberate planting in an area, which had not recently been a forest land). Thyme is indigenous **species** in Cyprus, very common to rocky slopes **(habitat**), disturbed ground and occasionally on sand dunes, in shrub lands and forests. It grows on all types of soils **(abiotic factor),** as it is a low-demand plant and prevents soil erosion.

Thyme has xerophytic (drought-resistant) **adaptations**. Thyme has been well known since ancient times as a good source of nectar for honey bees, and for its aromatic and medicinal properties. “Thyme is a source of food for bees” (Aristotle *Historia animalium*). Shepherds also used it as fuel when making the local goat cheese. Such was the demand for thyme that there was a class of traders called “throumpopoulides” (sellers of thyme).

A Cypriot amateur beekeeper has kept bee hives in his garden for the last three years, but he has not been able to increase their number. Cyprus has had very little rainfall and it faces desertification. The bee hives have not produced swarms and two beehives have perished. Human impact on the environment has been severe. The bee keeper observed that the number/ **population** of thyme plants in the Athalassa Park has been declining. It could be that thyme plants are stressed out.

The following questions 1 and 2 can be used to assess student knowledge of the relevant ecological terminology.

1. Match relevant terms to the descriptions given.

(A) Ecosystem or (B) Habitat

.... is a specific area in a given time that consists of all the living organisms that interact with each other and the abiotic environment. A specific area where a living organism lives is called a ....

(C) Population or (D) community

A group of individuals in a species is a …………………………………

All organisms in a habitat are described as a ……………………………

(E) Numbers or (F) Density

Population size refers to the ……………. in a population.

Population ……………. refers to numbers in a given area or volume.

2. State the abiotic factors that may affect an organism in an ecosystem.

Possible student answers include the following:

pH, temperature, light intensity, moisture, slope, wind, minerals in the soil …………..

Based on the results of any similar evaluation, the teacher will then design activities or classroom discussion for clarifying or introducing the relevant terms, so that students will have clear understanding and orientation for their activities and tasks.

Exercise 2

To estimate the density of an endangered plant species in a named ecosystem

The following activity can be used to teach students how to estimate the density of a specific plant that is present in an ecosystem relative to a named abiotic factor such as temperature. The teacher needs to explain to the students that scientists many times cannot possibly count every organism in a population. However, scientists can *estimate the size of a population.* Students need to learn how to collect data by taking random samples. This activity can first take place in the field without the students knowing the full practical details of the methodology. The students are asked to inquire about how a named abiotic factor may affect the density of the named plant that they have selected. The correct methodology can be provided to the students at the end of their investigation in order to make comparisons and even correct their own designed methodology. The full practical details of random sampling including apparatus to estimate the density of a specific endangered plant in an ecosystem in relation to an abiotic factor, such as, temperature is provided below.

Methodology of random sampling used to estimate the density of thyme plants that are present in a named ecosystem relative to a named abiotic factor that affects plant density.

I. State an environmental factor, e.g., TEMPERATURE ………………...
II. State the instrument needed to measure the specific abiotic factor, e.g., THERMOMETER …
III. Lay out two 10 m tape measures at right angles to each other, in a selected area within the ecosystem that includes the endemic plant of interest, to create an area of 100 m^2
IV. Generate ten random number coordinates using a calculator. If there are no calculators, place numbers 1-10 in a bag and pick randomly one number,

which will correspond to the X axis coordinate, replace and repeat to select the Y axis coordinate

V. Select a quadrant of an appropriate size………………… (e.g., 1m X 1m)

VI. Place the quadrant at the intersection of each pair of the coordinates

VII. Record all the other environmental measurements including the light intensity, using a light meter, the pH of the soil using a pH meter, and the % of moisture using a hygrometer.

Explain to the students why are these measurements needed.

The students need to consider the limitations of their experiment. The teacher will explain to the students that limitations in an experimental investigation are factors that they cannot control, no matter what they do.

VIII. Identify the endemic plant under investigation using keys and photographs…

IX. Count the number of individual endemic plants present in each quadrant.

Exercise 3:

Organization and representation of data

In order to teach how to record and present data in a table and graph format, the students are asked to record and present their data in a table. The correct format of the table is given below. The table below is given to the students, once they have designed their own table. Of course, the approach should take into consideration students' prior educational level and their abilities, knowledge and skills.

TABLE OF RESULTS

Quadrant number	***Number of endangered plants (e.g., Thyme plants) in a quadrant of 1 m^2***
1	
2	
3	
…	
10	
Total number of thyme in 10 quadrants	

Suggestions for use:

<u>Exercise 4</u>

In order to analyze data from their own investigation, the students will be asked to estimate the mean density of an endangered plant (explain that the mean density equals the average number of endangered plants per m^2). A question for further understanding can be: If the area under investigation is 10000 m^2 calculate the number of, e.g., *<u>thyme</u>* plants in the ecosystem under investigation?

The student teams will be asked to compare how the same abiotic factor affects the density of two different plants (or the same plant, found in a different ecosystem). The investigation is planned accordingly. The students need to plot a bar chart indicating: Mean density of each plant (Y axis) versus (type of plant X axis).

<u>Exercise 5</u>

The students will then be asked to consider the limitations of their experiment. The teacher will explain to the students that limitations in an experimental investigation are factors that they cannot control, no matter what they do. After discussion in their teams, then they can answer the following question:

Indicate whether the statement is true or false.

- Difficult to control all abiotic factors. **TRUE OR FALSE**
- Not all plants are counted due to difficulty in identifying them. **TRUE OR FALSE**
- Area selected may not represent plant density. **TRUE OR FALSE**
- No repetition has been carried out **TRUE OR FALSE**
- There may be seasonal variation in plant distribution **TRUE OR FALSE**

<u>Exercise 6</u>

To consider safety and ethical issues

The students will be also asked to consider any safety and ethical issues, when they are inquiring about the named ecosystem that they will be investigating. The students are expected to search the Internet, to discuss with each other, to answer questions from their teacher and/or to observe a demonstration?

Possible student answers considering safety include:

Possible risk from indigenous animals / unidentified plants / insect bites / falling branches/ slips and trips.

Possible student answers considering ethical issues include the following:

Minimize disturbance to the habitat …………..

A study visit

To suggest how conservation of specific endangered species can take place.

The activities are designed in such a way that all the answers can be discussed in the field by a team of interacting students and their teacher. The activities could be furthermore extended to technology related topics. A visit to a weather station, either on land or sea, demonstrating how instruments and equipment are used to observe atmospheric conditions can provide information for weather forecasts and for studying the weather and climate. The measurements taken using sensors include temperature, barometric pressure, humidity, wind speed, wind direction, and precipitation amounts. The students can thus understand the need to monitor multiple abiotic factors that can affect plant density over a period of time.

Furthermore, the students can visit a zoo or a University (e.g. a genetics laboratory) and discuss the role of a researcher, a botanist, a zoologist, a microbiologist, a mycologist and a geneticist investigating biodiversity in terms of conservation. Students should become able to suggest how conservation of specific endangered species can take place. The students can study the World Conservation Union (IUCN) Red Data List (http://www.iucnredlist.org) to find species classified as endangered and they can investigate how a specific species is protected in terms of conservation.

Activity 2

PLANT ADAPTATIONS AND THE EFFECTS GLOBAL WARMING ON ENDANGERED AND/ OR FARMED PLANT SPECIES

Stages of learning cycle	Activity
Elicit- Engagement	X
Exploration	X
Explanation	X
Extend - Elaborate	X

Learning aims:

1. To learn relevant plant terminology, such as, xerophytes, hydrophytes, mesophytes, halophytes, and plant adaptations mechanisms, such as: stomata, cuticle, large or small surface area to volume ratio, hairs
2. To become able to design and perform an experiment for investigating the effect of temperature or any other specifically selected abiotic factor on the development of Seeds of a selected plant or its seedlings that can be find in the ecosystem under investigation
3. To specify the dependent, independent and control variables of their designed experiment
4. To discuss and evaluate both the validity and the reliability of the outcomes of their designed experiments
5. To inquire about the construction of a greenhouse

Materials:

- A photo and keys of a known/named plant that grows in the local ecosystem
- Calculator
- Ruler
- Thermometer
- Hygrometer
- pH meter
- Light meter
- Soil

- Water
- Minerals

Suggestions for use:

Introduce the topic: Many scientists are concerned about the effect that climate change could have on the development of organisms and the yield of many important farmed foods, such as, maize, wheat, rice, etc. This activity investigates the effects of global warming on a specific plant found in the local ecosystem under investigation.

Plants are put into categories according to their adaptation to water availability.

- ***Hydrophytic***- adapted to aquatic or semi-aquatic conditions. Rice is semi-aquatic.
- ***Mesophytic***- adapted to middle water conditions, typical temperate terrestrial conditions. An example of a mesophytic habitat would be a rural temperate meadow, which might contain Goldenrod, Clover, Oxeye Daisy, and Rosa multiflora. Mesophytes make up the largest ecological group of terrestrial plants, and usually grow under moderate to hot and humid climatic regions.
- ***Xerophytic***- adapted to conditions of low water availability. This includes plants from a variety of conditions, including sand dunes, high alpine habitats and equatorial deserts. Sorghum is a xerophytic plant. Sorghum is a genus of numerous species of grasses, one of which is raised for grain and many of which are used as fodder plants either cultivated or as part of pasture.
- ***Halophytic***- adapted to high salinity conditions, coming into contact with saline water through its roots or by salt spray, such as. in saline semi-deserts, mangrove swamps, marshes and sloughs, and seashores. An example of a halophyte is the salt marsh grass Spartina alterniflora (smooth cordgrass). Relatively few plant species are halophytes - perhaps only 2% of all plant species

Exercise 1

To learn relevant plant terminology, such as, xerophytes, hydrophytes, mesophytes, halophytes, and plant adaptations mechanisms, such as: stomata, cuticle, large or small surface area to volume ratio, hairs

The students can be asked to inquire about the adaptations of a named plant, which grows in their local ecosystem. Depending on the ecosystem, the plant can belong to hydrophytes, mesophytes, xerophytes or halophytes.

The teacher may allow a team of students to present adaptations of their plant
High lighting key ecological words and allowing further class discussion in terms of comparison of plant adaptations and plant adaptation mechanisms

Assess student knowledge relating to adaptations of xerophytes
Read the following passage about the adaptations of *Convolvulus oleifolius,* which survives in dry conditions, and then write on the dotted lines the most appropriate word to complete the passage.

> Plants, which live in habitats where there is shortage of water, often have...................................... on the surface of their leaves, to reduce water loss by trapping a layer of still air around the leaf. This effect is also achieved by curling or rolling the leaves, so that the surface bearing most of the .... through which water loss occurs, is on the inside. Leaves may also have a thick waxy .... to reduce evaporation. Another adaptation is for the leaves to have a .... by having narrow linear leaves instead of broad leaves. Plants with such adaptations are known as ....

Exercise 2

To become able to design and perform an experiment for investigating the effect of temperature or any other specifically selected abiotic factor on the development of seeds of a selected plant or its seedlings that can be found in the ecosystem under investigation

A team of four to five students can be asked to inquire and write the methodology that they can follow to investigate the effect of temperature, or any other abiotic factor, on the development of a named plant that grows in their selected local ecosystem. The students should have the possibility to repeat observations over time, revisiting the same site and collecting data every day, every week, or even every month (or even every year). There will be a great variety of seedlings or seeds that can be investigated depending on the time of the season and the local ecosystem. The teacher should guide the team to plan their investigation with relevant questions, but without always providing the correct answers. Monitoring germination or growing of the seedling will entirely depend on team effort. This activity can also be linked with a visit to a local greenhouse. **The experiment can take place in the greenhouse investigating how a specific temperature affects germination of a stated number of seeds.** Students can experience hands-on design and installation projects using professional equipment and materials situated on-site greenhouse, which is dedicated to environmental sustainability.

Possible questions that a teacher may ask the students include:

1. Identify a suitable dependent variable for your inquiry.

- Measure of the growth of seedlings, e.g. surface area of leaves and/ or length of stem
- Number of seedlings germinated, if the investigation takes place in a greenhouse

2. State variables, other than the temperature, or the independent variable in general, which may affect the growth of the named seedling?

- light intensity/ wavelength;
- photoperiod
- type of soil / minerals {concentration and type;
- humidity ;
- pH ;
- moisture of ground ;

Other variables can also include:

- oxygen concentration and carbon dioxide concentration
- age / storage of seeds
- genetic type / source of seeds
- density of planting the seeds
- volume of water used for watering the plant

3. **Suggest how each variable can be controlled or monitored**.

4. **Why scientists are interested in building greenhouses?**

Maintaining environmental control in the greenhouse can be demonstrated. For example, the need to control temperature, lighting, humidity, and even CO_2 levels. Maintaining a balanced environment within your greenhouse will require the use of fans, venting systems, heaters, and monitoring CO_2 levels. It is important to discuss the value of greenhouses for science/research and for the economy.

5. **How do you build a greenhouse?**

This question can link biology with chemistry / physics and technology. Construction and materials range from simple, lightweight materials, such as, PVC piping and a plastic covering for a cold frame style greenhouse that needs no heat. This question needs to elaborate framed construction and glass panels requiring venting and exhausts systems. Framing material may be PVC pipe, wood, or aluminum. PVC frames are not strong enough for areas that receive a lot of snow or high winds. Choice of covering material also needs to take into consideration the weather and seasonal extremes of your area

Exercise 3

To discuss and evaluate both the validity and the reliability of the outcomes of the designed experiments

Introduce the topic: The idea behind reliability is that any significant results must be more than a one-off finding and be inherently repeatable. Other researchers must be able to perform exactly the same experiment, under the same conditions, and generate the same results. This can reinforce the findings and ensure that the wider scientific community will accept the conclusions. Without this replication of statistically significant results (this will apply to higher level biology students), the experiment and research cannot fulfil all of the requirements of testability. This prerequisite is essential to a hypothesis establishing itself as a tentatively accepted scientific truth.

A possible question that a teacher may ask the students include:

Describe what effect a non-controlled abiotic factor (variable) could have had on the results, if it had not been controlled.

Activity 3

THE SCIENCE OF TAXONOMY

Stages of learning cycle	Activity
Engagement	X
Exploration	X
Explanation	X
Extend - Elaborate	X

Learning aims:

- To identify living organisms in the local ecosystem
- To develop observation and interpretation skills
- To construct keys using common features of organisms
- To inquire about scientific classification –taxonomy- of organisms
- To inquire about the life cycle of a living organism
- To inquire about the role of an organism in the ecosystem
- To use genetics to identify common features of organisms
- To discuss the theory of evolution based on DNA homologies

Subjects: Biology, chemistry and technology

Materials:

In the field

Beating Stick and Net

Aspirator

Killing Tube

Light Trap

Keys

Camera

Container

In the lab

Dissecting Microscope

Compound Microscope

Scanning Electron Microscope

DNA Sequencing homologies

Suggestions for use:

Introduce the topic: The biodiversity of planet Earth is the total variability of life forms. Currently about 1.9 million species are known, but this is thought to be a significant underestimate of the total number of species. Every year, thousands of new species are discovered. Biologists use characteristics of each newly discovered species to classify organisms having similar characteristics. A classification system is used to assign a single universal name to each organism. Biologists in the field have to use their observation and interpretation skills to make deductions about the organisms they discover. This lets them build up an accurate picture of the role of the organism in its environment, how they interact with their surroundings and what threats they may face now or in the future.

