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Low-Cost Experiments for Biology Education

Teacher Training Department 2012

Low-Cost Experiments for Biology

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Prologue

The main objective of this guide is to enable science teacher trainers and teachers to introduce practical activities to their students, thus improving their critical thinking and problem solving skills. Practical activities allow linking theory with practice and daily life. Moreover, with practical activities you can address specific skills and attitudes with students such as team work, accuracy and creativity. Practical activities offer a motivating and engaging encounter with biology and may stimulate students to develop a stronger interest in science.

All experiments are designed with low-cost materials. Many of the main concepts in biology can be illustrated with low-cost materials. For students and teachers it stimulates creativity, but developing one's own experiment material is likely to give more satisfaction than using a purchased set. Using low-cost materials poses fewer problems on costs, maintenance and the supply of spare parts.

This guide complements other learning materials developed by the Ministry of Education, Youth and Sport (MoEYS), in cooperation with VVOB. These include the manual on student centred approaches, multimedia materials and biology posters with activity sheets.

To ensure optimal use of the experiments in this manual, we suggest following advice:

1. Prepare all the material for the experiment before the start of the lesson.
2. Stimulate students to think, to predict, to observe and to explain during the practical activity. In this way, they will grow familiar with the scientific method.
3. Allow as much hands-on time as possible for students.
4. Revise student understanding after doing the experiment and adjust your lesson plan if necessary.

The Ministry hopes that you all will make the best use of the materials to improve the quality of science education.

Preface

This manual was developed by the Ministry of Education, Youth and Sport, in cooperation with VVOB.

Its objective is to improve science teacher training by introducing student centred approaches. This manual contains a set of science experiments that will help teacher trainers to achieve understanding with their students of the main biology concepts outlined in the RTTC curriculum. All experiments have been tested by teacher trainers and teachers.

Complementary to the manual is a set of DVDs with short movie clips of all experiments in this manual in order to help teacher trainers with integrating experiments in their lessons. For each experiment we include a set of objectives, a link to the relevant lesson in the curriculum, the material needed to do the experiment, a detailed description of the procedure, observations, an explanation and additional questions. Where appropriate we add ideas for variations.

We are convinced that this manual will contribute to an improvement of science education in Cambodia. However, do not hesitate to send us your comments and suggestions.

We are looking forward to receiving your comments. We wish you an inspiring experience and many satisfying science lessons with this manual.

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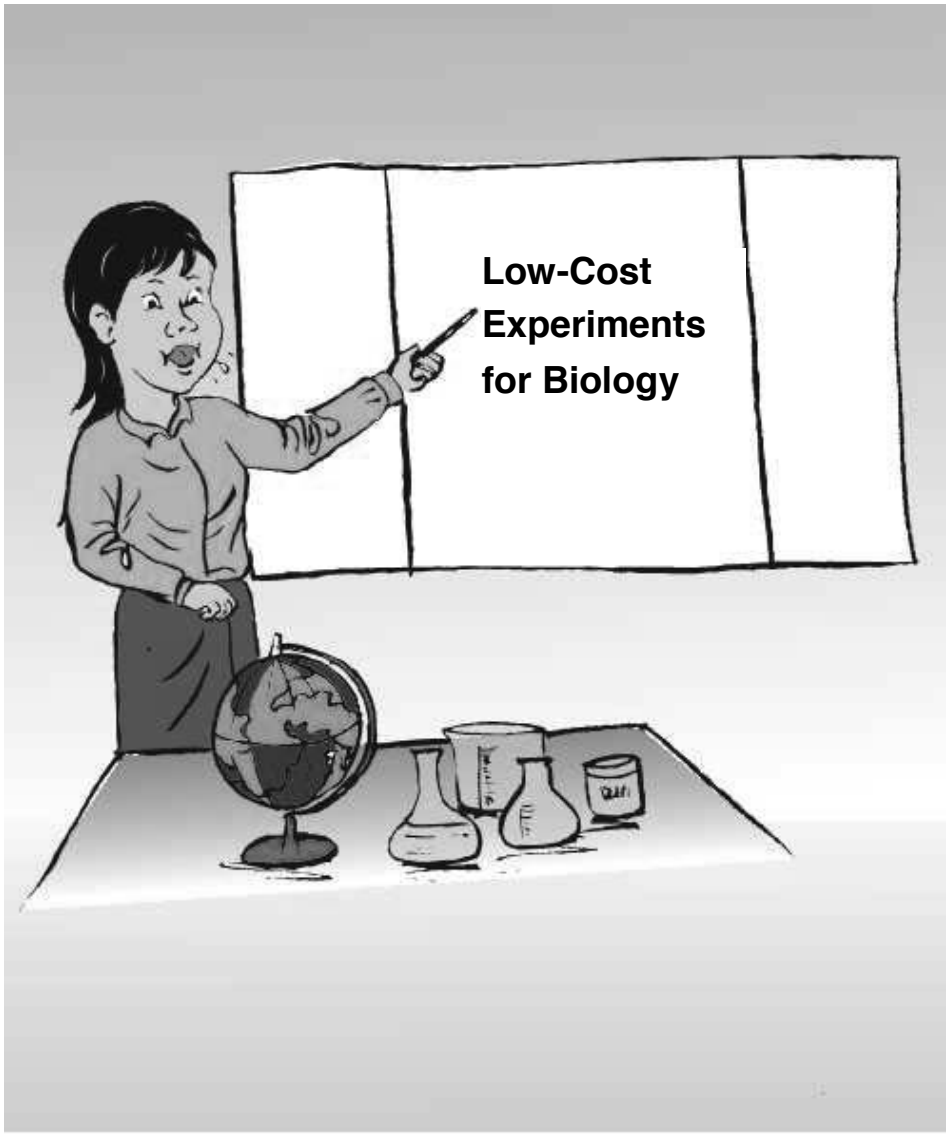
Low-Cost
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for Biology

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Introduction

With the publication of this manual of biology experiments, we want to give science teachers, and in particular biology teachers, a practical working tool for their invaluable work.

Often a lifelong interest in biology and science is engendered at the secondary school level. In our opinion this interest cannot be encouraged enough. This series of 34 educational experiments has been produced with the conviction in mind that they will provide didactic, original and even entertaining support in the teaching of the various biology concepts.

You can also access videos of these experiments on YouTube and on the krou website (http//krou.moeyes.gov.kh).

Each experiment has an accompanying text with conclusion, clarification and background information.

Biology Experiments

1. Experiments on the structure of plants

1.1 Growing plants on sponges

Objectives

- Students can explain how a plant grows.
- Students can describe what a plant needs to grow.
- Students can explain why seeds can germinate despite the lack of soil or light.

Position in curriculum

Grade 10, chapter 1, lesson 5, 2008

Materials needed

- Sponge (10cm x 10cm)
- Plastic bowl
- Salad seeds, flower seeds (or bean seeds)
- Magnifying glass (optional)

Procedure

- Place the sponge in the plastic bowl with enough water to soak it. Make sure that the sponge rises above the water level.
- Sprinkle a small amount of salad seed on the sponge and lightly pad them into it.
- Place the plastic bowl of sponge-soaked seeds in a sunny location.
- Keep the sponge wet.

Observations

Observe how the salad seeds grow and record your observations in a table (example below).

	Observation					
Seed growth	1 day	2 days	4 days	6 days	8 days	10 days

Explanation

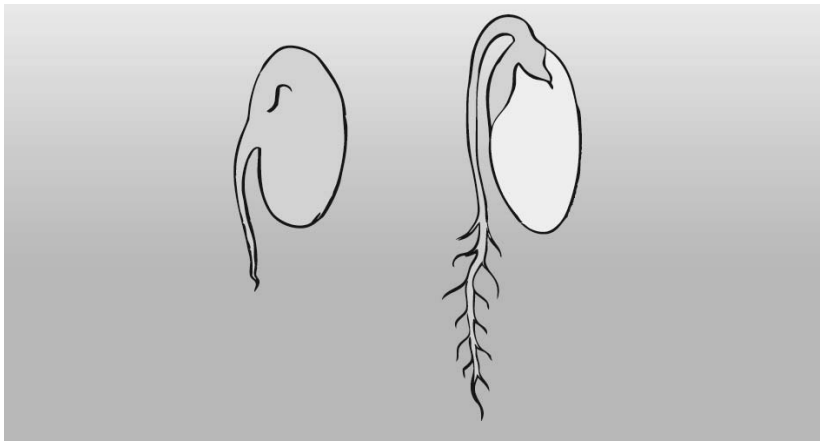
A seed is the part of the plant containing the embryo from which a new plant can grow. Usually the seed contains one embryo and a food supply. Larger seeds have more stored food than small seeds. Food stored in larger seeds is called the endosperm. Larger seeds can develop in the dark for much longer than small seeds, but eventually even seedlings that come from large seeds must reach a light source in order to survive.

Germination is when a seed begins to sprout and grow. In order for a seed to germinate, conditions must be right. There must be enough moisture and the right temperature. For different plants, the ideal conditions are different. Some seeds are more likely to germinate in the light while others prefer the dark. The first thing to happen is the seed soaks up water. Then the seed coat cracks. Next, either the radicle (the root) or the cotyledon (the seed leaves) emerges out of the seed coat. The developing seedling responds to light and gravity. Developing shoots grow against gravity, while developing roots grow towards gravity. This will

happen even in the dark. It is called *gravitropism*, meaning movement in response to gravity. Developing shoots also grow towards the light. This is called *phototropism*.

Conclusion

Usually seeds contain one embryo and a food supply. Developing seeds need water and light to start growing.



Questions

1. Why do the seeds sprout on the sponge?
2. Why do the seedlings die after a few days?
3. When can salad plants make their own food?

1.2 Transportation of water through plant leaves

Objectives

- Students can describe the transportation of water in plants.
- Students can explain the role of stomata in transporting.
- Students can explain the formation of water droplets in the top bottle.
- Students can relate the experiment to the water cycle on Earth.

Position in curriculum

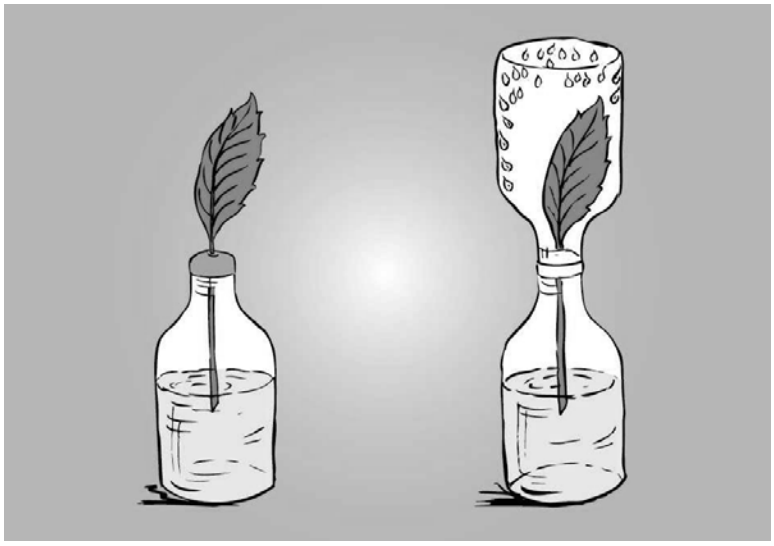
Grade 8, chapter 3, lesson 2, 2010
Grade 9, chapter 1, lesson 1, 2011
Grade 12, chapter 2, lesson 1, 2010

Materials needed

- Large plant leaf with long stem
- 2 plastic bottles (500ml)
- Water
- Clay
- Nail (slightly smaller than the size of leaf's branch)

Procedure

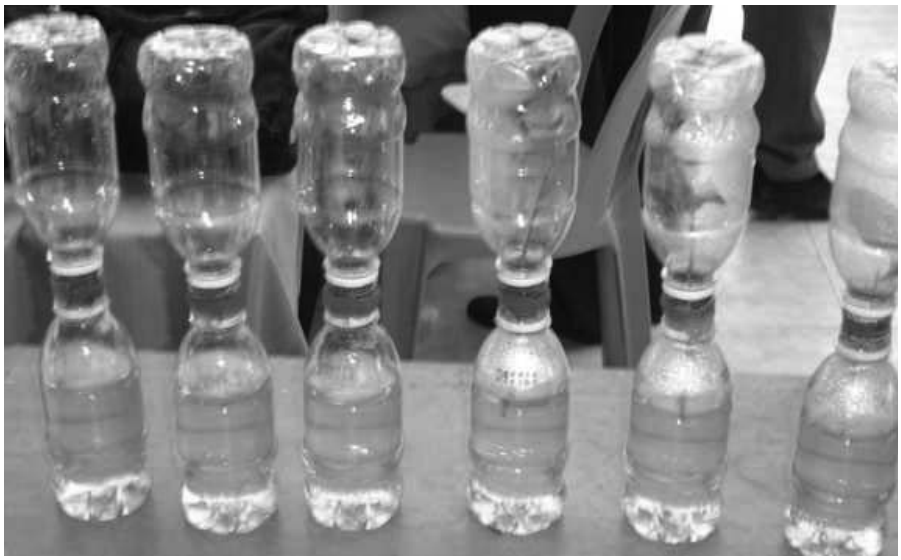
- Roll the clay and put it in the bottle neck.
- Make a hole in the plug with the nail so the stem fits in it.
- Insert the stem of the leaf through the clay. Be careful not to break the stem or crush the leaf.
- Press the clay plug inward around the stem to seal it.
- Fill one bottle with water and push the plug with the leaf in it into the top of the bottle. The end of the stem should be in the water.
- Carefully, turn the other bottle upside down on top of the first bottle. Again press the clay gently around any opening in order to seal the connection between the two bottles.
- Make the same structure but without the plant leaf. This will serve as a control experiment. In this way you can determine if any observations are caused by the presence of the leaf or not.