Exercise 1

- Allow a team of five students to observe the environment around them. The students must use a field notebook to sketch the organisms that they discover, and take notes on their features including shape, coloring, and behavior. The students must write down when and where they found the organism, and any interesting information about its behavior. They must learn to be as precise as possible. If you can, use a field guide or a specialist (e.g., botanist, forester, zoologist) to identify what kind of organisms they have found. Let the students know that they must keep track of any questions that occur to them.
- Discuss with the team why the organism must be kept alive. If they capture a live insect, and they want to observe it for a short while before setting it free, they must put it in a clear container with enough room for it to fly around and to breathe.
- Return the organism to its natural habitat.
- Allow the students to take a photograph of any interesting organism and to start a photo album.
- Without the right tools, insects can be tricky to catch. Ask the students to search the network for homemade bug-catching devices they can make by themselves.

- Use a stereoscope or a microscope in the laboratory to identify any relevant characteristics.
- Record the characteristics of the organism.

Possible Questions:

1. Classify the organism you have discovered into one of the five kingdoms listed below:

Prokaryotes	Small, simple, single cell, nucleus has no membrane.
Protoctista	Large single cell, nucleus is enclosed by a membrane.
Fungi	Multicellular, thread-like with specialized cells.
Plants	Multicellular, have specialized cells, do not have means of locomotion.
Animals	Multicellular, have specialized cells, have their own means of locomotion.

Students can be asked to raise questions that help them to

- identify living organisms in the local ecosystem
- observe
- inquire about scientific classification –taxonomy- of organisms so that they can learn about the life cycle of a living organism .

Indicative questions are:

2. Can you suggest what the organism under investigation eats, or how it gets its food?

3. Describe the habitat that the organism occupies.

4. Is it likely to be active at night or during the day?

5. a) Write the taxonomy of the species that you have discovered

- kingdom
- phyla
- class
- order
- family
- genus
- species

b) Its scientific name is ……………………………………………

c) Its common name is …………………………………………….

d) Who proposed a new system of classification?

Exercise 2

Construct a dichotomous key device that can be used to easily identify an unknown organism.

Introduction; The word dichotomous comes from two Greek words that together mean, "divided in two parts." A dichotomous key consists of a series of two part statements that describe characteristic of organisms. At each step of a dichotomous key, the user is presented with two choices. As the users make a choice about a particular characteristic of an organism, they are led to a new branch of the key. Eventually the users will be led to the name of the organism that they are trying to identify.

Exercise 3

Ask the students to inquire in the website for information about the role of the organism they have identified in the ecosystem.

- Gather responses and subsequent questions from students with little comment or direction.
- Allow students to collaborate in their team
- Student teams gather data.
- Re-evaluate question based on new data from all the teams
- Students present findings as an oral presentation, a poster presentation or an evaluative write-up.

Possible questions that will help the students inquire about the role of their chosen organism are :

1. The space where an organism lives and the role an organism plays within its ecosystem is referred to as a
   A) sampling
   B) population
   C) niche
   D) biome

2. An organism that creates its own food is called
   A) a producer
   B) a consumer
   C) a scavenger
   D) a decomposer

3. A consumer is
   A) an organism that produces its own food
   B) an organism that does not need food to survive
   C) an abiotic organism
   D) an organism that cannot produce its own food

4. Herbivores, carnivores and omnivores are
   A) plants, animals and micro-organisms

B) three types of consumers
C) three types of producers
D) three of British Columbia's 10 eco-provinces

5. An organism that eats decaying plants and animals is called
   A) a decomposer
   B) a parasite
   C) a carnivore
   D) a scavenger

6. Parasitism, commensalism and mutualism are
   A) three examples of producers
   B) the three main types of symbiotic relationships
   C) the three main types of ecological relationships
   D) three examples of abiotic interactions

7. Which of the following is a symbiotic relationship where one partner benefits and the other does not benefit or lose from the relationship?
   A) commensalism
   B) mutalism
   C) parasitism
   D) decomposition

8. Which of the following is a symbiotic relationship where both partners benefit?
   A) mutualism
   B) parasitism
   C) commensalism
   D) symbolism

9. Which of the following is a symbiotic relationship where one partner benefits and the other is harmed?
   A) commensalism
   B) mutualism

C) symbolism
D) parasitism

Study visit

Genetics as well as simple observations are used in classification today. Visit a genetic institute to investigate how DNA analysis can provide evidence in a taxonomic study.

Introduction: In modern biology, it is not considered satisfactory to consider adaptations, evolution, speciation and physiology as autonomous topics, but an appreciation of other disciplines, such as biochemistry, is essential. The study of molecular evolution by comparing protein and gene sequences can integrate biology with chemistry and Physics.

Discuss the theory of evolution based on DNA homologies

Activity 4

FLOWERING PLANT REPRODUCTION

Stages of learning cycle	Activity
Engagement	X
Exploration	X
Explanation	X
Extend - Elaborate	X

Learning aims:

1. To learn how to draw a biological diagram using a flower from their local ecosystem
2. To understand the significance of biological magnification
3. To relate the structure of a flower to seed production, whilst learning relevant terminology, such as, pollination, fertilization. To identify pollen grains using microscopy
4. To understand the structure of seeds
5. To evaluate the methods used by seed banks in the conservation of endangered plants
6. To inquire about the life cycle of a named insect and its role in pollination
7. To collect pollen from flowers and observe it under a microscope
8. To inquire about the effects of Global warming in seasonal flowering, pollination and seed biology
9. To design and perform an experiment to investigate the time that they can store selected seeds

Subjects: Biology, physics and technology

Materials:

- Hand lens
- Pencil
- Ruler
- Flowers

- Seeds
- Pollen grains
- Microscopes
- Stereoscopes
- Camera

Suggestions for use:

Introduce the topic: The floral industry attracts both the artist and the scientist. The floral industry involves flower production, distribution, design, retailing, operations, marketing, publishing, importing, research, teaching, greenhouse design and engineering, climate control systems engineering, soil analysis, sales and pest management. Field-work with a theme of ”wildflower hunting” is a wonderful way to get students to understand how a tiny flower can be such an important part of an entire ecosystem, thus promoting sensitivity to sustainability as well as teaching students about wild flower ethics. Students need to understand that wildflowers are fragile and many wilt and perish soon after being picked. Yet, the loss of an unknown to be endangered flower is not the only reason why wildflowers should not be picked. Students need to realize that wildflowers support entire ecosystems for pollinators, birds, and small animals on a micro scale. Insects, small birds, and animals depend on seeds, nectar, and pollen for their food supply and life support system. It may be a new idea to introduce students to some pollinators which are not very mobile, have very small home ranges, or depend on just one species of plant and die once their habitat has been destroyed.

Basic biology of flower reproduction

Sexual reproduction in plants occurs when the pollen (male sex cell/ gamete) from an anther is transferred to the stigma in a process called pollination. Self-fertilization occurs when pollen fertilizes the egg (female sex cell/ gamete) found inside the ovule of the same flower. The transfer of pollen to the stigma of an entirely different plant, a process called cross-pollination, may lead to cross-fertilization when the pollen fertilizes the egg inside the ovule.

When the egg inside an ovule is fertilized, the ovules will develop into seeds. The petals of the flower fall off leaving only the ovary behind, which will develop into a fruit. There are many different kinds of fruits, including apples and oranges and peaches. A fruit is any structure that encloses and protects a seed, so fruits are also "helicopters" and acorns, and bean pods. When you eat a fruit, you are actually eating the ovary of the flower.

Exercise 1

To learn how to draw a biological diagram using a flower from their local ecosystem
To understand the significance of biological magnification
To relate the structure of a flower to seed production, whilst learning relevant terminology, such as, pollination, fertilization.

The students can be asked to draw on the blank (next page) a selected flower (magnified approximately 5X) found in their local ecosystem (link with learning aims of activity 3: inquiring for the name of an unknown plant) indicating clearly the reproductive organs.

Instructions for a biological drawing

1. Use a pencil and unlined paper when drawing a biological diagram. Position the diagram at the center of the page. Draw only what you actually observe, as opposed to what you think you should be seeing.
2. Use sharp single lines to represent an object. Do not use soft lines characteristic of sketches. Make the illustration large, so that various parts of the specimen are easily distinguishable.
3. Represent darker areas of an object with stippling or dots. Do not shade any areas of the diagram.
4. Print when labelling the different parts of the diagram. Do not use the plural form when identifying a single part or object. Draw a straight line from each label to the part or object it describes. Make sure that these lines do not cross or overlap.
5. Keep in mind that the first part of a scientific name, or the genus name, must be capitalized. The second portion, or the species name, begins with a lower case letter--except when used in the diagram title. Underline scientific names.
6. Write the title of the diagram in capital letters and center it. Remember that the title must be concise and accurately explain the subject of the illustration.

7. Draw scale bars indicating the length and width of a specimen. A scale bar is a straight line that represents the relationship between space on your page and the actual space occupied by the specimen.
8. For microscopic specimens, indicate the magnification at which you observed the object through a microscope. Write this information in one of the corners of the page.
9. Use sharp single lines to represent an object. Do not use soft lines characteristic of sketches. Make the illustration large so that various parts of the specimen are easily distinguishable.

Read more: How to Draw a Biological Diagram | eHow.com

http://www.ehow.com/how_5695958_draw-biological-diagram.html

Drawing Magnification (D.M.)

D.M. = drawing length actual length

__Further information is given to the students in order to obtain uniform drawings and labeling of the reproductive organs of the flower__

The female reproductive structures are called carpels. In most flowers, the carpels are fused together to form a pistil. The stigma at the top is often sticky and is where the pollen attaches. Draw the stigma (J). The style is the long tube that attaches the stigma to the ovary. Each pollen, found on the stigma, will grow a tube, down the style, towards the ovule (s). Each ovule, contains an egg, is stored in the ovary. Draw the style (K), and the ovary (L). Draw the ovules (O). **Be sure to draw only what you see (refer to biological drawing instructions above).**

__Plants can only fertilize eggs of the same species. Special chemicals prevent sperm from fertilizing the eggs of flowers that are not of the same kind.__

The male reproductive structures are called the stamens. Draw and label the stamens (H). Each stamen consists of an anther (A), which produces pollen, and a filament (F), which supports the anther. Pollen produced by the anther is carried by insects, or other animals, to the pistil of another flower where it may fertilize an egg.

The receptacle is the part of the branch on which a flower forms. Draw the receptacle (B). Sepals are leaf like structures that surround and protect the flower before it blooms. Draw the sepals (C). Petals are the colorful part of the flower that attracts insects and even other small animals, such as mice, birds, and bats. Draw the petals (D).

All flowering plants have flowers, but some are not brightly colored. The petals of these flowers are reduced or absent and the plant relies on the wind or water for pollination.

Questions

Identify a flower which has a visiting insect .

Why do insects visit flowers?

Draw a circle around the characteristic of the flower

A. Large petals
B. Small petals
C. Hanging anthers
D. Small anthers
E. Presence of large numbers of pollen
F. Presence of small numbers of pollen

Additional information

Identification of pollen can be used in criminology investigations-forensics- and also to study climate change. Pollen grains and spores form the basis of palaeoclimate reconstruction, generally referred to as pollen analysis, or palynology. Where pollen and spores have accumulated over time, a record of the past vegetation of an area may be preserved. Often, changes in the vegetation of an area may be due to changes of climate. Interpreting past vegetation through pollen analysis may therefore offer a form of palaeoclimatic reconstruction. Sediments containing fossil pollen have been taken from peat bogs, lake beds, alluvial deposits, ocean bottoms and ice cores. Unfortunately, the difficulties associated with pollen analysis have meant that most palaeoclimate reconstructions have proceeded in a qualitative way only - the climate was wetter/drier or warmer/colder.

Exercise 2

Collect pollen from flowers and observe it under a microscope

Introduce the topic;

Pollen grains produced by different species of plant have a distinctive appearance. This allows us to work out what type of plant they came from, which in turn tells us the plants that used to grow in the area. We can observe the distinctive features of different types of pollen using a microscope. This helps us to identify what they are. Two useful features for identifying pollen are pores and furrows. Pores are holes in the surface of a pollen grain. Furrows are slits in the surface of a pollen grain.

Safety: Be considerate of sensitivity to pollen

Follow the methodology below describing how to collect pollen from flowers and observe it under a microscope

1. Place a dry, sterile, open bag/container under the opening male flowers. Gently tap the stem with a finger. The pollen will slowly settle into the container. (If you are careful, only a few flowers will fall into the mix.)
2. Remove any flower/plant parts that land in your container with the pollen. Tap them off gently before removing, to recover the pollen. (Moisture = BAD)
3. Dilute pollen with sterilized flour at a four-to-one ratio. This will allow more coverage if required (Optional)
4. Refrigerate until use. (Viable for around 3-5 days)
5. Immediately change your clothing and clean up before going near your female plants.
6. Use a paint brush to transfer some pollen from one of the flowers onto a slide and cover with a cover slip.
7. Using x400 magnification count the number of pollen grain visible in the field of view.
8. Using a different slide, transfer some of each type of pollen onto the slide. The pollen may stick better if the slide is slightly damp.
9. Observe, measure and draw each type of pollen at x400 magnification. Take care in measuring, so that you measure the pollen grain only and not any air bladders that may be present.

Extended possibilities for higher classes

- Identify the structural features of a wind pollinated flower and explain their role
- Identify the structural features of a maize fruit and explain their role
- Measure and calculate size of pollen using a microscope graticule
- Calculate the rate of germination of pollen tubes.

Exercise 3

To inquire about the life cycle of a named insect and its role in pollination
To inquire about the effects of Global warming in seasonal flowering, pollination and seed biology

Ask the students to read the passage below:

Changes in habitat or habitat loss pose the greatest threat to migratory pollinators. A single change along a migratory route can have long lasting and rippling effects that spread beyond any one population of pollinators.

“Bats, hummingbirds, moths and butterflies are among the pollinators that seasonally migrate long and short distances between mountain ranges, regions and countries. Their migratory routes are often well-defined "***nectar corridors***" where the sequence of flowering plants over a season offers pollinators sufficient energy to sustain their journey. Many of these nectar corridors are no longer fully intact. Land conversion has eliminated many floral resources over 20 to 60 mile segments, in some cases longer than the distance energy-depleted pollinators can fly in one day." (Our Forgotten Pollinators: Protecting the Birds and Bees. By Mrill Ingram, Gary Nabhan and Stephen Buchmann.)

Questions

1. Investigate the life cycle of an insect or another organism that is involved in pollination or requires a specific plant to feed that you have identified in the field study.
2. Inquire about the possibility of new emerging trends in flowering, linking with Global Warming (Refer to the activity of taxonomy).

3. Inquire whether the pollinator that you have identified follows a migratory route of long and short distances between mountain ranges, regions and countries.

Exercise 4

To understand the structure of seeds

To evaluate the methods used by seed banks in the conservation of endangered plants

Use the web link and the passage below to introduce research that takes place in the Royal Botanic Gardens(RBG) in Australia:

http://www.rbgsyd.nsw.gov.au/science/ Horticultural_ Research/seed_biology

The seed research program is integral to the Seed Quest project, and has provided strong collaborative links to other Millennium Seed Bank partners via projects, such as seed longevity testing. Seeds of many Australian species are expected to be long-lived in storage, with groups, such as, acacias, eucalypts, and casuarinas topping the list. However, the longevity of seeds of most species is unknown. In order to address this, the RBG are collaborating with Australian partners of the Millennium Seed Bank Project to rank a wide range of species according to the longevity of their seeds (Martyn, 2009). The ranking is useful for prioritizing, which species must be cleaned and stored first - a key task at the end of a busy collection season. The ranking will determine which species' seeds are likely to survive for long periods in storage, help us set appropriate re-testing schedules for banked seeds, and work out which species will need to be regenerated or replenished regularly with fresh seed.

Experimental work for this project has concluded in late 2009, with data analysis and a draft publication was produced .

Question:

Inquire in the network about the final status of the publication?

Additional information

Research also informs the germination testing program within the **SeedQuest** in **New South Wales** (NSW) Seedbank. More than 900 germination tests have been conducted during the SeedQuest NSW project, with more than 680 tests exceeding 75% germination. A review of seed quality, viability and germination has been conducted on NSW Seedbank collections in the family Rutaceae, confirming that these parameters are highly variable and reinforcing the need to take these issues into account for ensuring optimal regeneration of plants from conservation seed banks (Martyn, Seed, Ooi and Offord 2009). Threatened species in the family Rutaceae were more likely to have low seed fill than common species, while viability and germination were similar. This suggests that poor seed fill is a contributing factor to threat status and is an important parameter to measure.

In addition, two short publications describing seed collection methods in Zieria arborescens (Frith *et al*, 2009). have been submitted to a restoration-focused journal.

Question:

Inquire in the network about the final status of the germination testing program.

Additional information

Significant efforts have been made to educate students and seed bank practitioners in best-practice techniques for seed handling, storage and germination. This extension was made through seminars, formal training, community talks and seedbank tours, and the drafting of updated guidelines for 'Plant Germplasm Conservation in Australia' (Offord and Meagher 2009).

Exercise 5

Ask the students to design and perform an experiment to investigate the time that they can store selected seeds (e.g. from a tomato fruit) without loss in the germination rate.

Further information

Seeds are considered viable if they can germinate and produce a radicle (young root), which protrudes through the seed coat (testa). However with time, all seeds lose their ability to germinate. Scientists operating in a seed bank need their seeds to remain viable while in storage. Find the Seed Bank Projects in your country, which conduct research to determine the longevity of the seeds they store. Draw a flow chart to summarize the processes involved in the storage of seeds in a seed bank. Students should realize that seed banks storing seeds have a role in scientific research and in reintroducing species to the wild.

Possible questions

1. Inquire about the structure of a seed. Draw seeds or fruits of different plants.
2. From the appearance of the seed structures, make a guess at how each one is dispersed giving reasons for your answers.
3. What are the advantages for a plant having an effective method of seed dispersal?
4. Why is it useful for researchers to know the longevity of the seeds?
5. Why may seeds lose their viability with time?
6. Evaluate the methods used by seed banks in the conservation of endangered plants.
7. Inquire about the longest living seed. Your inquiry will require a web search engine.

Activity 5

PLANT EXTRACTS AND ANTIBIOTICS

Stages of learning cycle	Activity
Engagement	X
Exploration	X
Explanation	X
Extend - Elaborate	X

Learning aims:

- To implement an appropriate methodology for safely obtaining a plant extract
- To investigate the effect of different plant extracts/ antibiotics on bacteria
- To identify safety parameters

Materials:

Plant extracts

Agar plate seeded with known bacteria

Sterile Pasteur pipette

Bunsen burner

Beaker of disinfectant, 1%

Virkon or equivalent

Bench spray of disinfectant, 1%

Virkon or equivalent

Bactericidal soap

Paper towels

Marker pen

Forceps

Plant extract/ antibiotic/ impregnated paper discs

Adhesive tape

Incubator set at 30 °C

Suggestions for use:

Introduce the topic: Even though pharmacological industries have produced a number of new antibiotics in the last three decades, resistance to these drugs by microorganisms has increased. In general, bacteria have the genetic ability to transmit and acquire resistance to drugs, which are utilized as therapeutic agents. Such a fact is a cause for concern. Therefore, actions must be taken to control the use of antibiotic, develop research to better understand the genetic mechanisms of resistance, and to continue studies to develop new drugs, either synthetic or natural. The ultimate goal is to offer appropriate and efficient antimicrobial drugs to the patient.

According to World Health Organization, medicinal plants would be the best source to obtain a variety of drugs. About 80% of individuals from developed countries use traditional medicine, which has compounds derived from medicinal plants. Therefore, such plants should be investigated to better understand their properties, safety and efficiency.

In Argentina, a research tested 122 known plant species used for therapeutic treatments. It was documented that among the compounds extracted from these plants, twelve inhibited the growth of Staphylococus *aureus*, ten inhibited Escherichia coli, and four inhibited Aspergillus *niger* and also reported that the most potent compound was one extracted from Tabebuia *impetiginosa*. Hence, more studies pertaining to the use of plants as therapeutic agents should be emphasized, especially those related to the control of antibiotic resistant microbes.

Exercise 1

Extraction Methods

Ask the students to inquire about the methodology of preparing safely plant extracts from a plant that they have discovered in their local ecosystem .

Further information (it may be used to link chemistry with biology)

Advice abounds for the amateur herbalist on how to prepare healing compounds from plants and herbs (reference: Clin Microbiol Rev. 1999 October; 12(4): 564–582. PMCID: PMC88925.Plant Products as Antimicrobial Agents Marjorie Murphy Cowan).

Water is almost universally the solvent used to extract activity. At home, dried plants can be ingested as teas (plants steeped in hot water) or, rarely, tinctures (plants in alcoholic solutions) or inhaled via steam from boiling suspensions of the parts. Dried plant parts can be added to oils or petroleum jelly and applied externally. Poultices can also be made from concentrated teas or tinctures. Scientific analysis of plant components follows a logical pathway. Plants are collected either randomly or by following leads supplied by local healers in geographical areas where the plants are found. Initial screenings of plants for possible antimicrobial activities typically begin by using crude aqueous or alcohol extractions, and can be followed by various organic extraction methods. Since nearly all of the identified components from plants active against microorganisms are aromatic, or saturated organic compounds, they are most often obtained through initial ethanol or methanol extraction. In fact, many studies avoid the use of aqueous fractionation altogether. The exceptional water-soluble compounds, such as polysaccharides (e.g., starch) and polypeptides, including fabatin and various lecitins, are commonly more effective as inhibitors of pathogen (usually virus) adsorption and would not be identified in the screening techniques commonly used. Occasionally tannins and terpenoids will be found in the aqueous phase, but they are more often obtained by treatment with less polar solvents.

Exercise 2

In this activity, the students will be testing the effectiveness of several types of plant extract/ antibiotics/, which they have produced from plants selected from their local ecosystem,. on bacteria The standard method of doing this is to put discs of blotting paper soaked in the various extracts / and control antibiotics onto an agar plate that has been inoculated with the bacteria.

Question

Ask the students to inquire about the safety parameters that they need to apply during this investigation. Safety is an important aspect of this experiment and guidance on microbiology safety is essential.

The students need to investigate the following considerations:

Eye protection.

Pathogenic microorganisms

Aseptic techniques

Antibacterial disinfectant

Allergic reactions

First aid

Exercise 3

Ask the students to perform an experiment, which investigates the effect of different types of antibiotic/ plant extracts (the independent variable) on bacteria. Include details of a suitable dependent variable and how it can be measured.

Methodology

1. Wash your hands with the bactericidal soap. Spray the working area thoroughly with the disinfectant spray and wipe with a paper towel after waiting for the disinfectant to act (10 minutes with Virkon, longer with other disinfectants).
2. Prepare an agar plate seeded with bacteria. This may have already been done for you. Label the Petri dish on the base at the edge with your name, the date, and the type of bacterium it is inoculated with.
3. If not already autoclaved, sterilise the forceps by flaming them and allow to cool. Use them to pick up a plant extract / antibiotic disc. Raise the lid of the Petri dish and place the plant extract impregnated paper disc firmly in the centre of the agar; if individual discs are used they will need to be spaced evenly around the dish.
4. Tape the dish securely with two pieces of adhesive tape (but do not seal it completely), then incubate it upside down for 48 hours at 30 °C.
5. Wash your hands with bactericidal soap and clean the bench again using the Virkon spray.
6. After incubation, look carefully at the plate but do not open it. Where bacteria have grown, the plate will look opaque, but where the antibiotics have inhibited growth, clear areas called inhibition zones will be seen. Measure the diameter of the inhibition zones in millimetres and use this information to decide which antibiotic is most effective at inhibiting the growth of the bacterium.

A clear area where the bacterial growth has been inhibited should surround each of the discs. The simplest measurement would be to use a ruler and measure the diameter of the cleared area. It is straightforward to compare the results of different treatments if the clear areas are perfect circles. If the diameter varies, one possibility is to measure at the widest point. For a more precise measurement, the area of the clear zone would have to be determined. Students may suggest possible ways of doing this.

7. Collect data from other members of the class who used the other bacterial cultures.
8. Write a brief report of the results, comparing the different antibiotics, and the effects on the different bacterial cultures. Do some research to find out a bit more about the antibiotics that were effective against the bacterium you used.

Possible questions:

1. What factors determine the diameter of the inhibition zones?
2. Suggest how named variables you have could be controlled.
3. Discuss the reliability and validity of the experiment

WP3
Water in the Life of Man

European Science and Technology in Action Building Links with Industry, Schools and Home

Work package 3
WATER IN THE LIFE OF MAN
Teacher Information

European Science and Technology in Action: Building Links with Industry, Schools and Home

Main partner: **CUNI**

Version: 4.0 final

The development of the package was made by Čížková, Radvanová & Nedomová, CUNI

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A. Teacher Information

I. Unit description

The basis of every life is water. It is the main component of organisms. If there were no water, plants would die, animals would die of thirst. Water affects both living and inanimate nature. Water is really very important. People could not live without water. Today, every home has plenty of water, which is supplied by watermains or pumped from the well. We can buy bottled water. But from where is water taken? How is it that it is clean and drinkable? What would happen if nothing like this existed?

In this unit we will learn where the clean water is taken from, why it is necessary to supply fluids and what amount we should daily drink. We will explore what happens to water in our body. And compare which beverages are the most suitable. Further we will learn what the importance of kidneys for our life is and what would happen if they failed working.

Student level:

Students aged 12 – 18 years

Discipline(s) involved:

Biology, geography, chemistry, physics, mathematics, technology

Estimated duration: 12 – 14 hours

Goals:

In terms of our requirements, the main topic of the unit is fluid intake, a relationship between man and water and importance of kidneys for the life of man. Students will think about their fluid intake and learn about the process the water undergoes before it gets to our house e.g. in the form of Coca Cola. In addition they will learn how our body processes the fluid supplied and what the role of kidneys in this process is. While working, students will gain knowledge of human biology, geography, chemistry, physics and also technology.

Outputs:

After completing the unit, students should be able to:

- Ask questions and distinguish between those that can be answered on the basis of investigation and those that cannot be answered in this way.
- Plan, perform and evaluate the experiment or verification.
- Apply the obtained knowledge to the issues of everyday life.
- Discuss the given topic.

- Monitor and record their fluid intake, analyse it and draw conclusions.
- Discuss the importance of water and explain where the water is taken from.
- Explain the processes, the result of which is clean water.
- Describe the role of water in the individual human organs.
- Analyse particular types of beverages and decide why the beverage is suitable/unsuitable.
- Summarise the information on the issues obtained from the professional in the given discipline.
- Clarify the production of final urine and verify this assumption.
- Draw schematically the functioning of the artificial kidney.
- Explain the principle of haemodialysis and write a journal paper on this topic.
- Develop good habits of renal care.
- Evaluate the importance of kidneys for the life of man.

II. IBSE Character

In this unit, students have the opportunity to discuss, search the information, ask questions, answer them and evaluate their results. All activities have solutions, but each student can have different results, which leads to discussions among students. Some activities are focused on working with texts and pictures or own experiments. Others include excursions, on the basis of which the students summarise their findings or ask themselves further questions and plan possible solutions.

III. Pedagogical Content Knowledge

Scientific characteristics of content

Topic of water represents four interconnected planes.

1. <u>Importance of water</u>: Water in the human body performs many important and unique functions - for example, it is an essential component of cells, an important component of biochemical reactions, solvent of substances and further it serves to transmit the nutrients and other necessary substances (hormones, metabolites, antibodies, ...) or creates the systems equalizing the temperature of the body.

2. Drinking water: As drinking water we can consider healthy water, which even through a continuous consumption does not cause diseases or ill health by the presence of microorganisms or substances affecting by acute, chronic or late effects the health of individuals and their offspring. In addition, its sensory properties and quality do not impede its use for drinking and sanitary needs of individuals. Currently, drinking water is obtained by treatment of surface water in waterworks or water from underground springs or wells.
3. Absorption of water in the body: Water taken in beverages and food or formed in metabolic processes is absorbed in the small intestine, and a lesser portion also in the colon. This is done on the basis of different concentration, osmosis, in the presence of minerals of sodium and potassium. Unused, spent, water is excreted from the body through saliva, gastric or pancreatic juice, bile, intestinal secretions and faeces. The main dispensing of water is done through the urine, kidney filtration, vapour in breathing or evaporation and skin sweating.
4. Haemodialysis: This method allows removing toxic waste products of metabolism and excess water from the blood using a special dialysis unit popularly known as "artificial kidney". Patients with kidney failure usually come to haemodialysis three times a week to the so-called dialysis centres.

The aim is that students gain a comprehensive view of water as an important component of the human body through practical tasks that require investigation thinking from students. The main topic of the unit is the production of drinking water and haemodialysis. Production of drinking water in the waterworks has several basic phases – sedimentation, trapping of impurities with the use of chemicals, filtration through a sand filter, disinfection. The principle of haemodialysis is the diffusion of solutes through a semipermeable membrane. Opposite direction flow is used when a sterile dialysis solution of mineral ions and glucose flows along the membrane in the direction opposite to blood flowing.