Observations

After one hour observe the experiment and record your observations in a table (example below).

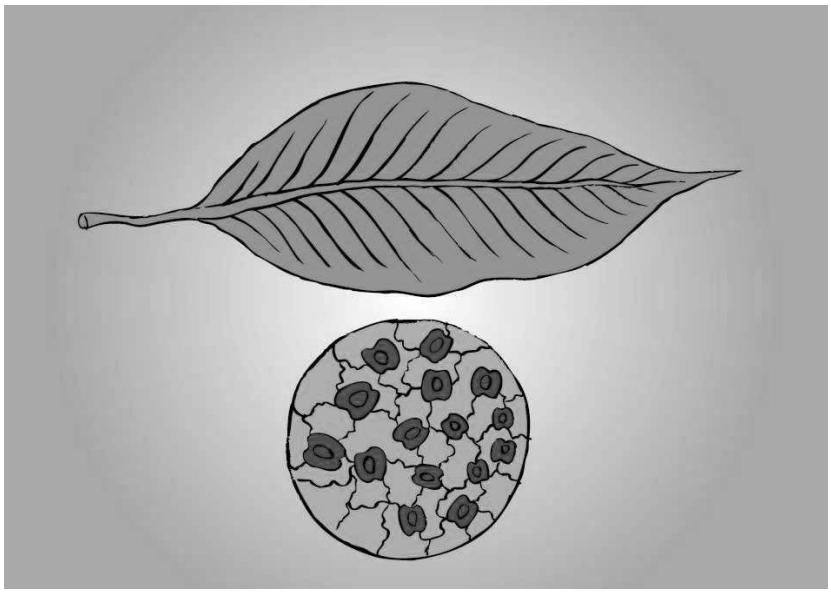
Observation	Bottle with the leaf		Bottle without leaf	
	Top bottle	Bottom bottle	Top bottle	Bottom bottle



Explanation

A plant loses water vapour through holes or pores called stomata. Plants often obtain too much ground water through their roots and get rid of what is not needed through these holes. Although you may not see it, plants give off litres of water each day. Leaves release millions tons of water vapour into the air every day. This is an earth process we never consider, but without it we could never live on this planet.

The entire amount of water on Earth is always the same – none is ever lost. The earth's waters are naturally recycled through rain, clouds, lakes, rivers, oceans, and especially by plant transpiration. We call this the water cycle.



Conclusion

Water and minerals within plants are transported by a process called transpiration. Stomata play an important role in this process.

Questions

1. Why do small droplets appear in the top bottle?
2. How can you be sure that the plant leaf is responsible for the formation of the droplets?
3. Which part of plant functions as transporter?
4. How would you measure the amount of water that is transported by the plant leaf?

1.3 Flowers change colours

Objectives

- Students realize how vital the roles of the roots and the stems are to the plants.
- Students can describe the transportation process in plant tissues.
- Students can explain the function of stomata in the transportation system of plants.
- Students can observe and make inferences from experimental data.

Position in curriculum

Grade 7, chapter 2, lesson 3, 2009
Grade 8, chapter 3, lesson 2, 2010

Materials needed

- 2 types of flowers (any flower which is white such as morning glory, and white bougainvillea)
- 2 plastic bottles (500ml)
- Food colouring or dyes
- Water

Procedure

- Fill the 2 plastic bottles half with water
- Drop 20-30 droplets of food colouring into each bottle
- Cut the branch of flower long enough and put it in each plastic bottle. Make sure the branch is under the water surface. In the case of cut flowers, it is very important for the stem tubes to be filled with water. The reason is this, no water can move up if the stem tubes are filled with air.
- Leave them for 2-3 hours.

Observations

	Observation			
	2 hours	3 hours	4 hours	5 hours
Morning glory flower				
White bougainvillea flower				

Explanation

The flower drank the coloured water and as the water travelled up the stem and into the petals, it carried the food colouring with it. As the food colouring reached the petals, they take on the colour of the water. Putting food colour in the water of the plants does not harm them. But like coloured dyes, chemicals that pollute the waters can get into the soil and ground water, contaminating our vegetables and plants. Some pollutants and chemicals, just like the coloured, may even travel up the plant and affect the way the plant grows. Incidentally, this is similar to why flamingos are pink. Flamingos eat a lot of shrimp and shellfish and they absorb the pink and red colours into their feathers, making them pink.

Conclusion

Flowers absorb water and transport it through the stems to the leaves in a process called transpiration. Substances dissolved in the water such as food colouring or pollutants are also transported, contaminating vegetables and plants.

2. Experiments on diffusion and osmosis

2.1 Diffusion

Objectives

- Students can demonstrate diffusion of a dissolved substance.
- Students can explain the process of diffusion and give an example.
- Students can explain how temperature affects the rate of diffusion.

Position in curriculum

Grade 7, chapter 2, lesson 3, 2009
Grade 8, chapter 3, lesson 1, 2010

Materials needed

- Pot or plastic bottle (1.5 or 2L)
- Cold water
- 2 soda bottles (or other small glass bottles)
- Marbles (or stones)
- Food colouring (few drops)
- Ice cubes
- Iron wire
- Cooking stove
- Iron pot
- Pliers

Procedure

- Heat approx. ¼ litre water.
- Use scissors to cut the iron wire into pieces of about 20cm and tie it to the soda bottle's neck
- Fill the pot nearly full of cold water (the colder the better, use ice cubes if possible)
- Fill the small bottle with hot water (2/3 full).
- If necessary, drop some marbles in the bottle, so the bottle will sink (if the bottle is heavy enough, the marbles are no need to use)

- Drop the food colouring into the hot water in the bottle and observe its spreading in the water.
- Then place this hot bottle into the pot of cold water. Make sure that the bottle is small enough to submerge in the cold water.

Observations

- Observe the speed of diffusion in the bottle of hot water.
- Observe the speed of diffusion when the bottle of hot water is placed into the cold water.
- Compare both speeds.

Explanation

Diffusion is the movement of particles from an area of higher concentration to an area of lower concentration. The result of diffusion is a gradual mixing of material. In a phase with uniform temperature, the diffusion process will eventually result in complete mixing or a state of equilibrium.

Conclusion

Diffusion is the movement of particles from an area of higher concentration to an area of lower concentration.

Questions

1. Why does food colouring spread faster in the hot water?
2. What can you see when the hot bottle was placed into pot of cold water?
3. Predict what would happen if you repeated the experiment but with cold water for the bottle and the pot.

2.2 Osmosis in plant tissues

Introduction

This experiment on osmosis allows students to observe and collect their own data, which they can process in a table or graph. It can also be used to teach students about the importance of a control when doing a science experiment.

Position in curriculum

Grade 7, chapter 2, lesson 3, 2009
Grade 8, chapter 3, lesson 1, 2010

Objectives

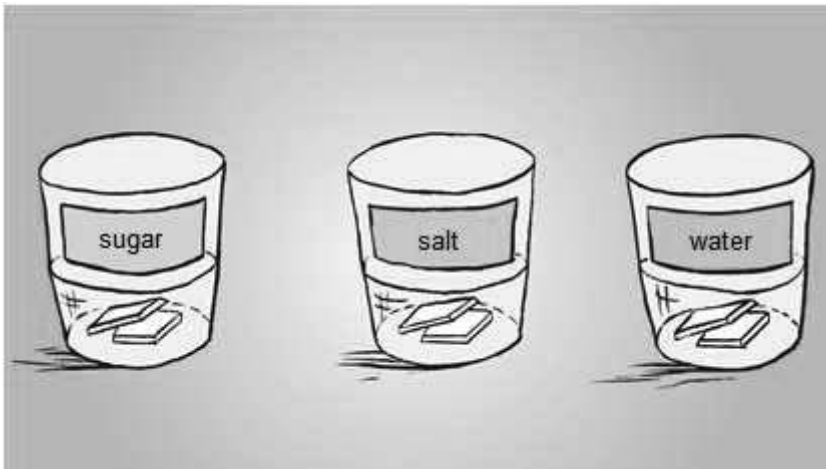
- Students are able to demonstrate osmosis using plant tissue.
- Students can explain osmosis and give an example in plants.
- Students can explain the difference between osmosis and diffusion.

Materials needed

- Small bowls or cups
- Water
- Sugar
- Salt
- Potato
- Knife
- Tissue
- Pencil or pen

Procedure

- Label three plastic bowls water, salt, and salt respectively
- Fill the bowls about 1/3 with water
- Dissolve salt into water. Keep adding salt until no salt dissolves anymore.
- Repeat the procedure to make a sugar solution.
- Use a knife the peel the skin of potato and make potato slices of approx. 6 cm long and 0.5 cm thick. Try to make the strips as identical as possible.
- Measure the strips and write the length down.
- Put one strip of potato in each solution



Observations

- After 30 minutes, take the potato strips out of the bowls.
- Dry the strips with paper tissue.
- Feel the strips and record you observations in a table.
- Measure the strips and record you observations in a table.

Solution	Observations	
	Length of potato strip	potato's characteristics
Water		
Sugar		
Salt		

Explanation

Osmosis is the movement of water molecules across a membrane from an area of higher concentration to an area of lower concentration. Osmosis is of great importance in biological processes where the solvent is water. The transport of water and other molecules across biological membranes is essential to many processes in living organisms. Biological systems use osmosis to pass water and some nutrients between cells.

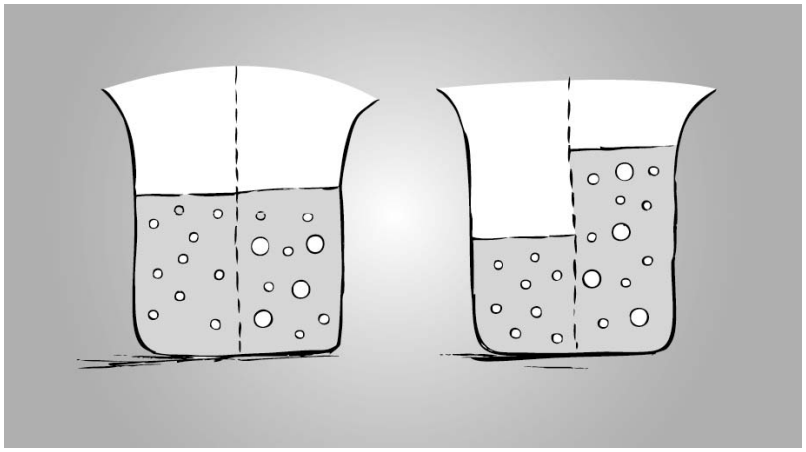
In order to understand osmosis three concepts are important:

1. Diffusion
2. Membrane structure and permeability
3. Water concentration (or activity) in the presence of dissolved compounds

Diffusion is the net movement of molecules from a region of high concentration to a region of lower concentration due to random motion of molecules. In a solution with equal concentration, some molecules will be moving out of a certain region and at the same time other molecules are moving into that region. Molecules move in all directions and are in continual motion.

Some membranes have such a structure that water molecules are small enough to pass through and sugar molecules are too large (and too polar) to pass through. If there was a membrane with twice as many water molecules on one side as there were on the other side, more water would flow from a higher concentration to a lower concentration of water. Eventually the concentration of water on each side of the membrane would be equal and the flow of water would be diffusing through the membrane in both directions at the same rate.