Didactic characteristics of content

Research shows that most of the experience and knowledge that students acquire in biology teaching have no real meaning for their real lives. Therefore, the topic of this unit is focused on sound fluid intake, which concerns every individual any day. This should increase the students' interest. The unit is further complemented by the role of dealing with the structure and function of artificial kidney in an effort to raise awareness among students about the problems of global growth in hidden nephrological diseases and the need for their early diagnosis.

The biological content in the unit is primarily related to the excretory system, circulatory system and digestive system. Actually, the unit may include all organ systems in which there is some form of water. The unit also offers the activities that require knowledge of chemistry, such as contents of organic or inorganic substances in beverages, pH, and osmotic phenomena in the cell. Further, knowledge of physics, mathematics and geography is also important.

IV. Industrial Content Knowledge

The industrial and commercial sectors include mainly industrial plants, research and educational institutions. Establishing a closer co-operation with them can be realised at two levels. At the local level, the centres working with aids for patients with renal impairment can be contacted; these aids have been developed by scientists or technicians. In particular, these are the dialysis centres that work with artificial kidney. Further, it is possible to organize a study visit to waterworks or bottling plants of water or Coca-Cola; the latter enjoys a great popularity among students. The following level is to establish contacts with research institutes and plants that are mainly engaged in the development and production of dialysers as the most important part of the artificial kidney. Another option for establishing cooperation with various plants is to invite the person who works in this area to the class, or at least to make an e-mail contact.

Some important websites:

http://eagri.cz/public/web/file/130548/VUME_2_UV_2010.pdf.

http://www.bbraun.com/

http://www.domaci-dialyza.cz/seznam-dialyzacnich-center?kraj=7

http://www.coca-cola.cz/onas-vyroba

V. Learning Path(s)

Optimal size of the group: 25 students

We recommend using cooperative forms of work in groups or in pairs. As a source of information you can use textbooks, the Internet or other scientific literature.

List of activities

Activity	Subject
1. Discussion over the importance of water	Biology
2. My water intake	Biology
3. Which water tastes better, bottled or tap water?	Technology, biology, chemistry
4. Waterworks or production of drinking water	Technology, biology, chemistry
5. Can we get drinking water?	Biology, geography
6. Analysis of beverages	Technology, biology, mathematics
7. How does the water travel through our body after drinking?	Biology
8. How is finite urine formed?	Biology, chemistry
9. Importance of kidneys for life	Biology
10. Is it possible to develop an artificial kidney?	Biology, chemistry, physics, technology
11. A visit to a dialysis centre	Biology, chemistry, physics, technology
12. World Kidney Day	Biology

Activity 1 – The teaching unit will start from the discussion. Students should be aware of the fact that every individual has his/her own water intake and that it can differ from the values referred to in the literature. Discuss how and how much fluid disappears from the body and whether we will really take so much fluid. Think about the impact of the lack of fluid on us, what is related to the availability of beverages and water at all. After this discussion we can move to the following activity.

Activity 2 – From the discussion, the students would like to know their fluid intake, which should be encouraged by this activity. Here the questions are prepared for them; they should be interested in the answers. They themselves will determine for how long it would be good to monitor their fluid intake to get good results.

Activity 3 – In this activity, students are motivated by the introductory text. This is followed by the questions that lead to reflection on how the topic of the introductory text is related to their life.

Activity 4 – This is an excursion to waterworks. Students should agree upon the date of the excursion and accordingly they should prepare themselves for this excursion.

Activity 5 – Students encounter the problem and have a few tools. They should establish a hypothesis and verify it subsequently.

Activity 6 – In this activity, students have beverage packaging (they may bring their own). The aim is to evaluate the appropriateness and inappropriateness of beverages for the human body. And think about whether to incorporate this beverage into the water intake.

Activity 7 – In this activity, students will use their knowledge or the working text or other literature to be able to solve tasks.

Activity 8 - In this activity, students will use their knowledge or scientific literature, or use the Internet to be able to solve tasks. Their findings will subsequently be verified in practice.

Activity 9 – In this activity, students establish a hypothesis, which is then, based on the submitted working text and their present experience, verified. Their findings are factually argued.

Activity 10 and 11 – Students should appreciate the benefits of technology development for human life. In case of excursions to the dialysis centre, students should agree upon the date of the visit and accordingly they should prepare themselves for this visit.

Activity 12 – Students search for the information needed to solve the task, and according to pre-agreed criteria they design promotional materials aimed at the prevention and diagnosis of nephrological diseases.

VI. Assessment

To assess the results of IBSE is not an easy task and it takes a long time. The teacher should be aware that the student learns new things through these activities, and therefore the teacher should not make comments, which could cause a loss of motivation. In addition, the teacher should ensure a safe environment in the classroom; i.e. nobody should laugh when the other student made a mistake. The possibilities of assessment differ from activity to activity. Not only knowledge is assessed, but first of all the skills and attitudes. It is necessary to proceed with students in slow steps through the individual phases of IBSE, always to provide a feedback on their progress through a formative assessment, not grading.

The output of activities 1, 9, 10, 12 is to develop the materials that can be used when working in other activities. After these activities, students can discuss whether the prepared materials contained all the important information, what their quality was and whether anything was missing or was irrelevant, etc. The activities 2, 3, 5, 6 to 8 are related to the application of knowledge and understanding of context. Each activity should be concluded with a feedback, on the basis of which the teacher can assess with the students to what extent the new information on water has been built into their own ideas and knowledge. The teacher can assess whether the student

- Is able to list the rules that must be followed as for the proper water intake
- Is able to explain how fresh water is obtained
- Is able to explain what is happening to water in different parts of the human body
- Is able to describe how the final urine is formed
- Is able to appreciate the importance of kidneys for life
- Is able to describe the principle of functioning of artificial kidney

VII. Student Learning Activities

Activity 1 Discussion over the importance of water

Learning Aim:

- *Students explain why each individual has a different fluid intake, which can differ from the values given in literature.*
- *Think about the impact of the lack of fluid on the human organism and explain the general relation between the availability of beverages and water.*
- *Create the rules for proper fluid intake.*

Materials:

- *Worksheet*

Suggestions for use:

First the students will be asked the following questions.

- *Why is it important to drink?*

Fluids must be continuously supplied. Enough water ensures the metabolism and excretion of harmful substances arising in the body. The water in our body is in every cell and all biochemical processes are bound to water. Water ensures the absorption of nutrients, their transport to the cells, dissolves and eliminates superfluous products of metabolism, moistens the air we breathe; by evaporation through perspiration it helps the body thermoregulation, regulates the level of the electron and proton in the cells (osmoregulation).

Source: http://www.rajec.com/cz/zdravi/voda-a-lidske-telo/voda-v-lidskem-tele

- *Why is it necessary to continuously supply fluids?*

In order to function properly, an adult human body must excrete every day approximately 2.5 litters of water. The body eliminates water in three ways - in the urine (1 - 1.5 litters per day), in faeces (100-200 ml per day; during diarrhoea there occurs up to 1.5 - 5 litre loss), by respiration (in the form of small droplets in the exhaled air the body loses 250 to 300 ml per day) and through skin (normally we sweat out 500 to 700 ml per day). Therefore we have to supply fluid to compensate for water balance (Suchánek, 1999).

- *What would happen if we did not supply water?*

Lack of water or dehydration causes both acute and chronic problems. Acute dehydration represents the loss of 2% of body weight. This acute dehydration is manifested by headache, fatigue, malaise, decline of physical and mental condition. The loss of such amount causes a performance decrease of 20%.

Children during this acute dehydration may have reduced ability to concentrate on teaching, and this may affect their school results.

Long-term lack of water can cause headaches, constipation as well as serious diseases such as renal disorders, formation of kidney and urinary stones. It also increases the risk of urinary tract inflammation, in the worst cases, occurrence of cancer (rectum or bladder), and cardiovascular diseases (Kožíšek, 2005).

- *How much fluid should we daily take?*

Every day we should get into the body 2 to 3 litres of fluid, but we must not forget that the water entering our body is bound in food, i.e. approximately 900 ml per day. This means that the rest, about 1.5 litres, we have to insert into the body in the form of fluid. This amount should not be drunk at once, but gradually during the day. The need for fluid is an individual matter and depends on many factors, both internal (body weight, activity, composition of food, current health status) and external (temperature and humidity of the ambient environment, the type of clothes ...) (Kožíšek, 2005).

- *How do I know when to drink?*

We are reminded of a lack of fluid by thirst, but do you think that thirst in time points to the need for water? Thirst is a sign that we have already been dehydrated. So to prevent dehydration, we should not follow the sense of thirst. Furthermore, the sense of thirst decreases with age. Another symptom of a lack of fluid is a dry mouth and stale lips (Kožíšek, 2005).

On the basis of discussion, the students create the rules for proper fluid intake:

- It is necessary to drink evenly throughout the day, starting in the morning.
- Every day we should drink at least 1.5 litres of fluid.
- We should not wait for thirst, which is already a manifestation of moderate dehydration.
- Consider which water will be the basis of your fluid intake (it should be tap water or still spring water, the suitability of other beverages vary in relation to the needs of a particular organism, the ongoing activity, health problems, weather, etc.).
- Limit a consumption of larger amount of highly carbonated water.
- If we drink mineral waters, we should try to change them and limit their number.

- Limit the consumption of sweetened soft drinks and Cola drinks.

Increased load needs also increased consumption of fluids.

Possible questions:

- *How long can we endure without fluids?*

Two – three days. Everything depends on the actual conditions.

- *Which beverages are the most suitable?*

The best drink is, of course, clean tap water from waterpipes or a well but also bottled infant and spring water. The appropriate drinks include also fruit and vegetable juice (preferably made from your own fruit and vegetables using a juice extractor) and sugar-free tea, especially green. These stimulate the activities of salivary glands and thus excellently quench thirst, promote secretion of digestive glands and metabolism. Medium and highly mineralized waters are not an appropriate basis for fluid intake and cannot be drunk in worsened state of health, such as kidney stones or high blood pressure. Daily intake of mineral water should not exceed 0.5 litres. It is appropriate to alternate the mineral water. The fluid intake cannot include milk and cocoa; these are rather liquid nutrition (Kožíšek, 2005; Slavíková, 2002).

- *Which beverages are inappropriate?*
- Lemonade, Cola drinks, flavoured mineral waters, energy drinks, etc. The reason for this inappropriateness is the sugar content, which on the contrary increases the sense of thirst. Another undesirable substance is carbone dioxide, which along with organic acids (flavours) damages tooth enamel, causes stomach and digestive disorders, but the recommended dosage stimulates urine production and encourages the digestive system (such as sipped ice cola helps for nausea). Moreover, cola drinks contain caffeine as coffee does. Caffeine increases urine production, so it takes away even more fluid from the body than we are trying to get by drinking. In addition, caffeine promotes children's tendency to hyperactivity, because it encourages the organism. Inappropriate fluids are definitely alcoholic beverages, which do not belong among fluids suitable for water intake. They can only be a tasty supplement of food and their daily consumption should not exceed 0.5 litre of beer or 0.2 litre of wine (Kožíšek, 2005).

Activity 2 My water intake

Learning Aim:

- *Students record their water intake, or how much fluid they take daily, which beverages they prefer, how much urine they approximately excrete.*
- *They will answer the questions in the worksheet.*

Materials:

- *The worksheet with questions and the table, which can be used for data recording.*

Suggestions for use:

Before monitoring their water intake, the students will study the questions below and formulate their hypotheses. Then they will suggest the procedure, which would be used to prove or disprove the hypotheses. They should propose monitoring and recording of their water intake. In the worksheet the students will find a prepared table to record their water intake, but they can propose their own table. The students should agree upon the duration of monitoring, but it is good to propose 4 days - 2 working days and 2 weekend days.

Questions:

- How much fluid do you take per day?
- Do you drink regularly during the day?
- How many times per day do you go to the toilet to urinate?
- What amount of urine per day do you approximately excrete considering the fact that the feeling of urination occurs with the urinary bladder volume of about 300 ml?
- Will there be a difference between the volume of water taken and water excreted in urine? If so, what is the cause of this difference?
- What fluid do you most often drink during one day?

Questions in conclusion:

- What is the difference between your fluid intake and the proper fluid intake?
- As for you, do you have any recommendations?

Possible questions:

- How many litres of fluid have you drunk since your birth?
- How many litres of fluid will you drink in total during your life provided you live long enough until at least 70 years?

- How many swimming pools of 50 m x 15 m x 1.5 m could it be?

  or
- What can be calculated from the observed data?

Activity 3 Which water tastes better – bottled or tap water?

Learning Aim:

- *The first objective is to express the opinion on the scientific level of the text searched in the Internet, to formulate the requirements on the subject – field (scientific) text, or to find another text in the literature or in the Internet, which would meet the requirements on the scientific level.*
- *The second objective is to formulate in own words an assumption, which water is preferred by the students and give reasons. At the end of this activity, students compare types of waters, which they either praise or criticise in terms of taste.*

Materials:

- *Worksheet, samples of bottled and tap water, cups*

Suggestions for use:

First, the students find in the Internet the text * comparing the quality of bottled and tap water. Then there will be a discussion over the requirements on a scientific text in comparison with a popularizing text. We will ask the students what type of water they prefer and why. We can also ask them what type of water is preferred by their parents. On the basis of discussion and retrieved text, students will establish a hypothesis, that would, in their opinion, capture the attitudes of consumer public (this can be restricted to the respective class) to bottled water and tap water. They will justify their assumption.

Then we will ask them how to verify the hypothesis and at the same time to find out whether some people really do not like tap water due to its low quality or whether it is just an imposed feeling under the influence of e.g. advertising. Students should also propose a questionnaire investigation and then exploration of taste quality of the respective samples of water (bottled and tap), whose origin would not be known to the students testing them. After the investigation, when the students made notes as for the respective samples or they evaluated them using a scale, they should learn what the type of water it was. They should compare these results with the hypothesis and draw a conclusion. The results of the individuals can be presented in the table or graph in respect of the whole class.

Note: They can work in pairs, when one of the students will be "taster"and the other "researcher", who will know the respective samples. Or this investigation can be carried out outside the lesson on another sample than that of the student's classmates.

*This text can be found for example on the website: http://www.rozhlas.cz/zpravy/spolecnost/_zprava/637057, http://www.allaboutwater.org/

Possible questions:

Students formulate their own questions. A large amount fo questions arise through this activity.