Adding sugars to water decreases the water concentration (or activity) because the sugar molecules displace water. If these two beakers were connected by a tube that contained a semi-permeable membrane, the water molecules would flow from a high concentration of water (see figure, on the left) to a lower concentration (see figure, on the right). This flow of water, from the higher water concentration to the lower water concentration, results in a change in volume of the two sides. The side that also contains sugar has a larger volume.



Conclusion

Osmosis is the movement of water molecules across a membrane from an area of higher concentration to an area of lower concentration. Osmosis is of great importance in biological processes where the solvent is water.

Questions

1. Make drawings in which you explain the process that causes the observed results.
2. Can you explain the different observation between the salt and the sugar experiment?

2.3 Osmosis in eggs

Objectives

- Students are able to demonstrate osmosis using chicken eggs.
- Students can explain osmosis and give an example in egg inner membrane.
- Students can explain the difference between osmosis and diffusion.

Position in curriculum

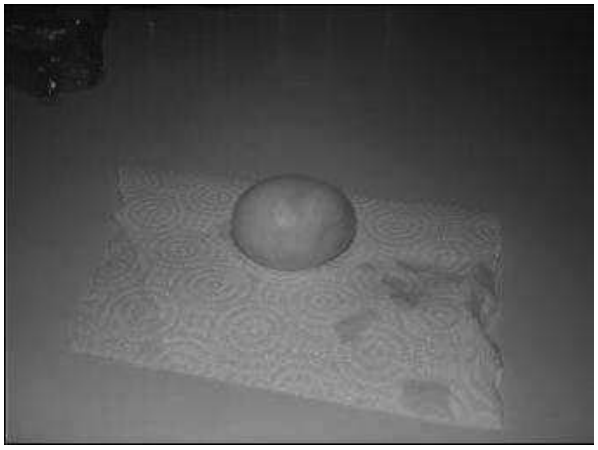
Grade 7, chapter 2, lesson 3, 2009
Grade 8, chapter 3, lesson 1, 2010

Materials needed

- 3 large eggs
- 3 2-liter plastic bottles (preferably wider rather than taller)
- White vinegar 150ml
- Water
- Blue food colouring (or another dark colour)
- Syrup 50ml
- Toothpick
- Tape measure (or a piece of string and ruler)
- Pen
- Paper
- Foil or plastic wrap (optional)

Procedure

This activity is completed in three parts. It is suggested that the first part of the activity is done in the afternoon or evening, the second part of the activity can be done the following afternoon or evening, and the third part the following day.



Part 1

- Place each egg in a separate plastic bottle.
- Pour vinegar into each bottle until it completely covers each egg. You may cover the bottles with foil or plastic wrap to reduce the smell.
- Leave the bottles on the table in safe place for approximately 24 hours. The vinegar will react with the eggshell and remove it, leaving only the inner membrane. The eggs will look like the one below when the shell is removed. It is ok if all the shell is not removed, as long as the majority of the shell is removed.

- Empty the vinegar out of each of the bottles and wash them thoroughly.
- Lightly rinse each of the eggs with water.
- Place the eggs back into the bottles.
- Label each of the glasses 1 thru 3 and use the table provided at the end of this activity to keep track of the four different eggs.
- Measure each egg around at the widest point using a tape measure or a piece of string. To use a piece of string, Take a piece of string and wrap it around the egg once. Mark with your finger the length of string that is needed to go around the egg once and measure it using a ruler. Record the length around for each egg using the table provided.
- Put all eggs into 3 glasses
- Cover one egg with water, one with water and a drop of blue food colouring, and one with molasses or syrup.
- You may also cover the glasses with plastic wrap or foil to lessen the smell. Wait several hours (such as until the morning) to see what happens to the eggs!

Part 3

- Carefully remove the eggs from the substances and rinse them carefully with water.
- Just as before, measure the eggs around at the widest part using either a tape measure or string and a ruler.
- Record the measurements in the table.
- Finally, place the eggs back inside the glasses after they have been properly washed or place them in new cups or glasses.
- Use a toothpick to carefully pop each of the membranes of the eggs.
- What did you notice about what was inside? Did any of the outside substance make it to the inside of the egg? Record your observations in the appropriate space in the table provided.

Observations

Record your observations in the table below.

Egg	Substance	Width before	Width after	What was inside egg?	Other observation
Egg1					
Egg2					
Egg3					

Explanation

A hard outer shell surrounds all chicken eggs. But did you know that underneath that shell is a membrane similar to what surrounds cells? In this experiment, we have removed the shell in order to examine more closely this membrane.

Osmosis is simply diffusion through a membrane. Substances will naturally try to “even out” meaning that, if they are able to move through the membrane, they will try and obtain the same density on either side of the membrane. Substances will move from an area of higher concentration (or density) to an area of lower concentration through the membrane. Once the concentration is equal on both sides of the membrane, it is said that the substance has achieved ***equilibrium***.

Conclusion

In a process called osmosis substances move from an area of higher concentration (or density) to an area of lower concentration through a semi-permeable membrane.

Questions

1. In which substances did the width of the eggs increase? Explain your answer?
2. In which substances did the width of the eggs decrease? Explain your answer?
3. In which substances did the width of the eggs stay the same? Explain your answer?

3. Experiments about the sense of taste

3.1 Sensitivity of sense of taste

Objectives

- Students can explain the importance of the sensory system in daily life;
- Students can perform an experiment to investigate the role of the aggregation state of on the taste;
- Students can describe the role of salivary glands in tasting food.

Position in curriculum

Grade 12, Chapter 3, lesson 2, 2010

Materials needed

- Grain sugar and spoon
- Paper serviette (napkin)
- Sugar water in a glass
- Stopwatch

Procedure

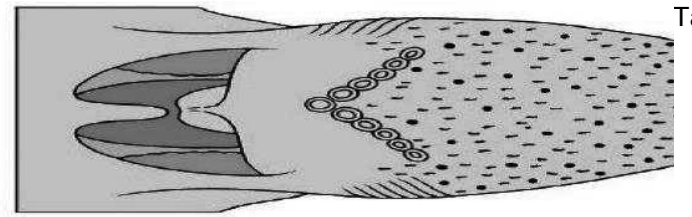
- Dry your tongue with the paper napkin
- Put some sugar on your tongue
- Record how long it takes to taste the sugar
- Dry your tongue again
- Take some sugar water into your mouth
- Record how long it takes to taste the sugar

Observations

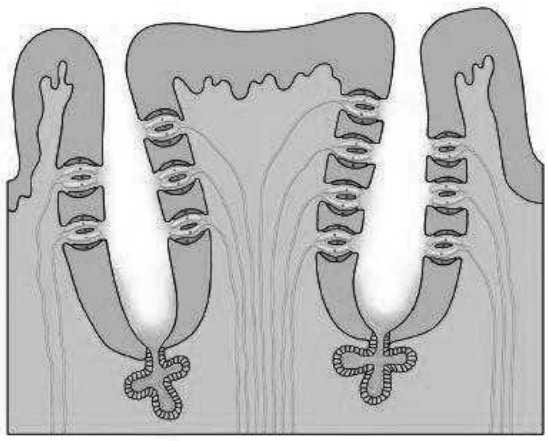
The time to taste the grain sugar:……..
The time to taste the sugar water:……

Explanation

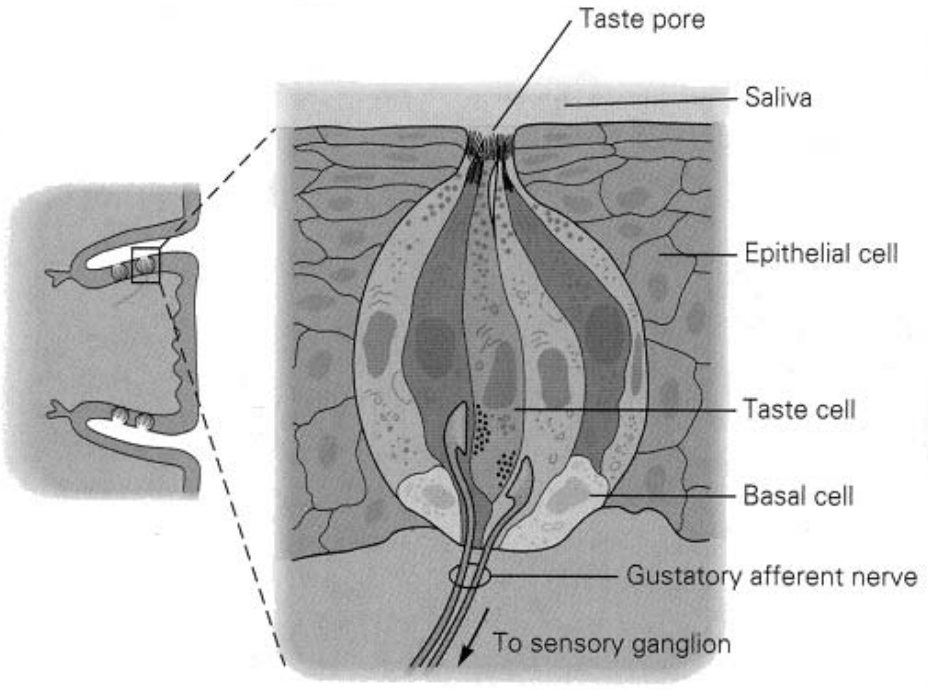
The taste receptors are situated in taste buds on the tongue (figure 1) and the palate. Figure 2 shows the cross-section of 1 taste bud. There are several gustatory buds drawn. We recognize the saliva gland coloured in blue. Each gustatory bud contains 60 to 100 taste receptor cells and support cells. An action potential is generated in the receptor cell when a food molecule binds on his villi. So food molecules first have to dissolve in saliva (or water or any other fluid) before they can reach the villi. The action potential causes an electric impulse that passes through the nerve (see figure 3) to the brain.



Taste buds



Gustatory buds



Conclusion

We taste the sugar water immediately but the grain sugar only from the moment that it dissolves in our saliva. This means that sugar or other foodstuff first has to dissolve in saliva before the taste receptors can receive it.

Questions

- In which state of aggregation do substances need to be, so that we can taste them?

(Substances need to be dissolved in a fluid. Only fluid molecules can stimulate the taste receptors.)

- Why are the saliva glands located in the taste buds?

(All the food that we eat has to become dissolved in a fluid. Saliva glands produce saliva. All food particles on the tongue encounter saliva, dissolve in this fluid and can stimulate in this way the taste buds.)

3.2 Relationship between sense of taste and smell

Objectives

- Students can explain the importance of the sensory system in daily life;
- Students can perform an experiment to test the sense of taste;
- Students can interpret experiment results.

Position in curriculum

Grade 12, Chapter 3, lesson 2, 2010

Materials needed

- 6 glasses or cups
- Grain sugar
- Water
- Sugar water or honey
- Lime juice
- Chips
- Coffee (or other food)

Procedure

part 1

- Take a little bit of sugar or salt on the top of your finger and hold it against your palate.
- Repeat this for the cheeks.

part 2

- One person closes the eyes and nose.
- The other person gives him/her different food.
    - Write a (+) for a good answer
    - and (–) for a wrong answer
- Rinse the mouth with water after every tasting
- Repeat the tasting with open nose (and closed eyes)

Observations

part 1

We also taste with the palate.

part 2

	Nose Closed	Nose Open
Lemon juice		
Honey or sugar solution		
Chips		
Fruit juice		
Coffee		

Explanation

The taste buds are scattered around all the places that food and drink touch: the cheeks, throat, palate (roof of the mouth) but are concentrated on the tongue's upper surface.
We only taste the 5 primary tastes with our taste receptors in the mouth. The complete taste of food is a result of the cooperation of the taste and smell receptors.

All the tastes are composed of the 5 primary tastes sweet, sour, acid, salt and umami. But if we want to taste the full taste of food, we also need to use the smell receptors. The sensitivity of the smell receptors is much higher than those of the taste receptors.

Conclusion

We only taste the primary tastes with our taste receptors in the mouth. The complete taste of food is a result of the cooperation of the taste and smell receptors.

All tastes are composed of the 5 primary tastes sweet, sour, acid, salt and umami. But if we want to taste the full taste of food, we also need to use the smell receptors. The sensitivity of the smell receptors is much higher than those of the taste receptors.

Questions

1. Can you explain why we taste less when we have a cold?

(A cold is a viral disease which infects the mucous membrane of the nose. The mucous membrane swells and less air with smell particles from the food we eat enter the nose. The smell receptors are less stimulated and as they help to form the taste, we taste less.)

3.3 Adaptation of sense of taste

Objectives

- Students can explain the importance of the sensory system in daily life;
- Students can perform an experiment to test the adaptation of the sense of taste;
- Students can explain the adaptation of the sense of tastes.