Activity 4 Waterworks and production of drinking water

Learning Aim:

- *Students will explain the operation and importance of waterworks for the life of man.*
- *They will find out how the waterworks operates, which tasks are performed by the employees and what qualification they should have.*
- *They characterise the individual steps of waterworks operation.*
- *Students describe the individual phases of water purification, from pumping of water from the source, through its consumption, to its return to the nature.*

Materials:

- *Worksheet*

Suggestions for use:

Task 1:

A list of structures for water treatment in the Czech Republic can be found at http://eagri.cz/public/web/file/130548/VUME_2_UV_2010.pdf. (It is also possible to find out a similar website in the respective mother tongue). Students will get information about when the excursion to waterworks will take place. Each student will prepare at least one question for the waterworks guide. Questions should relate to water pumping, both mechanical and chemical purification of water, history and problems of supply, etc.

Task 2:

Students work out the task in the worksheet. They know the answers from the excursion or they will find them out in the Internet.

Phases:

A – monitoring of water quality in the watercourse

B – watermeter

C – treated water back to the nature

D – supply

E – waste water

F – pumping of water

G – purification of waste water

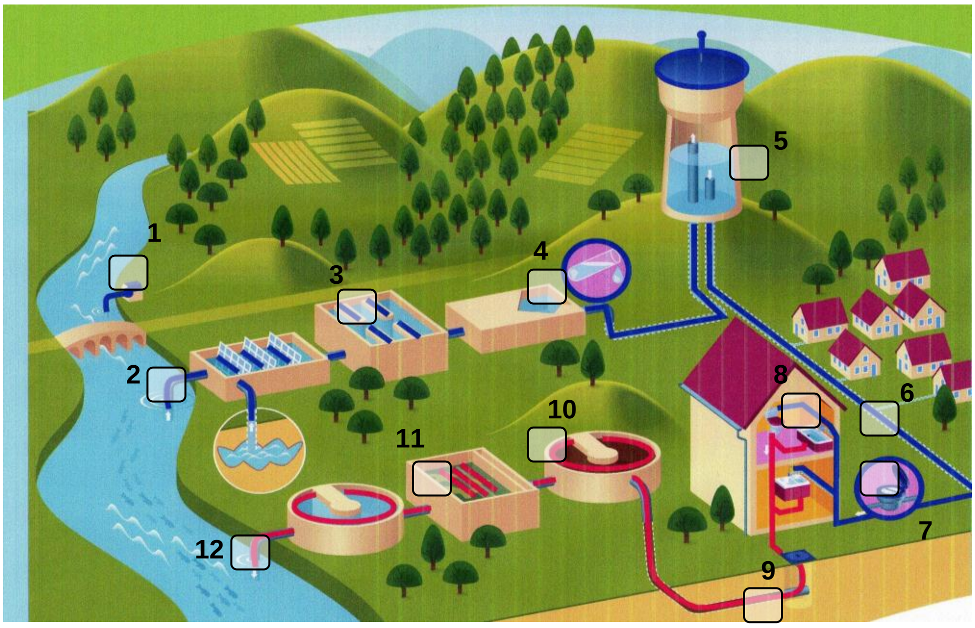
H – waste water in the household

I – storage of drinking water

J – production of drinking water

K – drinking water in the household

L – inspection and chlorination



Source: http://www.pvk.cz/

Key: 1 - A, 2 - F, 3 - J, 4 - L, 5 - I, 6 - D, 7- B, 8 - K, 9 - H, 10 - E, 11 - G, 12 - C.

Possible questions:

Students formulate their own questions. A large amount of questions arise through this activity.

Activity 5 Can we get drinking water?

Learning Aim:

- *Students apply the process, which takes place in nature (water filtration through layers of rocks) to the given problem.*
- *They explain the concept of filtration.*

Materials:

- *Worksheet, PET bottle, sand, hay, crumpled paper, a glass of dirty water (soil with vegetation poured with water), a large empty container, matches, soap, etc.*

Suggestions for use:

- Motivation: Imagine that you are in South Asia. You are very thirsty and the only water available is muddy water from puddles. How to purify this water to make it drinkable? You have only these things: PET bottle, sand, hay, crumpled paper, a glass of dirty water, a large empty container (ideally a 3-litre jar), matches and soap (items can be differently replaced or others can be added).
- Task: Students work in groups and their task is to build a water purification device using the above items.
- Solution: This is rough dirt filtering through the sand filter (emphasize that this process also occurs in the nature). The water that soaks into the ground is naturally cleaned when passing through the rock layers.
- Question: Is the water cleaned in this way drinkable? Healthy?
- Answer: No!!! A variant how to partially "disinfect" water without chemistry is to leave it in a transparent container in the intense sun. UV light will destroy germs or to boil water over the fire.

or

- *We will ask the students to propose the way how to find out the (un)safety of filtered water.*

Possible questions:

Students formulate their own questions. A large amount of questions arise through this activity.

Activity 6 Analysis of beverages

Learning Aim:

- *Students analyse the individual beverages, distinguish between appropriate and inappropriate beverages for water intake, and explain why they are advantageous and disadvantageous.*
- *They will calculate the energy value of their metabolism, which can be compared with their classmates.*

Materials:

- *Worksheet with questions and a table, packaging of various beverages e.g.:*

Photo: Martina Nedomová

Suggestions for use:

Task 1:

First, the students will set the questions that would lead to the analysis of the given beverages they were asked to bring. According to their own opinion, they will answer these questions. Thus the hypotheses will be established for the respective questions.

Task 2:

Students will propose the procedure for solution how to verify their hypotheses. They should figure out that they can use the nutritional table for each beverage. Individual information on the composition of the beverages will be supplied into the table. The table will contain the amounts of 100 ml. Some beverages may not show the substances in 100 ml content, so it is important to recognize this fact and to convert them into desired units.

Table: amount to 100 ml

beverage	energy value (kJ)	proteins (g)	saccharides/ out of them sugars (g)	fats (g)	fibre(g)	sodium (g)	caffeine (g)

Task 3:

Using these data in the table, students will go back to the questions and compare their answers with the results and draw the conclusion.

Task 4:

The table contains the energy values. Students will write what type of energy it is and why we need it. They will verify their answers in the literature or in the Internet. Further they should be able to estimate how much of this energy they themselves need. The hypothesis will be verified using the formula which can be found e.g. in the Internet.

- Questions:

a) What is the energy value? Why do we need this energy?

b) How much energy do you need?

- Answers:

Can be found in the Internet or other sources.

a) Refers to the energy, which the given product contains. It is the energy necessary for the functioning of the whole organism.

b) Basal metabolism is the amount of energy needed for functioning of human organs and ensuring of basic life functions. It excludes the energy needed for daily movement. Computation of basal metabolism:

Male: BM = 66 + (13.7 x weight (kg)) + (5 x height (cm)) – (6.8 x age) kcal

Female: BM = 655 + (9.6 x weight (kg)) + (1.85 x height (cm)) – (4.7 x age) kcal

1kcal = 4.2 kJ

In order the body could provide not only basic life functions but also daily activity (walking, running, ...), it needs to have 30% extra energy of basal metabolism.

Possible questions:

- Which beverage will have the highest energy value?
- Where can you find the highest protein content?
- Which beverage will be the sweetest?
- Will there be a sugar-free beverage?
- Which beverage will be the fattest?
- Will there be any beverage containing antioxidants? If so, which one?
- Which beverages contain caffeine?
- Can a beverage cause allergies?
- What are antioxidants? What do they serve for in our body?

Activity 7 How does the water travel through our body after drinking?

Learning Aim:

- *Students express in their own words what is going on with water in the picture.*
- *They will propose verification of their answers from the literature or the Internet sources.*
- *They will verify and evaluate their answers.*

Materials:

- *Worksheet, working text, or other literature*

Suggestions for use:

Students will be provided with worksheet tasks. They will define answers to all tasks. After that they will suggest verifying the accuracy through the answers found in other sources, such as literature or Internet sources. These sources will be offered to them. These could be e.g.: Jelínek, Zicháček – Biologie pro gymnázia, Kočárek – Biologie člověka, Novotný, Hruška – Biologie člověka pro gymnázia in the Czech language or other similar sources in the mother tongue of the students.

Solutions to worksheet:

What happens to water in this part of the organism?

Picture A – Food and water are taken through the mouth and continue into the pharynx and oesophagus.

Picture B – Water is fed into the stomach from the oesophagus, and together with food it continues into the small intestine.

Picture C – Water is fed from the stomach into the small intestine where it is absorbed. A smaller portion of water is also absorbed in the colon.

Picture D – Small catheters enter each villus and absorb water and nutrients. Tiny blood vessels then enter the larger vessels and distribute nutrients with water along the body.

Picture E – The renal artery supplies blood into the kidney where it is cleaned of waste products; nutrients and water are re-absorbed and discharged back into the body by the kidney vein.

Picture F – Nephron is the basic unit of the kidney. In the glomerulus the primary urine is formed by filtration of blood. From it, in other parts, water and other necessary substances are absorbed and the final urine is produced and drained from the kidney.

Picture G – Urine is supplied to the bladder by ureters from the kidneys and then it continues through the urethra out of the body.

* The working text, see the worksheet for students.

Possible questions:

Students formulate their own questions. A large amount of questions arise through this activity.

Activity 8 How is final urine formed?

Learning Aim:

- *Students will propose practical verification of production of final urine and verify the validity of the established hypothesis.*
- *They will describe the individual pictures showing the gradual production of final urine and express in their own words what happens to the filtrate in each picture.*
- *They will propose the verification of their answers from literature or Internet sources.*

Materials:

- *Worksheet, scientific literature or the Internet, hay infusion, microscope, slide and cover glass, pipette, two beakers, tap water (distilled water), salt (NaCl)*

Suggestions for use:

Task 1:

First, students discuss the osmotic phenomena in the cell. Then they will be provided with worksheet tasks.

Note: The teacher is recommended to prepare a hay infusion.

a) *Formulate a research problem about the process of production of final urine.*

Research problem:

Will a cell of paramoecium in salty (hypertonic) environment lose or suck water?

b) *Establish your hypothesis about the manner of final urine production and justify your assumption.*

Hypothesis:

The cell of paramoecium will lose water in salty (hypertonic) environment and it will shrink.

Justification:

The cell of paramoecium loses water in salty (hypertonic) environment as it tries to dilute it.

c) *Propose tools to use during your experiment and justify your selection.*

Tools:

hay infusion, microscope, slides and cover glass, pipette, two beakers, tap water (distilled water), salt (NaCl)

Justification:

hay infusion as a source of ciliates, aids for microscopy are necessary for the preparation and observation of microscopic slides, beakers to hold demonstration material and to prepare a saline solution, salt is used to prepare the saline solution, water to prepare aqueous environment

d) Think of the experiment procedure and record it step by step.

Add a small drop of rich culture of paramoecium on the slide glass. Cover with a cover glass and observe. Then add a drop of saline solution (10% solution of NaCl) and observe once more.

Source: http://www.tfsoft.cz/photo/detail.php?a=700&p=1&f=343&rc=6

Now go back to your hypothesis. Has it been proved or disproved by the results of the experiment?

The hypothesis has been proved on the basis of the experiment performed. The cell of paramoecium was losing water after adding the saline solution and it shrank.

Task 2:

Students can find the pictures of the respective parts of nephron in the Internet*.

Students will define the answers to the respective parts of the task in the worksheet. Then they will verify their correctness in the scientific literature or in the Internet, where they search for the correct answers.

a) Proximal tubule

This section is well permeable for both water and salt. Resorption of water is passive after transtubular osmotic gradient that forms active resorptions of sodium and other solutes. Water diffuses through the tubular cells and accumulates in the peritubular area, which increases the hydrostatic pressure in this area; this change in capillary forces then leads to resorption of water into the peritubular capillaries. Absorption of water and solutes in the proximal tubule is proportional, i.e. fluid leaving the proximal tubules is isoosmolar, and creates approximately 70 % of volume filtered in glomeruli.

b) Loop of Henle

The thin descending part of Loop of Henle is permeable to water that is resorbed here in about 15%, but is not permeable to salt. The driving force for again passive resorption of water is hyperosmolarity of kidney marrow. The ascending part of Loop of Henle (thin and thick) is impermeable to water, but, on the contrary, permeable to NaCl. The resorption of salt therefore occurs in the ascending limb of Loop of Henle, i.e. passively in the thin part and actively in the thick part where the sodium is resorbed along with potassium and chlorides. Salt re - absorption in the ascending loop reaches 20% of the total amount of ultrafiltrate. The fluid leaving the Loop of Henle is hypoosmolar because the resorption of solutes in this section prevails over resorption of water.

c) Distal tubule and collecting duct

A coiled portion of the distal tubule is impermeable to water; the resorption of salt here is active. The end of the distal tubule is the place where both water and salt may or may not undergo resorption; this part is under the hormonal control. A usual amount of water and salt resorbed through distal tubules is about 5 %. Urine leaving the distal tubule remains hypoosmolar.

A collecting duct is responsible for final treatment of urine according to the needs of the organism. Backward resorption of water is here under the hormonal control of ADH, which opens for water the aqua channels (aquaporins) in the apical membrane. Without ADH, the collecting duct is impermeable to water. Backward resorption of sodium in the collecting ducts is under the hormonal control of aldosterone, which stimulates its re-absorption via epithelial sodium channel. The collecting ducts usually resorb about 4 % of filtered sodium and about 9 % of filtered water.

Source: http://pfyziollfup.upol.cz/castwiki2/?p=5063

*These pictures can be found on the website such as: http://pfyziollfup.upol.cz/castwiki2/?p=3695, http://science.kennesaw.edu/~jdirnber/Bio2108/Lecture/LecPhysio/PhysioExcretory.html, http://www.engin.umich.edu/~cre/web_mod/viper/kidney_function.htm

Possible questions:

Students formulate their own questions. A large amount of questions arise through this activity.

Activity 9 Importance of kidneys for life

Learning Aim:

- *Students will appreciate the indispensability of kidneys for life and defend their standpoints in the group on the basis of presented arguments.*

Materials:

- *Worksheet, working text*

Suggestions for use:

We will begin with the discussion over the advertisement where a man in material poverty sells one of his kidneys. We will ask the students how much they value this organ and whether they would act in a similar manner in such a situation. We try to highlight the ethical aspect of the example. A discussion over trafficking in human organs is possible. Then they will be provided with a worksheet with the introductory text and questions that will be worked out independently and the findings will be discussed in a group.

Advertisement:

Sale of organs or the kidney under the Christmas tree to every (rich) family

Subject: Sale of kidney

Description of goods sold: I am a thirty year old man, do not drink, smoke and I regularly practise sports - I am in good health. Blood group 0, vaccinated against common diseases, I have never had a serious illness. For financial reasons, one of my kidneys is offered for sale.

Price: 1 500 000 CZK, in the case of multiple bids the highest wins

RE: Rushing, I and my wife live with my mother in law - I really NEED to live on my own!

*Source:*http://tomassoukup.blog.idnes.cz/c/19442/Prodej-organu-aneb-ledvina-

pod-stromecek-do-kazde-bohate-rodiny.html
Possible questions:
• *Is the price of kidney undervalued or vice versa overpaid? (in terms of who provides and in terms of who may or may not buy it)*

Activity 10 Is it possible to develop an artificial kidney?