Position in curriculum

Grade 12, chapter 3, lesson 2, 2010

Materials needed

- Grain sugar or sugar water or salt
- Water
- Spoon
- 2 glasses

Procedure

- Fill half-full glass 1 with water and 1 spoon of sugar or salt and glass 2 with same amount of water and 3 spoons of sugar or salt. Stir well.
- Taste from glass 1 (and spit out)
- Taste from glass 2 (and spit out)
- Taste again from glass 1 (and spit out)

Observation

- How does the water taste? (Salty)
- How does the water taste? (Saltier)
- How does the water taste? (Normal, not salty anymore)

Explanation

Taste adaptation is a gradual decline of taste intensity with prolonged stimulation. This means that a taste gets less strong after tasting it for a while. The taste receptor cells generate and send less frequently impulses to the brain when they are stimulated with the same food molecule for a long time.
However, during a normal meal the taste of food does not seem to decrease or disappear.
During eating, the presence of saliva, the interactions between taste and smell particles and mouth movements affect the duration of taste intensities. This also explains in part why results of adaptation experiments can differ between individuals.

Conclusion

A certain taste becomes less strong after tasting it for a while. The taste receptors are subject to adaptation. The taste buds on the tongue react on the amount of salt in the water. They are only sensitive for little differences in the amount of salt. They can adapt the level around which they are sensitive for salt.

Questions

1. Does adaptation also exist for other senses?

(Yes, also for the sense of sight, sense of smell and sense of touch.)

4. Experiments about respiration

4.1 Comparison between inhaled and exhaled air

Objectives

- Students can explain the importance of external (and internal) respiration;
- Students can compare the amount of O_2 and CO_2 in inhaled and exhaled air.
- Students can link the conclusion of the experiment with the theory about respiration.

Position in curriculum

Grade 8, Chapter 4, lesson 2, 2010

Materials needed

- 2 equal glasses
- Thermometer
- 2 small candles
- Matches
- Freshly made limewater *
- Test tube
- Straw

**How to prepare limewater ($Ca(OH)_2$ – solution):*
Dissolve CaO_2 in (distilled) water and stir well. Filter the mixture. You obtain a clear solution: limewater.

Procedure part 1

- Breathe out in a glass.
- Measure the temperature in the classroom.
- Breathe out several times on the thermometer.

Observation part 1

The temperature of the exhaled air is higher than the temperature of the classroom
Remark: as the temperature in Cambodia is relatively high, the difference between the temperature of inhaled and exhaled air is not so big.

Procedure part 2

- Light the 2 candles
- Breathe out several times in one glass.
- Put this glass on top of a candle and at the same time, put the other glass on top of the other candle.

Observation part 2

The candle under the glass with exhaled air extinguishes first.
Remark: the 2 candles must be equally strong. Breathe in and out in the glass without moving the glass away from your mouth. Try to let as less air as possible enter the glass while you put it above the candle.

Conclusion part 2

A candle needs oxygen to burn. The candle filled with exhaled air extinguishes first so the exhaled air contains less oxygen.

Procedure part 3 (A)

The gas in soda water is CO_2

A. How can we prove CO_2 in a gas?

- Fill half of the 2 test tubes with limewater
- Put some drops of soda-water in test tube 1
- Put some drops of normal water in test tube 2

Observation part 3(A)

- The clear, colourless solution of test tube 1 becomes white and turbid.
- The clear, colourless solution of test tube 2 stays the same.

Conclusion part 3(A)

We can prove the presence of CO_2 by adding limewater.

B. What is the difference in CO_2 content of inhaled and exhaled air?

Procedure part 3(B)

- Fill 2 test tubes half with lime water.
- Put some air from the classroom in the limewater from test tube 1 by shaking the test tube.
- Breathe out through the straw in the test tube 2.

Observation part 3(B)

- The clear, colourless solution of test tube 1 becomes only a little bit white and turbid.
- The clear, colourless solution of test tube 2 becomes fully white and turbid.

Explanation

Exhaled air has a much higher percentage of CO_2 compared to inhaled air and a lower percentage of oxygen (but this difference is not so big). The body can only absorb a small amount of the oxygen from each lungful of air, so much of the inhaled oxygen is breathed out again. Oxygen content of inhaled air is 21 %, that of the exhaled air is 15.5-17 %. The CO2 content of the inhaled air is 0.04 %, compared to 4 % in exhaled air (100 x higher concentration).

The humidity of inhaled air is dependent on the geographical location. It is about 0 % in dry climates. Humidity of exhaled air (water vapour) is 6 %. This is because during its passage through the mucous airways, water dissolves into the air. The temperature of exhaled air is higher than that of inhaled air, but when the temperature of the classroom air exceeds 25°C, the difference will be very small.

Final conclusion

Exhaled air:

- contains more water vapour
- is warmer
- contains less O_2
- contains more CO_2

than inhaled air.

Question

1. Link the conclusions with the way the respiration system functions. Explain each difference.

It is better to start with this experiment before you give the theory about respiration but if this is not possible, then let the pupils/students explain in which part of the theory they learned more about what they just have seen in this experiment.

4.2 Holding your breath

Objectives

- Students can understand the importance of respiration
- Students can compare the breath in different conditions
- Students can collect experimental data and make a graph of the results

Position in curriculum

Grade 8, chapter 4, lesson 2, 2010

Materials needed

- Stopwatch
- Plastic bag
- Pen or pencil

Procedure

- Divide students into groups of 4 or 5 students.
- Let students predict how long they can hold their breath.
- The first student takes a deep breath and holds his/her breaths as long as he/she can, while someone in the group records the time. Be sure the student holds his/her nose while he/she hold his/her breath. Record the results in the table below.
- Let students predict the change in how long they can hold their breath after breathing into the bag?

- Now, breathe normally for a few minutes. Then, open a plastic bag and swish it through the air to fill it with air. Hold the bag over his/her mouth and nose and breathe into the bag normally for 1 minute.
- At the end of the time breathing into the bag, take a deep breath of the air from the bag and hold the breath as long as they can while someone in the group records the time. Write results in the observation table.

Observations

Complete the data from all the members of a group in the chart below.

Person's name	Time (normal air)	Time (air from bag)
Student 1		
Student 2		
Student 3		

Explanation

Usually, you breathe automatically, without even thinking about it. However, you can control your breathing voluntarily when you want to. For example, you can stop breathing and hold your breath for a while. However, you cannot hold your breath forever.

All parts of your body, including the muscles and the brain, depend on the breathing muscles and the circulation working together to deliver the oxygen needed by all body cells and to remove the carbon dioxide produced by all body cells. The part of your body that is the most sensitive to lack of oxygen is your brain. If the brain is deprived of oxygen for a few minutes, parts of the brain can be permanently damaged.

Because it is so important to maintain a continuous supply of oxygen, the part of your brain which controls breathing will not let you hold your breath for a long time. After a short while this part of your brain will automatically start the breathing rhythm again, even if you try very hard to hold your breath.

Conclusion

Human beings need oxygen to live. We can only hold our breath for a few minutes before the part of our brain which controls breathing will intervene. If there is a higher concentration of CO2 in the air (and thus a lower concentration of oxygen) we cannot hold our breath as long.

Questions

1. While you are breathing into the plastic bag, what happens to the concentration of carbon dioxide in the bag?
   a. What happens to the levels of carbon dioxide in your lungs?
   b. What happens to the levels of carbon dioxide in your blood?
   c. What happens to the levels of carbon dioxide in your brain?
   d. While you are breathing into the plastic bag, what happens to the levels of oxygen in the bag?
   e. In your lungs, blood, and brain?
2. Why would it be very unhealthy to hold your breath for too long?
3. Were the results similar for all members of your group?

4.3 Cellular respiration

Objectives

- Students can explain the importance of (external and) internal respiration;
- Students can make observations from an experiment demonstrated by the teacher;
- Students can interpret experiment results;
- Students can link the conclusion of the experiment with the theory about internal respiration.

Position in curriculum

Grade 8, Chapter 4, lesson 3, 2010

Materials needed

- A bottle of glass with a big opening
- A spoon (a deep heat-resistant spoon)
- Candle flame
- Sugar
- Limewater

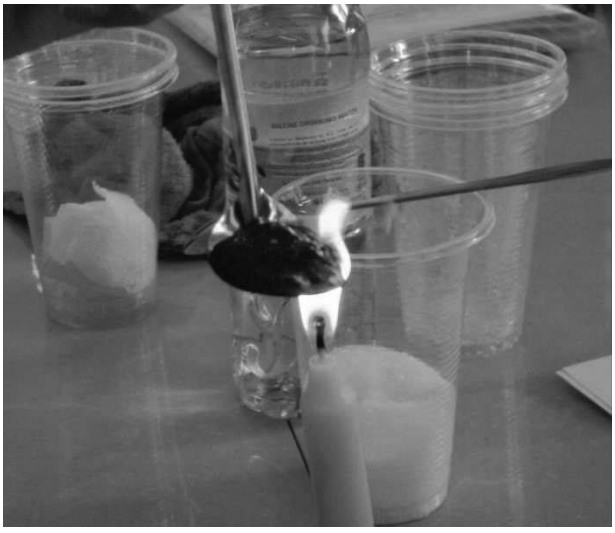
Procedure part 1

Remark: if the students don't know yet that we can prove CO_2 with the indicator limewater, than first start with procedure 3. A. from the experiment 4.1 "Comparison between inhaled and exhaled air?"

- Fold the spoon in that way it can hang in the bottle but stays a few centimetres above the bottom of the bottle (see figure).
- Put a little bit of sugar in the spoon and move the spoon into the flame.
- When the sugar is brown and not boiling anymore, let the sugar make contact with the flame until it burns.
- Put the burning spoon immediately in the bottle. Observe the side of the bottle and the burning mass. Touch the bottle.
- Close the bottle when the flame is extinguished.
- Wait until the smoking stops, then take out the spoon and close the bottle immediately. Make sure that there is not a lot of air going out and coming in the bottle.

Observations part 1

- Burning sugar: the white sugar becomes first brown. After the burning it is turned into black (carbonized) and has lost weight.
- Side of the bottle: the side becomes damped and feels warm.



Procedure part 2

- Open the bottle a little bit (make the opening as small as possible) and add approx. 5 ml limewater.
- Close the bottle and shake it. The air in the bottle mixes with the limewater. Observe the colour and transparency of the limewater.

Observations part 2

- Limewater: the transparent, colourless limewater becomes white and turbid.

Explanation

Cellular respiration is the main way for a cell to gain useful energy. Respiration converts biochemical energy from nutrients to energy stored in adenosine triphosphate (ATP). The waste products CO_2 and water are released. The reactions involved in respiration are catabolic reactions that involve the oxidation of one molecule and the reduction of another.
Nutrients commonly used by animal and plant cells in respiration include glucose, amino acids and fatty acids. A common oxidizing agent (electron acceptor) is molecular oxygen (O_2). The energy released in respiration is used to synthesize ATP to store this energy. The energy stored in ATP can then be used to drive processes requiring energy, including biosynthesis, locomotion or transportation of molecules across cell membranes. The chemical reaction of the oxidation of glucose (= respiration of glucose) is:

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ + energy

We can examine the oxidation of glucose by burning sugar.

Conclusion

Burning sugar forms CO_2, water and heat. The burning process needs oxygen. When there is no more oxygen, the burning stops.

Questions

1. Which gas is formed by burning glucose?
2. Link the conclusion of this experiment with the theory about the internal respiration.

   Write down the overall chemical reaction that takes place: $C_6H_{12}O_6 + 6\ 0_2 \rightarrow 6\ CO_2 + 6\ H_2O + energy$
3. What is the name of the opposite reaction that takes place in plant cells? *Photosynthesis*

4.4 Chemicals in tobacco smoke

Objectives

- Students can explain the importance of a healthy respiration;
- Students can recognize the toxic chemicals in tobacco smoke;
- Students can interpret experiment results;

Position in curriculum

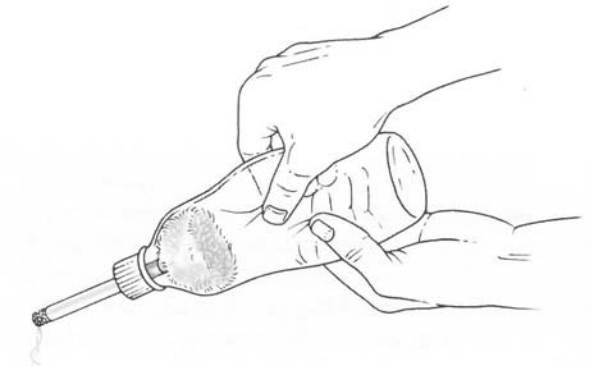
Grade 7, chapter 5, lesson 2, 2009

Materials needed

- Cigarette
- Empty plastic bottle with lid. Make a small opening in the lid to put the cigarette in (see figure)
- Cotton wool
- Matches

Procedure

- Put some cotton wool near the opening of the bottle.
- Take off the filter of the cigarette and put the cigarette through the opening that you made in the lid
- Light the cigarette with the match
- Squeeze the bottle to push the air out and then restore the shape of the bottle so the air comes back into the bottle.