Learning Aim:

- *Students apply their knowledge about the function and structure of kidneys to the given problem.*

Materials:

- *Worksheet, scientific literature or the Internet*

Suggestions for use:

Students will be first motivated by a short story informing briefly about the development of artificial kidney and this topic will be discussed with them. Then they will be asked to supply the worksheet table with the properties that the artificial kidney should have in order to save human life and their answer will be justified.

Which properties should it have in order to save human life?

Properties	Justification
Removal of excess fluid (water)	Incidence of oedema
Removal of waste products of metabolism (urea, creatinine)	Flooding the organism with waste products and consequently apathy, weakness, headache, shortness of breath, vomiting, diarrhoea, chest and bone pain, pale itchy skin

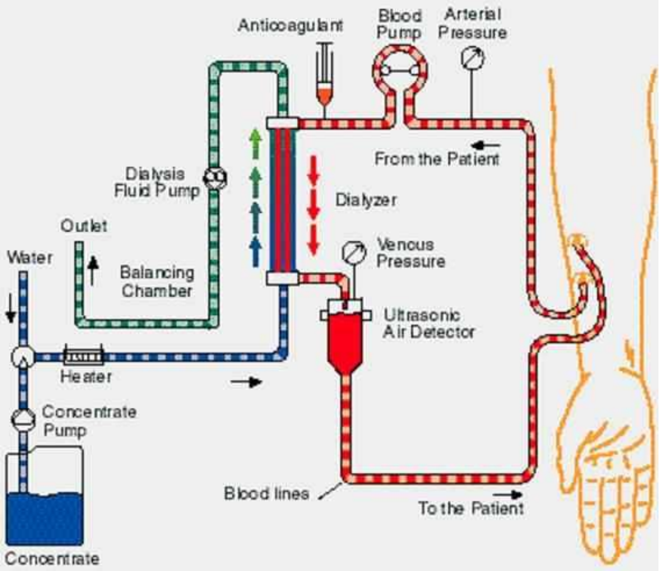
Subsequently, students complement their existing knowledge about kidney function and structure of the retrieved information on the operating principle of artificial kidneys from scientific literature or the Internet. Based on the information obtained, they will draw a diagram of functioning of artificial kidney.

On what principle should it operate?

During dialysis, a dialysis unit (artificial kidney) provides an extracorporeal circulation and produces a dialysis solution. This solution must have the exact composition and temperature. The solution a mixture of water and its solutes (sodium, potassium, calcium, magnesium, chlorine, bicarbonate anion, glucose). For central water treatment in the dialysis centre, a water treatment plant is used, which is based on the principle of reverse osmosis. It is a water filtration through membranes under high pressure. In addition to the dialysis unit itself, a dialyzer is necessary for dialysis. It consists of a semipermeable membrane that separates blood from the dialysis solution. This membrane allows the passage of substances with small molecules (urea, creatinine, etc.) as well as of excess fluid from the bloodstream of the patient. These components are transferred to the dialysis solution and with it they then leave the dialysis unit as waste. Today, capillary dialyzers are used, where the membrane consists of a hollow fibre. Several tens of thousands of these fibres are connected in parallel. Blood flows through the cavity of each fibre and a dialysis solution flows around the outer wall of each fibre in the opposite direction. Based on the gain of patient weight, the operator sets the size of ultrafiltration on the dialysis unit. Then the unit, depending on blood pressure on the dialyzer membrane and the volume of ultrafiltration, calculates and sets the appropriate pressure for the dialysate. This ensures that the patient leaves the dialysis with optimal weight. In order to reduce blood clotting, heparin is dosed into the blood during dialysis.

Source: http://www.inmed.cz/index.php?page=princip_dialyzy

Draw the scheme.



Source: http://www.gml-dialyza.cz/index.php?multi=dialyza&parent=1

Finally they will search the scientific literature or the Internet for where and how to make dialyzers* and where, in their neighbourhood, a closest dialysis centre is located. Their findings will be supplied into the worksheet.

Search the Internet or the scientific literature for details of where and how to make dialyzers, the most important part of the artificial kidney.

The main element of the dialyzer is a semipermeable membrane that partially replaces the renal function. This membrane consists of a bundle of polysulphonic hollow fibres, capillaries. Polysulfone dissolved in dimethylacetamide is pushed through more than a thousand of subtle circular nozzles in the centres of which there are smaller nozzles for injecting precipitate solution. Behind the mouth of the nozzle a porous hollow fibre, membrane, is created; this enters the coagulation bath. In the coagulation bath, solid stable capillaries are formed by precipitation and chemical conversion. After that the fibres travel to the washer consisting of several separate baths of specially treated (ultraclean) water. Here, the capillaries are flushed, thereby removing undesirable residues (e.g. solvents) from the previous chemical reactions. Fibres are then dried in hot air.

We are constantly monitoring the quality of water in the washing baths and air temperature in the drying chambers. Each fibre is examined using a microscope for a corresponding diameter, wall thickness and porosity. Chromatography examination is also performed to confirm the correct composition of mixtures used.

The individual parts of dialyzers are assembled under perfectly clean conditions on automated lines, with partial service of personnel. Finally, all dialyzers are subjected to strict tests, such as membrane integrity test.

Find in your neighbourhood the closest dialysis centre.

* This text can be found for example on the website*:* http://braunoviny.bbraun.cz/, http://www.bbraun.com/

Possible questions:

Students formulate their own questions. A large amount of questions arise through this activity.

Activity 11 A visit to a dialysis centre

Learning Aim:

- Students will explain what events are performed in the dialysis centre, what rules must be followed during the dialysis, who works here and what education the person has to have.
- They will complement the information on the functioning of artificial kidney.

Materials:

- *Worksheet*

Suggestions for use:

Students will be informed about the date of the excursion. We will let them write down the questions that they would like to ask the medical staff to supplement the missing information on the matter. As the output of the excursion, students can write an article for the school magazine about the operation of dialysis centre, complemented with their own photographs taken during the excursion or the interviews with patients or the experience of medical staff.

Possible questions:

- How does haemodialysis work?
- Where, who and when is it carried out?
- What can I do during these 4-5 hours of dialysis?
- How does each respective haemodialysis go on?
- How to prepare for it before it starts?
- Who is eligible for haemodialysis?
- Who is ineligible for haemodialysis?

- What are its advantages over abdominal dialysis?
- What are the disadvantages? What will limit me?
- What can be a complication of haemodialysis? How do I know?
- If I decide for haemodialysis, can I change my decision in future?
- What will happen if I undergo transplantation in future?

* This text can be found for example on the website: http://www.nefrologie.eu/cgi-bin/main/read.cgi?page=hemodialyza, http://kidney.niddk.nih.gov/, http://www.kidney.org/

Activity 12 World Kidney Day

Learning Aim:

- *Students will explain what are the causes, manifestations and possibilities of treatment of chronic disease (failure) of kidneys.*
- *They will evaluate the incidence of disease worldwide and possibilities of prevention.*
- *They will propose and prepare promotional materials according to the agreed criteria.*

Materials:

- *Wordsheet, scientific literature or the Internet, markers, crayons, drawing tools*

Suggestions for use:

First, students will be introduced to the problem by discussing with them the fact that most people do not know about their disease because the chronic kidney disease usually does not hurt. Then we will ask them how they would ensure an early diagnosis of the kidney disease with the affected persons so that the treatment was easier and thus there was also a lower risk of other diseases. Then we will let the students search from relevant sources for information about kidney function, causes and manifestations of chronic disease (failure) of kidney, prevention and treatments, disease incidence in the world's population. Based on this information the students agree upon a uniform and pre-arranged target of advertising campaign and suggest possible forms and design of advertisement. Their works along with the informative article can be then published in the school magazine or they can hold discussions with classmates where they present their findings on the given topic.

Note: We recommend downloading a couple of current flyers from the World Kidney Day from the Internet, printing them out and at the beginning of the activity handing them out among the students

Causes, manifestations and treatment

Chronic renal insufficiency is characterized by progressive loss of renal function due to renal disease or renal damage with a system disease of organism (diabetes, obesity, high blood pressure). Such damage often runs for a long time without obvious symptoms causing serious problems to the patient.

However, damage to kidneys caused by any chronic disease, leading to a reduction in their function, can be very accurately measured. It is expressed as glomerular filtration rate or amount of filtered urine, which occurs in the kidneys. According to the degree of reduction in glomerular filtration, the chronic disease can be divided into five stages.

Stage	Description	GF ml/min	GF ml/s
1	Damage to kidneys with normal or higher GF	>90	>1.5
2	Damage to kidneys with moderate reduction in GF	60–89	1–1.49
3	Moderate reduction in GF	30–59	0.5–0.99
4	Severe reduction in GF	15–29	0.25–0.49
5	Failure of kidneys	<15 or dialysis	<0.25 dialysis

A current stage of renal impairment is also reflected in the selected treatment - from medication, diet and regime measures in mild manifestations to a dialysis or transplantation with function loss greater than 80-90%.

Renal insufficiency after its discovery usually accompanies the patient throughout the rest of his/her life and often tends to spontaneously worsen despite the provided treatment. Therefore, patients are under close supervision of professional nephrology outpatient clinics, where they undergo a regular physical examination, blood pressure checks, and blood and urine tests.

Rate of deterioration of renal function is dependent on the nature of underlying disease, the effectiveness of therapeutic measures, but also on the approach of the patient to the therapy. Renal failure (the last stage of chronic kidney disease, when it is vitally necessary to artificially replace the kidney function) may therefore occur within a year, as well as after several decades.

The first clinical symptoms appear only when the kidney function drops to 35 - 40% of its original capacity, but unfortunately, very often even much later. These include headache, weakness, rapid onset of fatigue, anorexia, recurrent vomiting, frequent urination (especially at night), increased thirst, pale skin, high blood pressure, growth failure in children.

Should the renal function worsen until the stage of their failure, we can also observe the apathy, weakness, headache, shortness of breath, vomiting, diarrhoea, oedema, chest pain, bone pain, pallor, and itchy skin. At this point the start of dialysis treatment is clearly necessary. Even so it applies that each patient should be assessed individually with regard to the renal function and overall condition of the patient.

Prevention

Do not smoke, avoid being overweight, regular exercise, healthy diet, stick to water intake, reasonable consumption of alcohol, regular preventive examinations

The incidence in the world's population is about 10%.

Source: http://www.ledviny.cz/nemoci-ledvin

Proposal of advertisement:

Television advertising, radio advertising, walking advertisement, flyer, poster, billboard, banner, etc.

Possible questions:

Students formulate their own questions. A large amount of questions arise through this activity.

WP3
Water in the Life of Man

European Science and Technology in Action Building Links with Industry, Schools and Home

Work package 3
WATER IN THE LIFE OF MAN
Classroom Materials

European Science and Technology in Action:
Building Links with Industry, Schools and Home

Main partner: **CUNI**

Version: 4.0 final

The development of the package was made by Čížková, Radvanová & Nedomová, CUNI

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Start Date: 1st January 2010 Duration: 48 months

Activity 1

Discussion over the importance of water

Discuss the importance of water for human organism.

Build up the rules of proper fluid intake.

What are the rules of proper fluid intake?

a)……………………………………………………………………………………………………
……………………………………………………………………………………………………

b)……………………………………………………………………………………………………
……………………………………………………………………………………………………

c)……………………………………………………………………………………………………
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d)……………………………………………………………………………………………………
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e)……………………………………………………………………………………………………
……………………………………………………………………………………………………

f)……………………………………………………………………………………………………
……………………………………………………………………………………………………

g)……………………………………………………………………………………………………
……………………………………………………………………………………………………

h)……………………………………………………………………………………………………
……………………………………………………………………………………………………

i)……………………………………………………………………………………………………
……………………………………………………………………………………………………

Activity 2

My fluid intake

Think about your fluid intake and answer the following questions. First, express your assumptions (hypotheses), then suggest a procedure for verification and after the hypothesis verification go back to the questions and add the results.

- **How much fluid do you take per day?**
  Hypothesis: ……………………………………………………………………………..........
  ……………………………………………………………………………..........
  Result (prove or disprove the assumption): ……………………………......................
  ……………………………………………………………………………..........
  The result differs from the assumption. Try to find out the cause. ....
  ....
- **Do you drink regularly during the day?**
  Hypothesis: ……………………………………………………………………………..........
  ……………………………………………………………………………..........
  Result (prove or disprove the assumption): ……………………………......................
  ……………………………………………………………………………..........
  The result differs from the assumption. Try to find out the cause. ....
  ....
- **How many times per day do you go to the toilet to urinate?**
  Hypothesis: ……………………………………………………………………………..........
  ……………………………………………………………………………..........
  Result (prove or disprove the assumption): ……………………………......................
  ……………………………………………………………………………..........
  The result differs from the assumption. Try to find out the cause. ....
  ....
- **What amount of urine per day do you approximately excrete considering the fact that the feeling of urination occurs with the urinary bladder volume of about 300 ml?**
  Hypothesis: ……………………………………………………………………………..........
  ……………………………………………………………………………..........

Result (prove or disprove the assumption): …………………………………………..........................

…………………………………………………………………………………………….............

The result differs from the assumption. Try to find out the cause. ....

....

- **Will there be a diference between the volume of water drunk and excreted in urine? If so, what is the cause of such difference?**

Hypotheis: ………………………………………………………………………….............

…………………………………………………………………………………………….............

Result (prove or disprove the assumption): …………………………………………..........................

…………………………………………………………………………………………….............

The result differs from the assumption. Try to find out the cause. ....

....

- **What fluid do you most often drink during one day?**

Hypotheis: ………………………………………………………………………….............

…………………………………………………………………………………………….............

Result (prove or disprove the assumption): …………………………………………..........................

…………………………………………………………………………………………….............

The result differs from the assumption. Try to find out the cause. ....

....

- **Propose a way to verify your hypotheses. For verification you can use the following table.**

………………………………………………………………………………………………………

……………………………………………………………………...

Day	Morning - noon (6:00 - 12:00)			Noon - evening (12:00 - 18:00)			Evening - morning (18:00 - 6:00)			Total	
	Fluid intake		Number of urinations	Fluid intake		Number of urinations	Fluid intake		Number of urinations	Amount of fluid (Litres)	Number of urinations
	Amount of fluid (Litres)	Type of fluid		Amount of fluid (Litres)	Type of fluid		Amount of fluid (Litres)	Type of fluid			

Conclusion:

- **What is the difference between your fluid intake and the proper fluid intake discussed in activity 1?**

……………………………………………………………………………………………………..................

……………………………………………………………………………………………………..................

- **As for you, do you have any recommendations?**

……………………………………………………………………………………………………..................

……………………………………………………………………………………………………..................

Activity 3

Which water tastes better – bottled or tap water?

Find the article in the Internet comparing the quality of bottled and tap water.