- When the cigarette is burned out, remove the cotton wool from the bottle.
- Smell and look at the cotton wool

You can repeat this experiment with new, white cotton wool and a cigarette with filter.

Observations

The cotton wool becomes black.

Explanation

A cigarette is a small roll of finely-cut tobacco leaves wrapped in a cylinder of thin paper for smoking. Most cigarettes are filtered and include reconstituted tobacco and other additives. Statistically each cigarette smoked shortens a person's lifespan by 11 minutes. Smokers who die of tobacco-related diseases lose on average 14 years of life. Cigarette use by pregnant women has also been proven to cause birth defects, including mental and physical disabilities.

The smoke of cigarettes contains tar: a black adhesive liquid, nicotine and CO_2. Cigarette tar refers to the toxic chemicals that are added during the production of tobacco cigarettes. The tar in tobacco cigarettes is a major cause of lung cancer, emphysema and bronchitis. The toxins from the tar can damage lung cells that protect against tumours. Cigarette tar also damages cilia in the lungs, which protect the lining of the lungs.

Conclusion

The smoke of cigarettes contains tar: a black adhesive liquid (and nicotine and CO_2).

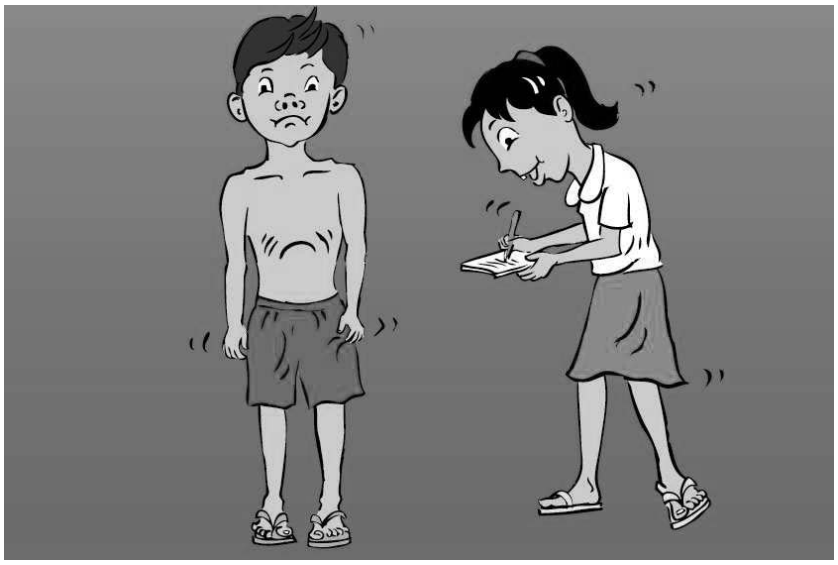
4.5 Breathing

Objectives

- Students can explain exhalation and inhalation through diaphragm and rib muscles
- Students can make and use a breathing model with simple materials available locally
- Students are aware of the importance of healthy exhalation and inhalation.

Position in curriculum

Grade 8, chapter 4, lesson 2, 2010



Materials needed

- 2 small balloon
- 1 large balloon (or thin rubber-made strip)
- Rubber band
- Plastic tube (50cm)
- 2 plastic bottles (2l or larger)
- 2 wooden bars
- Wire (2m)

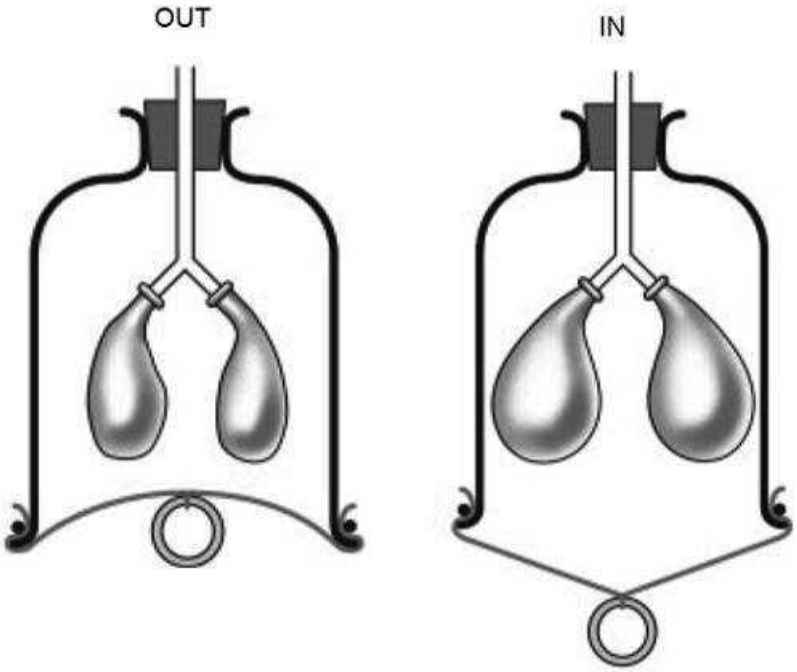
A. Model diaphragmatic breathing

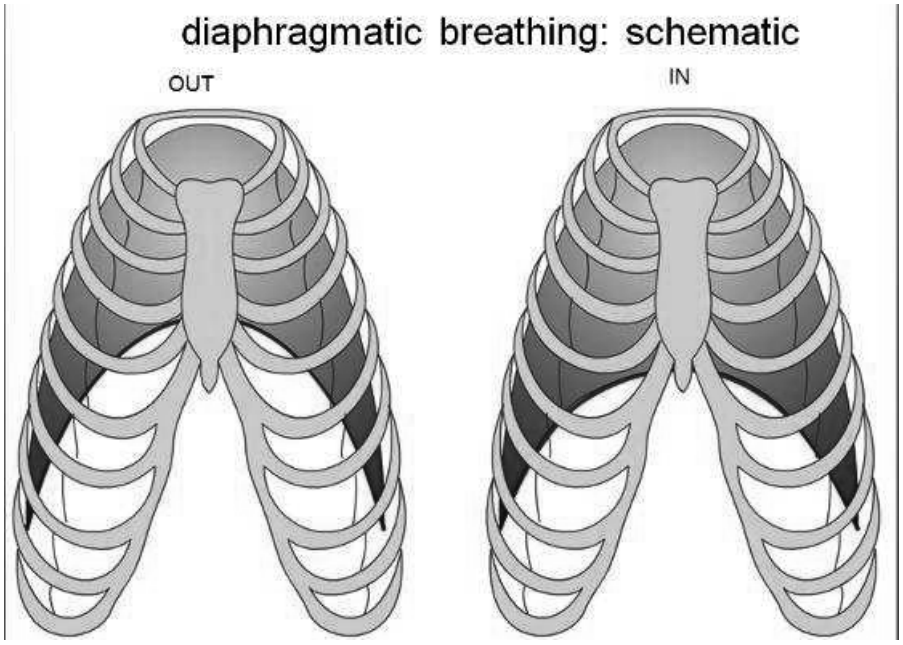
Description

The balloons represent the lungs, the tube that comes out the bottle is the trachea, and the 2 (smaller) tubes are the branches. The plastic bottle is a representation of the chest (ribs and muscles between the ribs) and the big balloon underneath is the diaphragm. Make sure that no air can escape from the connection between the trachea and chest, trachea and branches and the branches with the smaller balloons.

Usage

As shown in the scheme, when you pull down the “diaphragm” (diaphragm contracts), a lower pressure is created in the chest. The lungs stretch out and more air comes automatically in the lungs. This is inhaling by diaphragmatic breathing. When the diaphragm relax (push the “diaphragm” upward), the pressure in the chest increases and air moves out.

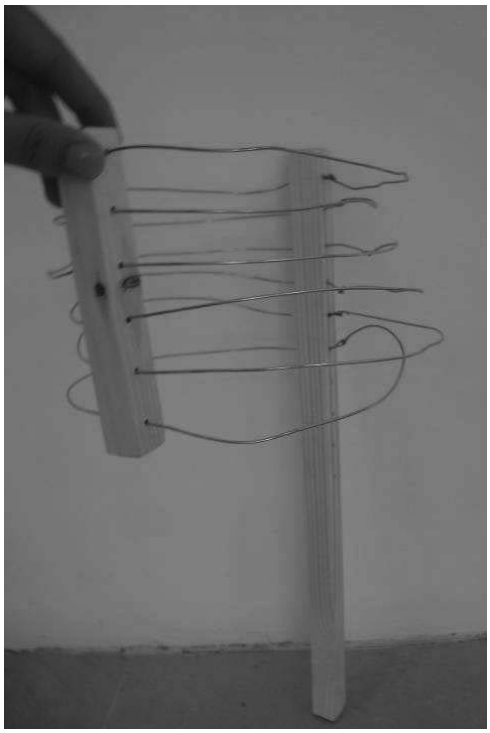




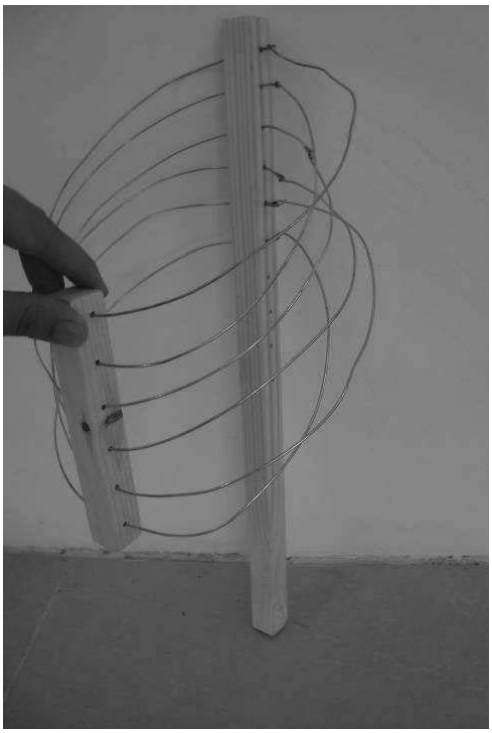
B. Model chest breathing

Description

The model consists of two bars in wood and some circles in metal that go through the wood. The longest bar represents the spine, the shortest one the breastbone (sternum). The metal circles represent the ribs.



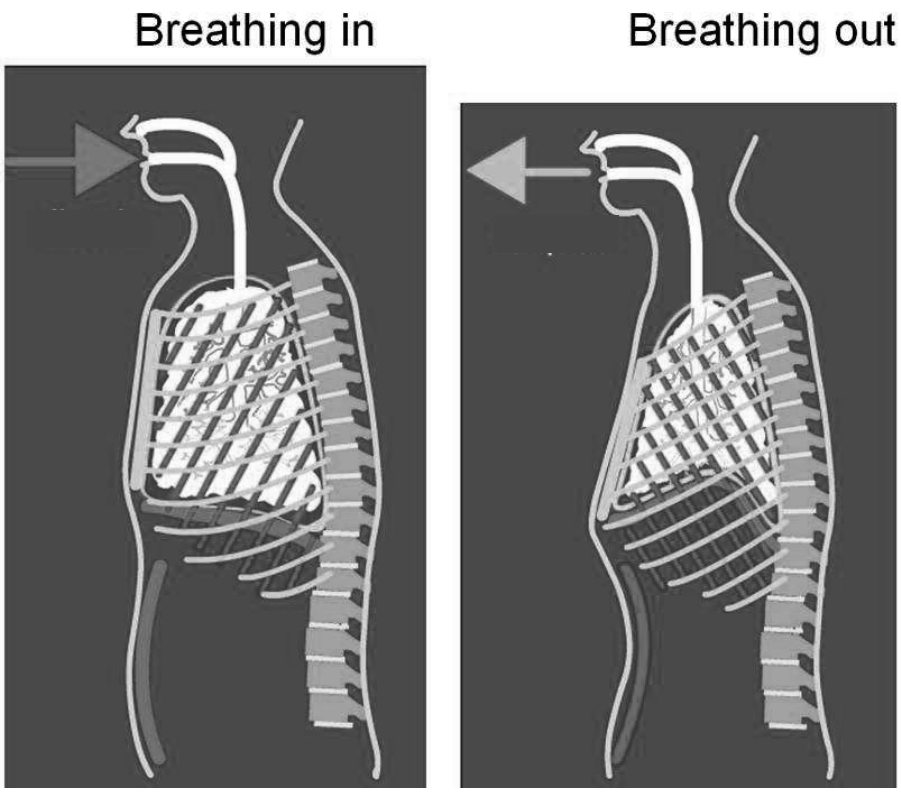
Breathing in



Breathing out

Usage

As shown in the left photo below, when the internal intercostal muscles (red lines in left figure beneath this text) between the ribs contract, the ribs and breastbone are moved upward and forward. When we move the breastbone of the model upwards, we remark (look from above at the model) that the space inside the chest becomes bigger. As a consequence, the lungs stretch out and air enters the lungs.
In the figure below, the combination of both ventilation ways is shown.



Explanation

Air moves between the atmosphere and the lungs in response to pressure differences. Air enters the lungs when the air pressure in the lungs is lower than the pressure outside the body, and air moves out when the pressure in the lungs is higher than the atmospheric pressure. These pressure changes are generated through changes of the chest cavity. There are 2 ways to enlarge the chest cavity: by contracting the diaphragm (diaphragmatic breathing) and by contracting the rib muscles (chest breathing). Usually, we combine both ways of breathing: the muscles between the ribs and the diaphragm contract, the chest cavity enlarges, pressure falls down so the lungs expands, lowering pressure in the lungs and the consequence is that air fills the lungs. This process is called inhalation. When the muscles between the ribs and the diaphragm relax, the chest cavity becomes smaller. The pressure thus increases and air moves out. This is exhalation.

Conclusion

Two low-cost models can be used to explain the workings of the respiratory system.

4.6 Model of spirometer

Objectives

- Students can explain advantages of spirometer
- Students can make and use this model properly
- Students can calculate volume of air in lungs by using spirometer
- Students can be healthy being aware of their lungs' air capacity

Position in curriculum

Grade 8, chapter 4, lesson 2, 2010

Materials needed

- Plastic bottle (5 litre bottle)
- Plastic tube (diameter of 1-2cm and length of 3m)
- Glue
- Scissors
- 1 large container
- Coloured markers

Description

The model is made of a big bottle (5 litre). Before cutting the bottom away, write the marks 0 litre, 1 litre,. Start with 0 litre at the top of the bottle. Make a hole in the top of the bottle and fit a tube in it. Remove the bottom of the model.

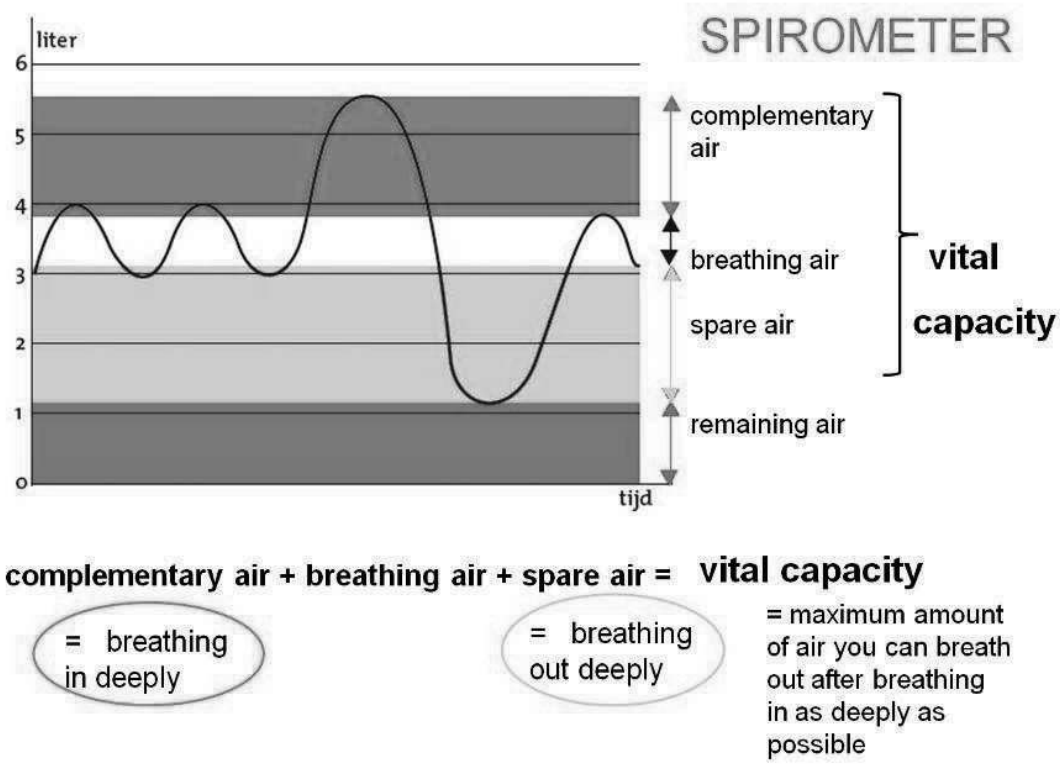
Usage

Put the model in a big basin of water. The level of water in the basin has to equal the 0 litre mark of the bottle. Breathe in and breathe out deeply in the tube. The bottle will rise in the water. When you have completely breathed out, verify which mark is closest to the water level. If this is for example 3,5 litre, than your vital capacity is 3,5 litre.

Background knowledge

A spirometer is an apparatus for measuring the volume of air inhaled and exhaled by the lungs. In medicine, it is used as a first test of the health condition of the patient's lungs. Lung diseases such as asthma, bronchitis and emphysema can be ruled out with these tests.

Lung volumes and lung capacities refer to the volume of air associated with different phases of the respiratory cycle. Lung volumes are directly measured. Lung capacities are calculated from lung volumes. The average total lung capacity of an adult human male is about 6 litres of air, but only a small amount of this capacity is used during normal breathing. This volume is called breathing air. An average human breathes 12-20 times per minute. The figure below shows the different lung volumes. The vital capacity is the maximum amount of air you can breathe out after breathing in as deeply as possible. For healthy persons, the vital capacity depends on gender (higher in males than females), length of the person (higher in larger persons) and age of the person (higher in adults than children). Persons that do a lot of sports also have a higher vital capacity. The total lung capacity is the viral capacity plus the remaining air.



Conclusion

A spirometer is an apparatus for measuring the volume of air inhaled and exhaled by the lungs. The vital capacity is the maximum amount of air you can breathe out after breathing in as deeply as possible. A working spirometer can be made with low-cost materials.

5. Experiments about the sense of sight

5.1 The dissection of a cow's eye

Introduction

The following experiments are best done by each student/pupil. They have to feel and see it with their own body. Let the students/pupils describe the observations. Let them search for an explanation or conclusion. The background knowledge is information for the teacher. You can teach it to the students/pupils AFTER you have done the experiment. The purpose of the experiments is that students/pupils discover themselves the new lesson content.

Objectives

- Students can perform a dissection of a cow's eye.
- Students can name the different parts of a cow's eye.
- Students understand how light is collected and transmitted to the brain.

Position in curriculum

Grade 12, Chapter 3, lesson 2, 2010

Materials needed

- Cow eye, pan, scissors, tweezers and gloves
- Soap, water and paper towels (for cleaning)

Procedure

**** Observing the external structure***

1. Rinse the eye with water and place it in the pan with the larger bulge or tear gland on the top of the eye. The eye is now in the position like it would be in a body as you face the body.

2. On the outside of the eye, locate the following structures:
   - Fat: surrounds the eye and cushions it from shocks
   - tear or lacrimal gland: forms a bulge on the top outer area of the eye and produces tears to wash and disinfect the surface of the eye
   - tear ducts: tubes to carry the tears from the gland to the eye
   - optic nerve: a white cord on the back of the eye about 3mm thick just toward the nasal side; the electric impulses that are formed in the photoreceptors are sent by the optic nerve to the brain.
   - muscles: reddish, flat muscles around the eye to raise, lower and turn (right and left) the eye

3. Turn the eye so that it is facing you and examine following structures on the front surface:
   - Eyelids: two moveable covers that protect the eye from dust, bright light, and impact
   - Sclera: the tough, white outer coat of the eye that extends completely around the back and sides of the eye

- Cornea: a clear covering over the front of the eye that allows light to come into the eye (The cloudy nature of the cornea is caused by the death of this tissue. It is transparent as long as the organism is alive.)
- Iris: round black tissue that you can see through the cornea; it controls the amount of light that enters the inner part of the eye (is coloured in human eyes)
- Pupil: the round opening in the centre of the eye that allows light to enter and whose size is controlled by the iris

Observing the internal structure

- Pierce with the sharp point of the scissors through the white part of the eye or sclera just behind the edge of the cornea. Make a hole large enough for your scissors.

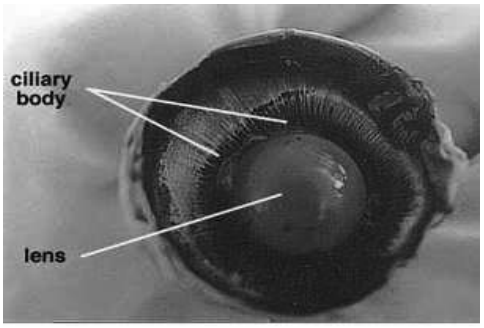
- Carefully cut around the eye as shown with the black line in the photo.
- After completing the cut, carefully remove the front of the eye and put it in your dissecting pan.
- Place the back part of the eye in the pan with the inner part facing upward.
- Locate the following internal structures of the eye:

a. **cornea:** is the transparent front part of the eye that covers the iris, pupil and anterior chamber. Cut into the cornea to notice the thickness.

b. **aqueous humour:** fluid in the front of the eye that runs out when the eye is cut

c. **iris:** black (in humans coloured) tissue of the eye that contains muscle fibres

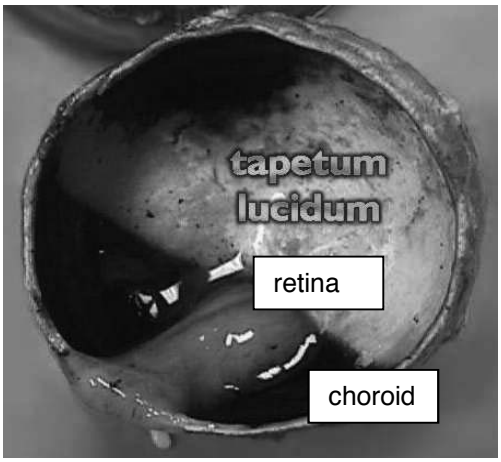
d. **ciliary body or muscle:** located on the back of the iris. The lens is held in place by the **suspensory ligaments** that join with the smooth muscle in the ciliary body.



e. **lens:** can be seen through the pupil; The normal lens is convex shaped and somewhat elastic. Remove the lens by cutting with the scissors around the edges of the lens.

f. **vitreous humour:** clear gel that fills the space between the lens and the retina of the eyeball

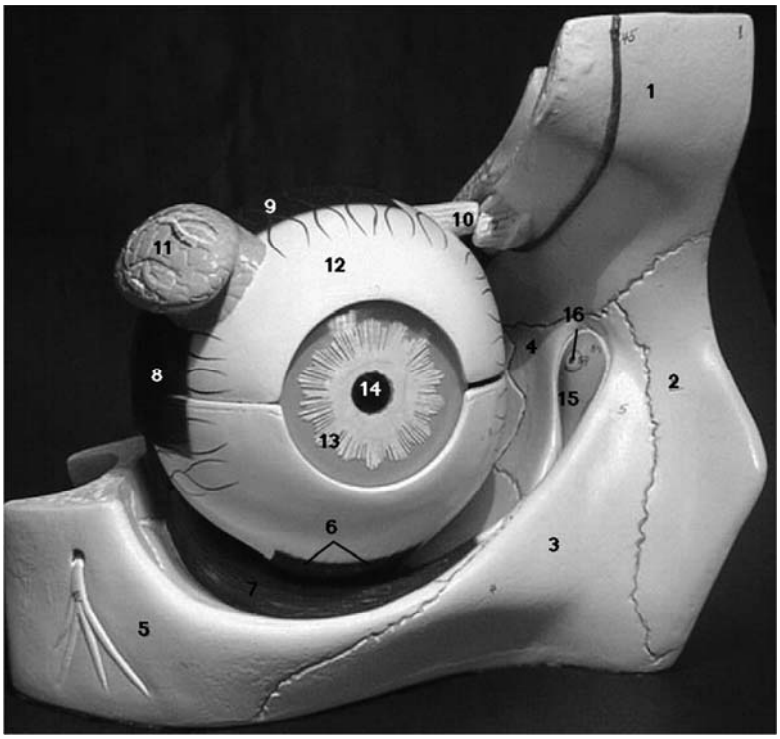
g. **retina:** yellow-brown tissue in the back of the eye where light is focused; connects to the optic nerve. The retina is attached to the back of the eye at just one spot: the optic nerve. Use the tweezers to separate the retina from the back of the eye and see a shiny, blue-green layer called the **tapetum lucidum**. This layer assists night vision by reflecting light back through the retina. Humans don't have a tapetum, but cats and cows do.