Task 1: Would you consider the previous text as professional (scientific)? If not, which properties should a scientific text satisfy? Or, as an example, find and present another text that you consider to be scientific (use literature sources or the Internet).

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Task 2: Do you agree with any of the opinions expressed in the previous text and why? What is your own opinion?

……………………………………………………………………………………………………
……………………………………………………………………………………………………

Task 3:

Now think over the article and write your own assumption, which water you and your family prefer. What methods and procedures do you choose to prove or disprove your assumption (hypothesis)?

Hypothesis: ……………………………………………………………………………………

Justification: …………………………………………………………………………………..

Proposal on how to proceed: ………………………………………………………………

……………………………………………………………………………………………………

Investigation:

Describe the taste of the individual samples of water:

Sample №. 1:	
Sample №. 2:	
Sample №. 3:	
Sample №. 4:	
Sample №. 5:	

Results:

Which water did you like best? Sample №. …

Add the type of water to the individual samples:

Sample №. 1:	
Sample №. 2:	
Sample №. 3:	
Sample №. 4:	
Sample №. 5:	

Conclusion:

Compare the results of your research with your hypothesis and form a conclusion (where the error could have occured, what caused these results, ...).

…………………………………………………………………………………………….....……….

……

Task 4:

Your task is to establish the hypothesis that would, in your opinion, capture the attitudes of consumer public (your class) to bottled water and tap water. Justify your assumption. Then imagine that you are researchers whose task is to prove this hypothesis. What methods and procedures will you select to prove or disprove your hypothesis?

Hypothesis: ……………………………………………………………………………..............

Justification: ………………………………………………………………………………..

Proposal on how to proceed: ………………………………………………………………

……………………………………………………………………………………..................

Investigation:

Write how many people (schoolmates) prefer the individual samples of water:

Sample №. 1:	
Sample №. 2:	
Sample №. 3:	
Sample №. 4:	
Sample №. 5:	

Results:

Which water is preferred by your class? Sample №. …

Conclusion:

Compare the results of your research with your hypothesis and form a conclusion (where the error could have occured, what caused these results, ...).

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Activity 4

Waterworks or production of drinking water

We have planned an excursion to a water treatment plant in the waterworks.

Task 1:

Each of you will prepare questions that you would like to ask throughout the excursion. These questions should relate to water pumping, mechanical and chemical purification of water, history and problems of supply, etc., in short, everything that you are interested in as for water treatment.

Your questions:

………………………………………………………………………………………………...........................

……

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…………………………………………………………………………......................................?

*Waterworks equipment photos for example can be found at: http://ostravablog.cz/

Task 2:

From the excursion you have learned how water is treated in waterworks. Add the individual phases of water circulation into the following picture of water industry.

Phases:

A – monitoring of water quality in the watercourse

B – water meter

C – cleaned water back to the nature

D – supply

E – waste water

F – pumping of water

G – purification of waste water

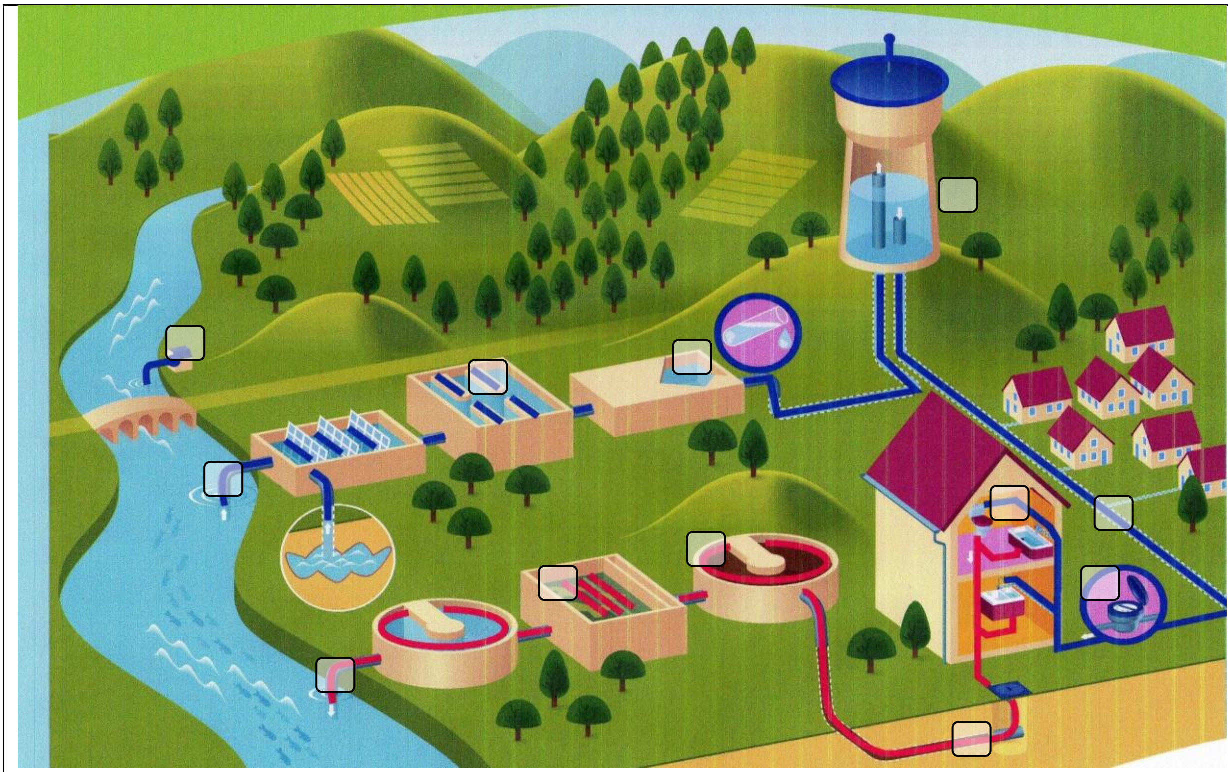
H – waste water in the household

I – storage of drinking water

J – production of drinking water

K–drinking water in the household

L – inspection and chlorination



Source: http://www.pvk.cz/

Activity 5

Can we get drinking water?

Imagine that you are in South Asia. You are very thirsty and the only water available is muddy water from puddles. How to purify this water to make it drinkable? You only have these things: PET bottle, sand, hay, crumpled paper, a glass of dirty water, skewers, knife, and matches. Propose a procedure that could be used for water purification. Which tools would you use?

Source: http://www.flexiobklady.cz/produkty-pisek-prirodni.php

Source: http://kralicek.wbs.cz/Krmeni.html

Source: http://horz.cz/spotreba.asp

Source: http://www.stockphotos.cz/image.php?img_id=14477875&img_type=1

Hypothesis: ………………………………………………………………………………….......

Justification: ……………………………………………………………………………........

Tools: …… ……………………………………………………………………...................

Justification: ……………………………………………………………………………….

Working procedure: ……………………………………………………………………………………
………
………
………

Result:

Has the water been purified? ………………………………………………………………………

Conclusion (What was incorrect?, What should have been correct?, Why does it work like this?):

………
………

Activity 6

Analysis of beverages

In this task, you are provided with different types of packaging of selected beverages that you can bring yourselves. They may be similar to those in the pictures:

Photo: Martina Nedomová

Task 1:

First, ask yourselves questions that would apply to the analysis of the composition of the given beverages. These questions may relate to their different composition. For inspiration you can use the following questions in the worksheet. According to your own opinion, answer your questions. Thus the hypotheses will be established that you will verify in the following task.

1. Question:

Hypothesis:……………………………………………………………………………….........

2. Question:

Hypothesis:……………………………………………………………………………..........

3. Question:

Hypothesis:……………………………………………………………………………..........

4. Question:

Hypothesis:……………………………………………………………………………..........

5. Question:

Hypothesis:……………………………………………………………………………..........

6. Question:

Hypothesis:……………………………………………………………………………..........

7. Question:

Hypothesis:……………………………………………………………………………..........

8. Question:

Hypothesis:……………………………………………………………………………...............

Task 2:

How would you proceed to verify your hypotheses? Apply your proposal of procedure for how to get answers to questions. For inspiration you can use the table in the worksheet.

Procedure proposal:……………………………………………………………………….....

……………………………………………………………………………………………….....

beverage	energy value (kJ)	proteins (g)	saccharides/out of them sugars (g)	fats (g)	fibre(g)	sodium (g)	caffeine (g)

Task 3:

Go back to the questions and compare your answers with the results of your investigation and form a conclusion. If the answers were icorrect, write about why you first probably thought like this. You can write about what was a surprise for you and what attracted your attention.

Conclusion:……………………………………………………………………………………

……………………………………………………………………………………………..................

Task 4:

During the analysis you met the energy value of beverages.

a) What type of energy is it and why do we need it?

Hypothesis:…………………………………………………………………………….........

……………………………………………………………………………………….................

Procedure to verify the correctness of hypothesis: …...

……………………………………………………………………………………….................

Conclusion:…………………………………………………………………………….....

....

b) How much energy do you need?

Hypothesis:…………………………………………………………………………….........

……………………………………………………………………………………….................

Procedure to verify the correctness of hypothesis: ……...

……………………………………………………………………………………….................

Conclusion:……………………………………………………………………………….......

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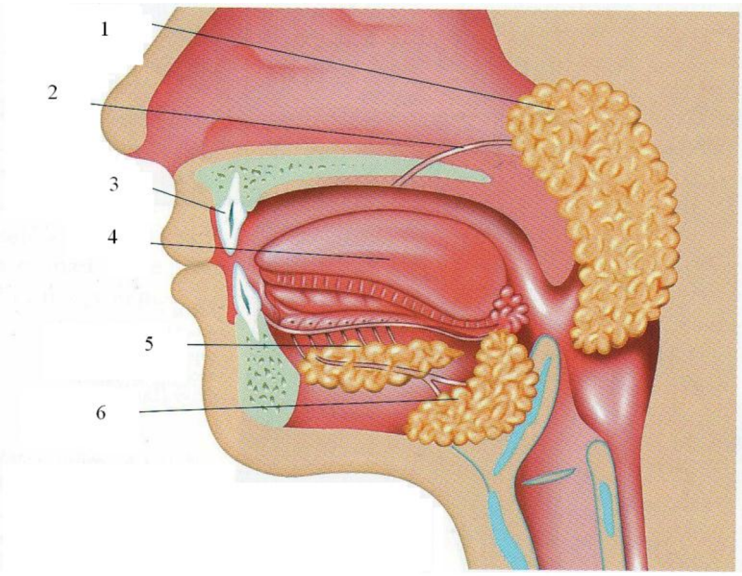
Activity 7

How does the water go trough our body after drinking?

Below you will find the pictures that show the individual parts of the human body. Your task is to establish a hypothesis refer briefly to the processes the water undergoes in the given picture and draw them into the path of water as a line.

Start from your current knowledge. Then suggest how you would verify whether your answers are correct. Once verified, go back to the pictures and write down the correct results.

Picture A: Oral cavity



1 – parotid salivary gland
2 - salivary duct
3 - tooth
4 - tongue
5 - sublingual salivary gland
6 - submandibular salivary gland

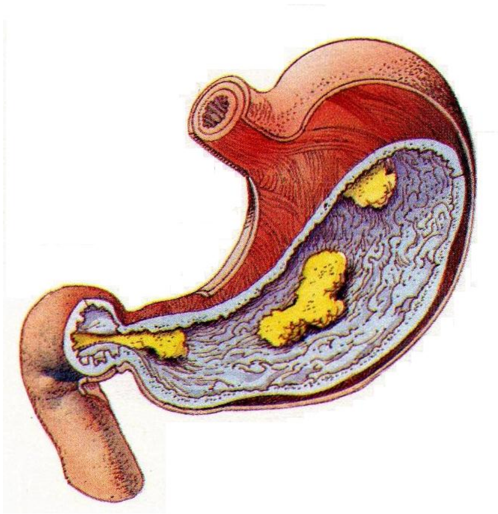
Source: Winston, 2005

What happens to water in this part of the organism?

Hypothesis:………………………………………………………………………………........

Result:……………………………………………………………………………….................

Picture B: Stomach with part of the duodenum



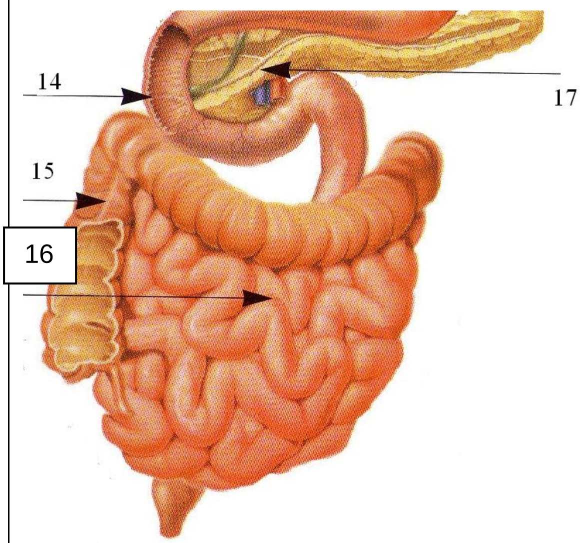
Source: Adams, 1992

What happens to water in this part of the organism?

Hypothesis:……………………………………………………………………………........

Result:…………………………………………………………………………….................

Picture C: Small intestine and colon



14 - duodenum
15 - colon
16 - small intestine
17 - pancreas

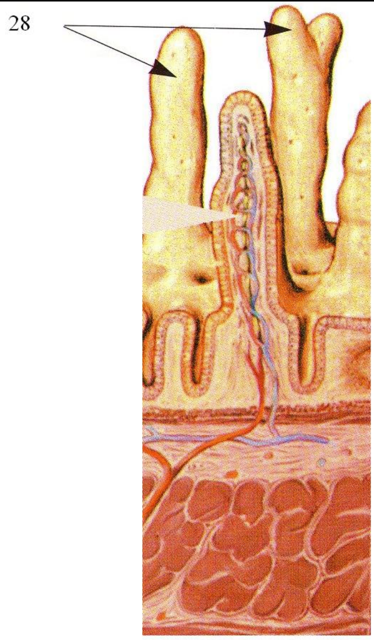
Source: Trojan, Schreiber, 2002

What happens to water in this part of the organism?

Hypothesis:……………………………………………………………………………........

Result:…………………………………………………………………………….................