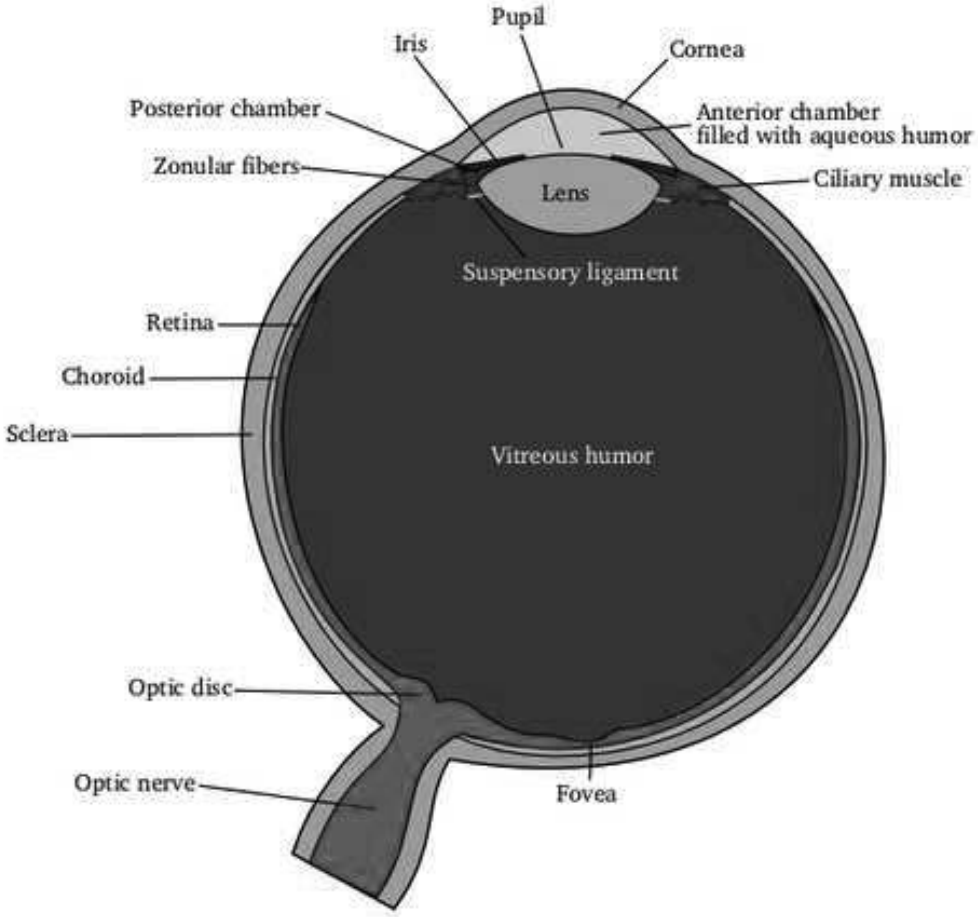
h. **choroid:** The choroid coat is dark and relatively thin. Use the tweezers to separate the choroid from the outer sclera. Verify that the eye has three distinct layers: the retina, choroid and sclera. The choroid contains an extensive network of blood vessels that bring nourishment and oxygen to the choroid and the other two layers. The dark colour, caused by pigments, absorbs light to avoid reflection inside the eye.

External model of the right eye

6. Inferior Rectus (inferior straight eye muscle)
7. Inferior Oblique (inferior oblique eye muscle
8. Lateral Rectus (lateral straight eye muscle)
9. Superior Rectus (superior straight eye muscle)
(10. Trochlea of Superior Oblique)
11. Lacrimal Gland
12. Sclera
13. Iris
14. Pupil
15. Nasolacrimal Duct
(16. Lacrimal Punctum)



Longitudinal cut of the eye



Explanation

We see because the light that hits the eyes is processed through the photoreceptors into electric impulses. These photoreceptors are located in the retina of the eye. The impulses are sent by the optic nerve to the brain which interprets what we see. To understand how the eye works, we study the anatomy of the eye. The cow's or pig eye is similar to the eyes of all mammals including humans. The model of a human eye can be used during the dissection to maximize students' understanding of the anatomy.

Conclusion

Cow eye consists 3 main layers; sclera, retina, and choroid. We see because the light that hits the eyes is processed through the photoreceptors into electric impulses. These photoreceptors are located in the retina of the eye. The impulses are sent by the optic nerve to the brain which interprets what we see.

Questions

1. Name the three layers you sliced through when you cut across the top of the eye:

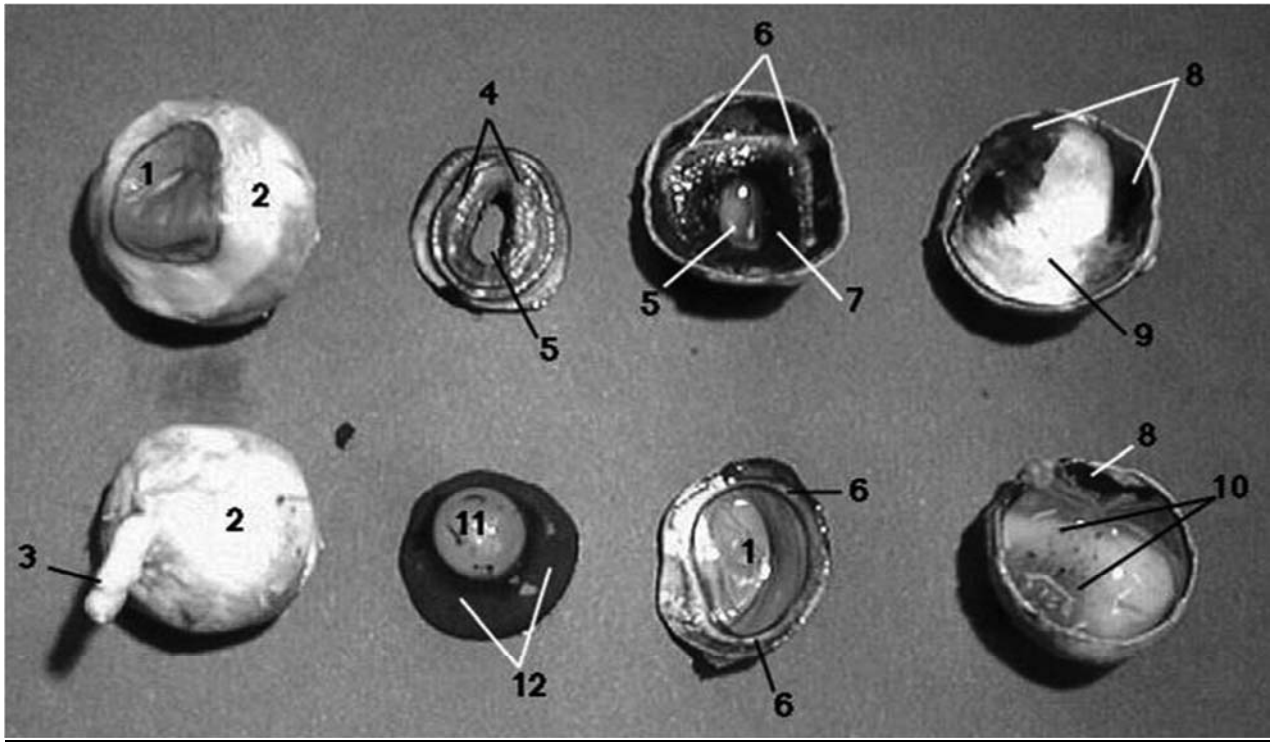
a. _____
b. _____
c. _____

2. Match the following parts of the eye to their function:

Contains the photoreceptors for vision.	ciliary body
The coloured portion of the eye	Sclera
This structure changes shape to focus light on the retina.	tapetum lucidum
The opening in the iris through which light passes.	Retina
The iridescent portion of the choroid layer in nocturnal animals.	Lens
Consists of muscles, which control and shape the lens.	Iris
The white part of the eye.	Pupil

3. Use the pictures below to name the parts of the eye:

1.	7.
2.	8.
3.	9.
4.	10.
5.	11.
6.	12.



5.2 Accommodation of the lens

Objectives

- Students can explain the importance of the accommodation of the lens for the sense of sight;
- Students can make observations from an experiment on their own body;
- Students can interpret experiment results;

Position in curriculum

Grade 12, Chapter 3, lesson 2, 2010

Materials needed

- A word written on the whiteboard.

Procedure

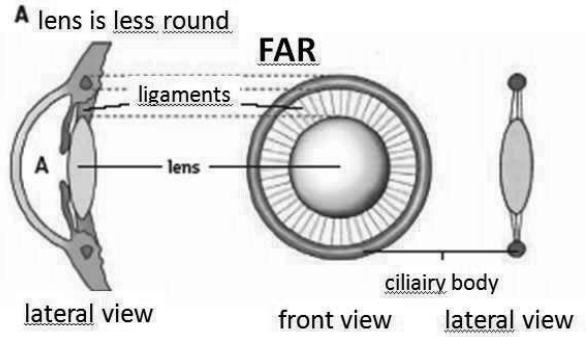
- Discuss the research question: do we see the whole range of vision in a clear, sharp way?
- Stretch your arm towards the whiteboard and look at your finger. In the meanwhile, can you read the word on the whiteboard?
- Look at the whiteboard and read the word on it. Can you see your finger in a sharp, clear way on the same moment?

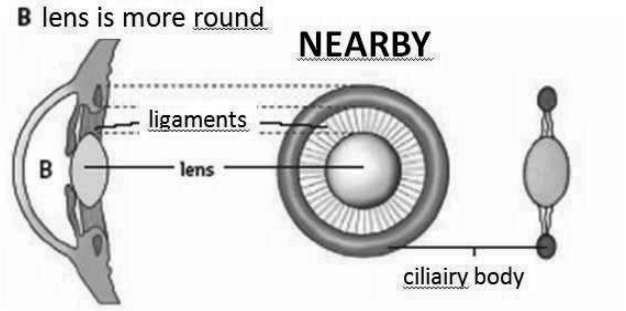
Observation

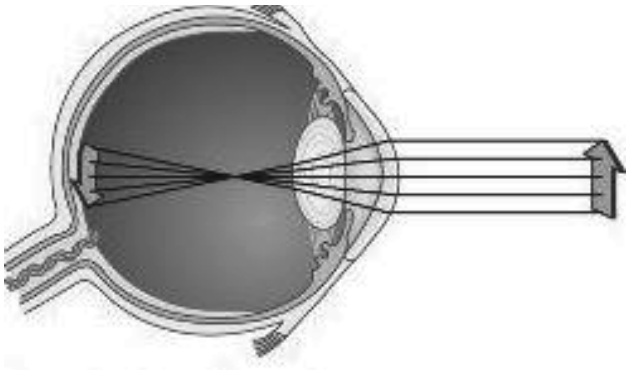
- We see our finger sharp and clear but we can't read the word on the blackboard.
- Next, we can read the word on the whiteboard but can't see our finger in a sharp, clear way.

Explanation

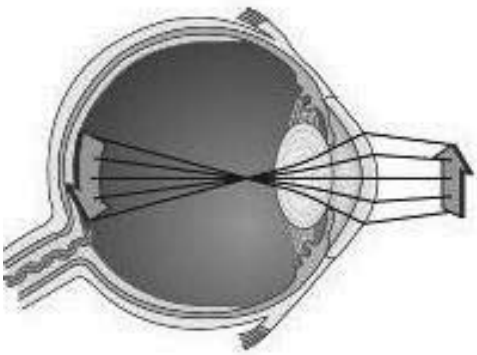
The lens changes shape to focus the light reflecting from distant or close objects onto the retina. This adjustment to suit the distance between the eye and the viewed object is called accommodation. To focus on a very close object, the ciliary muscle contracts, rounding the lens so that it can bend incoming light rays at sharper angles. Looking a long time to a close object often causes a warm and tired feeling in the eyes. This is because the ciliary muscle remains contracted while looking to nearby objects. To relieve this eyestrain, look a certain time into the distance. When you view a faraway object, the ciliary muscle relaxes and the lens flattens.



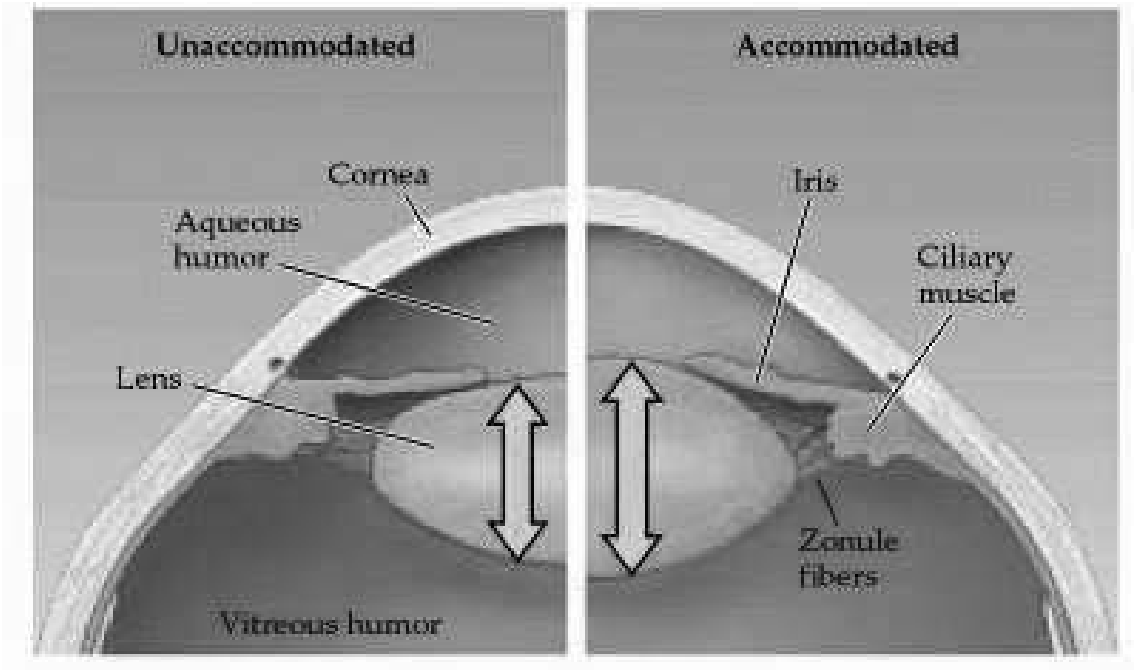




Distant image: lens is flattened



Close image: lens is rounded



Conclusion

We can't see the whole range of vision in a sharp clear way. If we look at close things, we don't see things far away sharp and contrary: if we look at objects far away, we can't see objects nearby sharp.

Question

1. When we look around, we see all objects, close and far away, always sharp. Can you explain this?

(When we look around, our eyes look very (fractions of a second) fast from object to object. So we get the impression that every object is sharp.)

5.3 Role of the iris

Objectives

- Students can explain the importance of light for the sense of sight;
- Students can make observations from an experiment on their own body;
- Students explain the relationship between light and pupil.
- Students can explain in their own words how the eye copes with differing amounts of light

Position in curriculum

Grade 12, Chapter 3, lesson 2, 2010

Materials needed

No material is needed.

Procedure

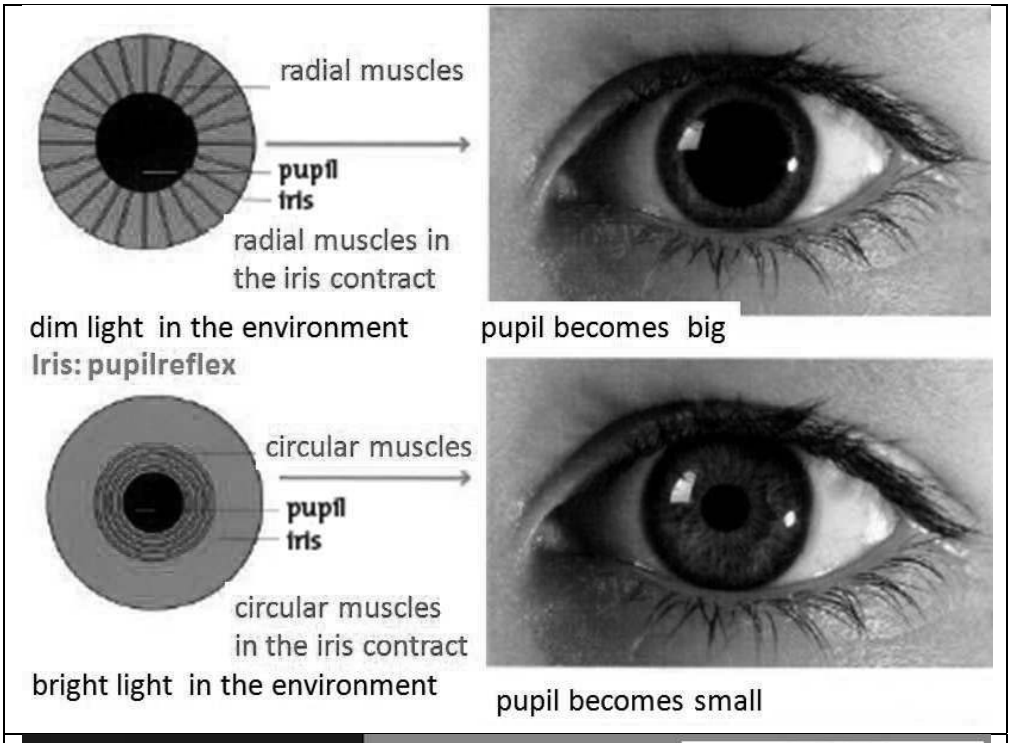
- A student closes one eye during 1 minute.
- The student opens his/ her eye and the second student looks immediately at the diameter of the pupil and compares it with the other eye.

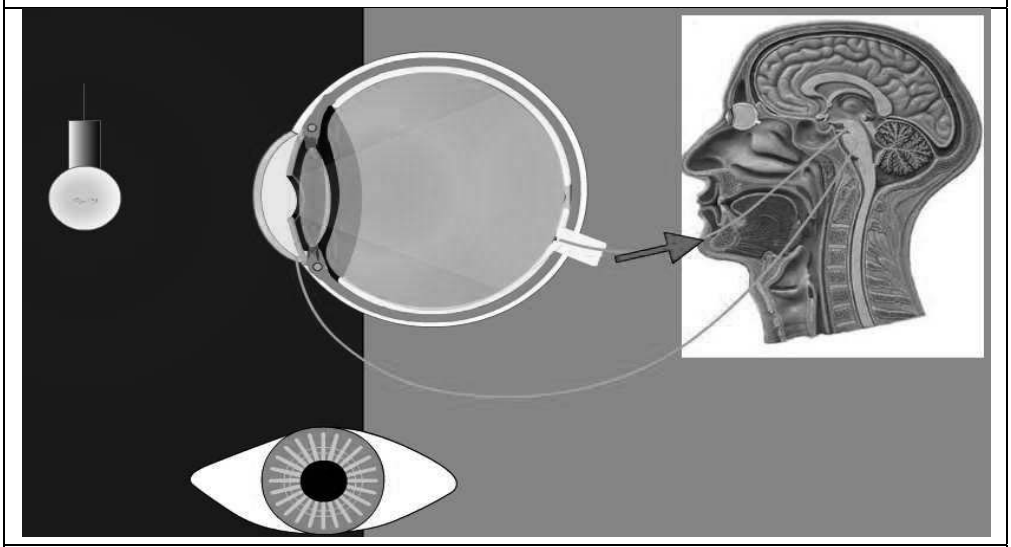
Observation

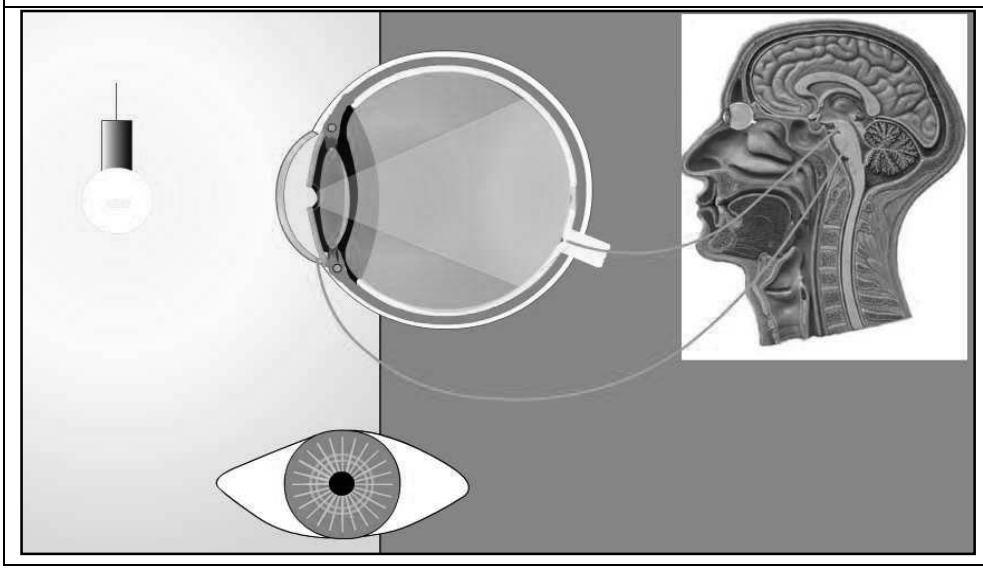
The pupil of the eye that was closed for a time is bigger than the pupil of the other eye. The pupil becomes very fast smaller. It might be difficult to see with people with dark eyes (as nearly everyone in Cambodia), look very carefully.

Explanation

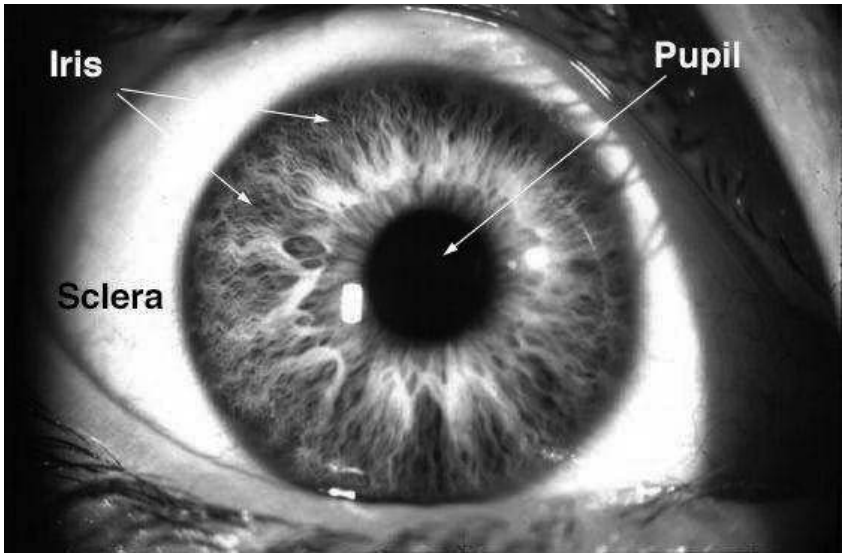
The iris regulates the amount of light entering the eye. An opening in the iris, the pupil, admits light. In bright light, the pupil becomes smaller so that the retina doesn't receive excess stimulation. In dim light, the pupil dilates, letting more light strike the retina. The pupil in the iris regulates thus the amount of light falling into the retina. The image of an object is sharper when it is projected with the correct amount of light.







Source: Arteveldehogeschool



Source: Arteveldehogeschool

Receptors in the retina register dim light and send this information to the brain stem. As a consequence, an impulse goes to the radial muscles in the iris. They contract, so the pupil becomes bigger.

The receptors in the retina register the bright light and send an impulse to the brain stem. A second impulse lets the circular muscles in the iris contract. The pupil becomes smaller.

Conclusion

The diameter of the pupil depends on the amount of light that reaches the eye. In bright light, the pupils become smaller. In the dark, they become wider (bigger).

5.4 The “blind” spot on the retina

Objectives

- Students can explain the importance of light for the sense of sight;
- Students can make observations from an experiment on their own body;
- Students can give the reason why we sometimes enable to see the object and sometimes doesn’t.

Position in curriculum

Grade 11, Chapter 4, lesson 2
Grade 9, chapter 5, lesson 12

Materials needed

Paper with the pictures below.

Procedure

- Hold this paper more or less 40cm in front of your eyes.
- Close your left eye and look with your right eye to the square. You see in the corner of your eye the triangle.
- Keep on fixing on the square and bring this paper closer to your eyes.