Picture D: Small intestina wall



28 – willi

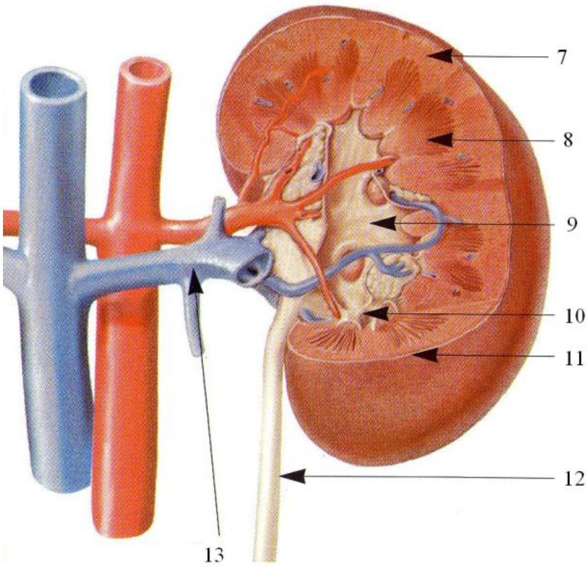
Source: Trojan, Schreiber, 2002

What happens to water in this part of the organism?

Hypothesis:…………………………………………………………………………………........

Result:…………………………………………………………………………………..................

Picture E: Kidney



7 - kidney cortex
8 - kidney medulla
9 - renal pelvis
10 - cup of kidney
11 - fibrous casing
12 - ureter
13 - renal vein

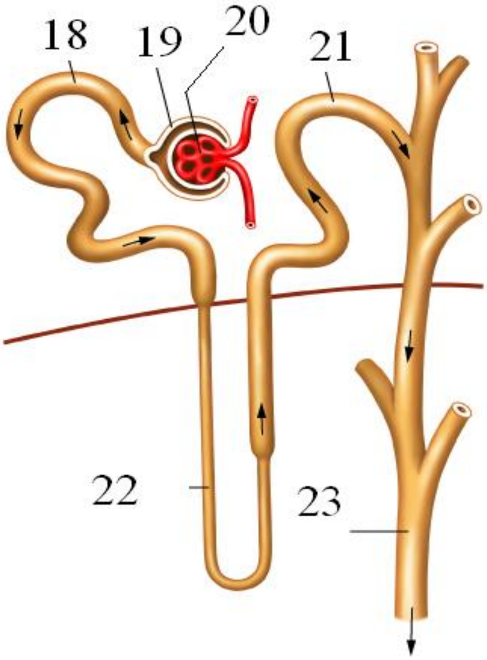
Source: Trojan, Schreiber, 2002

What happens to water in this part of the organism?

Hypothesis:…………………………………………………………………………………........

Result:…………………………………………………………………………………..................

Picture F: Nephron



18 - proximal tube
19 - Bowman pouch
20 - glomerulus
21 - distal tube
22 - loop of Henle
23 - collecting duct

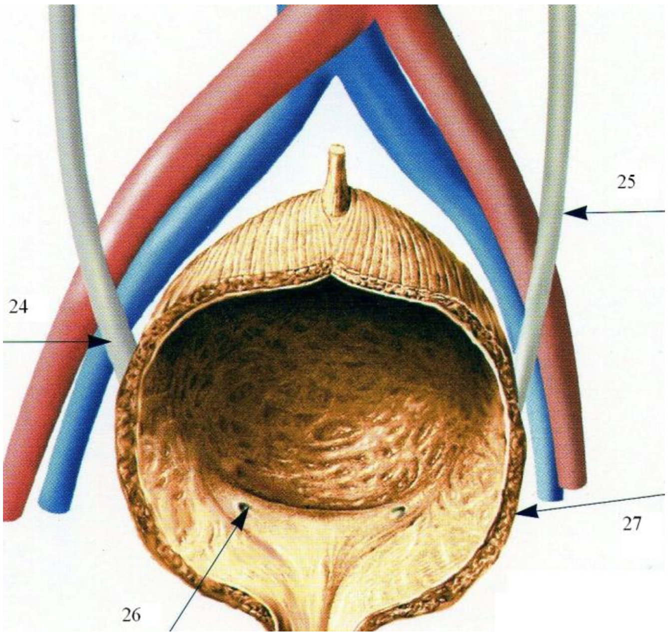
Source: www.beltina.org

What happens to water in this part of the organism?

Hypothesis:……………………………………………………………………………………........

Result:………………………………………………………………………………..................

Picture G: Urine bladder



24 - ureter
25 - ureter
26 - outcome of the ureter
27 – urine bladder

Source: Trojan, Schreiber, 2002

What happens to water in this part of the organism?

Hypothesis:……………………………………………………………………………………........

Result:……………………………………………………………………………….................

Procedure to verify all hypotheses:………………………...
……………………………………………………………………..…………..............
……………………………………………………………………...…………..............
……………………………………………………………………...…………..............

Conclusion: (evaluate your results)
………………………………………………………………………………..................
………………………………………………………………………………..................
………………………………………………………………………………..................

The working text that can be used to verify your hypotheses:

Water is a major constituent of the whole organism. The amount of water in the body is dependent on the age, weight and gender of the individual. The total amount of water in the body of an adult is approximately 30 to 40 liters, i.e. about 50 to 60%. Water is taken into the body through the mouth as it is with food. Water passes through the pharynx and esophagus into the stomach, then it moves into the small intestine and colon. The amount of water that is excreted along with feces is about 100 ml. We daily drink 1.5 to 2.5 liters of water. So, where to does water disappear from the organs of the digestive system? Absorption occurs mainly in the colon, and only in smaller quantities in the small intestine. Along with water, nutrients such as fats, sugars, proteins and ions are also absorbed. But what the absorption actually is? The inner wall of the intestine is formed by the so-called villi, which are very well supplied with blood. Each villus is connected with intestinal capillaries into which the water enters through the intestinal wall and is further distributed with nutrients throughout the whole body. However, in a similar manner, the blood also receives waste and unwanted substances; therefore the body must get rid of these substances. To remove these substances from the blood is the task of kidneys. The blood is brought into the kidney by a renal artery, which is divided in the kidney into small capillaries. These then participate in the construction of the nephron (anatomical and functional unit of kidneys). Blood vessels in the kidney cortex form a vascular blob, the so-called glomerulus, where from fluid, the so-called primary urine, is filtered into Bowman's pouch. Daily, about 170 liters of this urine is created. This filtrate then proceeds to the kidney marrow via other parts of nephron, i.e. via a proximal tubule (duct of 1st order), loop of Henle and distal tubule (duct of 2nd order). In these parts, there occurs an intense absorption of water and nutrients into the blood capillaries that converge in the renal vein. The resulting fluid is called the final urine. This urine is then drained by a collecting duct, where the water is also resorbed into the renal calyces. Renal calyces converge in the renal pelvis, followed by the urethra, which carries urine to the bladder. Here, urine accumulates and when the bladder is filled up to about 350 to 400 ml, it results in the need to urinate. This feeling can be suppressed up to the volume of 700 ml. From the bladder, urine flows out through the urethra (adapted from Novotny, Hruška, 2007, Jelinek, Zicháček, 2002).

Activity 8

How is final urine produced?

Task 1:

Propose an experiment to demonstrate the course of physiological processes in the nephron that are involved in production of final urine. A culture of paramoecium in hay infusion is available.

a) Formulate a research problem about the process of production of final urine.

Research problem: …………………………………………………………………………..........

…………………………………………………………………………………………….............

b) Establish your hypothesis about how the final urine is produced and justify your assumption.

Hypothesis:

…………………………………………………………………………...............................

Justification: ……………………………………………………………………………...........

c) Propose the tools that you will use during your experiment and justify your selection.

Tools: …………………………………………………………………………………................

……………………………………………………………………………………………............

Justification: ……………………………………………………………………………...........

……………………………………………………………………………………………............

d) Think of the experiment procedure and record it step by step.

Working procedure: ………………………………………………………………………..........

……………………………………………………………………………………………………

…………………………………………………………………………………………………..

……………………………………………………………...

e) Now go back to your hypothesis. Has it been proved or disproved by the results of the experiment?

Result: …………………………………………………………………………………..............

……………………………………………………………………………………………............

Conclusion (What was incorrect?, What should have been correct?, Why does it work like this?): ……………...

……………………………………………………………………………………………………

……………………………………………………………………………………………………..........................

Task 2:

Find in the Internet the pictures of the individual parts of nephron. Explain what physiological processes in the given nephron segments are involved in the production of final urine.

Start from your current knowledge. Then suggest how you would verify whether your answers are correct. Once verified, go back to the pictures and write down the correct results.

A. Proximal tube

Hypothesis:…………………………………………………………………………………………

Result:……………………………………………………………………………………………..

B. Loop of Henle

Hypothesis:…………………………………………………………………………………………

Result:……………………………………………………………………………………………..

C. Distal tube and collecting duct

Hypothesis:…………………………………………………………………………………………

Result:……………………………………………………………………………………………..

Procedure to verify all hypotheses:………………………...

…………………………………………………………………………..……………….............

…………………………………………………………………………..…………….............

…………………………………………………………………………..…………….............

Conclusion: (evaluate your results)

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Activity 9

Importance of kidneys for life

In the eyes of the greater part of the general public, the kidneys are almost an insignificant organ. Perhaps everyone knows why it is necessary to take care of the heart and how to protect oneself against obesity. Many patients have a great fear even from a banal respiratory infection. Few, however, know what the risk in itself can conceal the damage or kidney failure. It is true that we have two kidneys, and if one of them fails, the other one can largely replace it (Kočárek, 2010). Yet the desperate patients from rich countries are willing to give a fortune for a new healthy kidney.

a) Based on the data from the introductory text and your own experience, establish a research problem about the importance of human kidney.

Research problem: ……………………………………………………………………………..

…………………………………………………………………………………………………

b) Formulate the hypothesis that would express the assumption about the importance of kidneys for life. Justify this assumption.

Hypothesis:

…………………………………………………………………………………………………

Justification:

…………………………………………………………………………………………………

c) Study the working text below about the importance of kidneys for life. In the text, search for the arguments that made you change your original judgment about the importance of the kidneys in the human body. Discuss your findings in a group.

Arguments: ………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

d) Now go back to your hypothesis. Has it been proved or disproved on the basis of the information obtained?

Result: ………………………………………………………………………………………….

…………………………………………………………………………………………………

Conclusion (What was incorrect?, What should have been correct?):
……
....
....

Working text:
Kidneys are a paired bean-shaped organ, 10-12 cm long, located in the lumbar region beneath the layer of muscles and beneath the lower ribs. They are fixed in the fat pouch that protects the kidneys from shocks, cold, etc. For life they are absolutely necessary because they fulfill a number of important tasks that can not be performed by any other organs.
Renal function:

- excretion of excess water and minerals – production of urine
- excretion of metabolic waste (metabolism) – kidneys eliminate waste products that the body cannot use any more, e.g. urea, creatinine, uric acid and many others. Therefore, in case of kidney diseases, the level of urea, creatinine and also of other substances is often increased and according to the level of increase, even the level of renal function can be estimated – glomerular filtration.
- control of the internal environment of the body - the kidneys affect the amount of water, sodium, potassium, calcium, phosphorus, magnesium and other minerals in the body, control the acidity (pH) of the internal environment of the body. Therefore, in case of kidney diseases, there is often observed a proneness to swelling, excess of potassium, phosphorus and also magnesium and increased acidity of blood; sometimes there occur excessive losses of water, sodium or potassium.
- control of blood pressure - kidneys control both the amount of fluids and salts in the body, which directly affects the pressure, and also control the blood pressure hormone (by releasing certain substances into the blood) and also by influencing its neural control. Therefore, in case of kidney diseases, there is observed a proneness to high blood pressure.
- control of haematopoiesis - kidneys produce erythropoietin, an hormone that is essential for the production of red blood cells - erythrocytes. Therefore, kidney diseases show a proneness to anemia, i.e. deficiency of red blood cells.
- excretion of extragenous and toxic substances from the body - in addition to the excretion of metabolic waste, kidneys allow excretion of a variety of extragenous substances e.g. drugs. Therefore, in case of kidney diseases, doses of certain drugs have to be often adjusted, or replaced by other drugs.
- activation of vitamin D - vitamin D produced in the skin through exposure to sunlight, must be further activated in the kidneys to fulfil its function. This is also the reason why, in case of kidney diseases, there occurs a vitamin D deficiency and it must be supplied, often even directly in the activated form, to prevent damage to bones or other organs.
- degradation of hormones and other substances produced in the body – kidneys degrade e.g. the hormone insulin. Therefore, in case of kidney diseases, with diabetes treated with insulin, it can happen that the consumption of insulin gradually decreases – since the delivered insulin remains longer in the body.

Source: http://www.nefrologie.eu/cgi-bin/main/read.cgi?page=zdrave_ledviny

Activity 10

Is it possible to develop an artificial kidney?

In case of kidney failure, it is nowadays common that the patient is rescued from ultimate death by dialysis or an artificial kidney. Not always it was so, since only a few decades have passed from the implementation of the first dialysis machine and the performance of the first successful dialysis treatment. Using the first artificial kidney in humans is associated with the name of Dutch physician Willem Kolff. In 1943 he tried to apply this treatment to 15 patients. Although patients showed transient improvement, their survival was short and all of them eventually died. Only 2 years later, in 1945, the artificial kidney saved the first life.

Imagine that you are a military doctor during the World War II and you are expected to save the life of a soldier with acute renal failure. If you do not immediately get an artificial kidney, he will certainly die due to intoxication (poisoning).

- What properties should an artificial kidney have to save human life?

Properties	Justification

- On what principle should it work?

- Draw its diagram.

- Search in the Internet or in the literature for details about where and how to make dialysers, the most important part of the artificial kidney.

- Look for the closest dialysis centre in your vicinity.

Activity 11

A visit to a dialysis centre

We have planned an excursion to a dialysis centre.

Write questions that you will have to ask the medical staff to be able to describe the content of the following pictures in a form of coherent scientific text.

Source: *http://www.zdn.cz/denni-zpravy/z-domova/dialyzacni-strediska-varovala-ze-nebudou-mit-dost-penez-na-lecbu-462604*

Dialysis centre

Your questions:...
....?

Source: *http://www.zdn.cz/clanek/zdravotnicke-noviny/zit-bez-ledvin-bude-tezsi-kvuli-skrtum-462669?category=z-domova*

Hemodialyser

Your questions:...
....?

Source: http://www.zdn.cz/clanek/sestra/cevni-pristupy-u-dialyzovanych-pacientu-462309

Arteriovenous fistula

Your questions:...

....?

Write more questions that you are interested in as for the given issue, and that you would like to ask the medical staff or the patients.

Your questions:

....

....

....

....

....?

Activity 12

World Kidney Day

Imagine that you are the employees of advertising agency and have received an order from the International Federation of Foundations for Kidney Diseases and the International Society of Nephrology to devise an advertising campaign for World Kidney Day. Its aim is this year to raise general public awareness of hemodialysis as a possible treatment of chronic disease (failure) of kidneys.

Your task is now to search in the internet or in the scientific literature for the relevant information on the given issue (e.g. information about kidney disease, how one can get sick, characteristics of hemodialysis, other methods of treatment ...). You must also agree upon the objective of the advertising campaign, target group of people, choose an appropriate form of advertising, and then propose its design.

Notes:

Proposal of advertisement: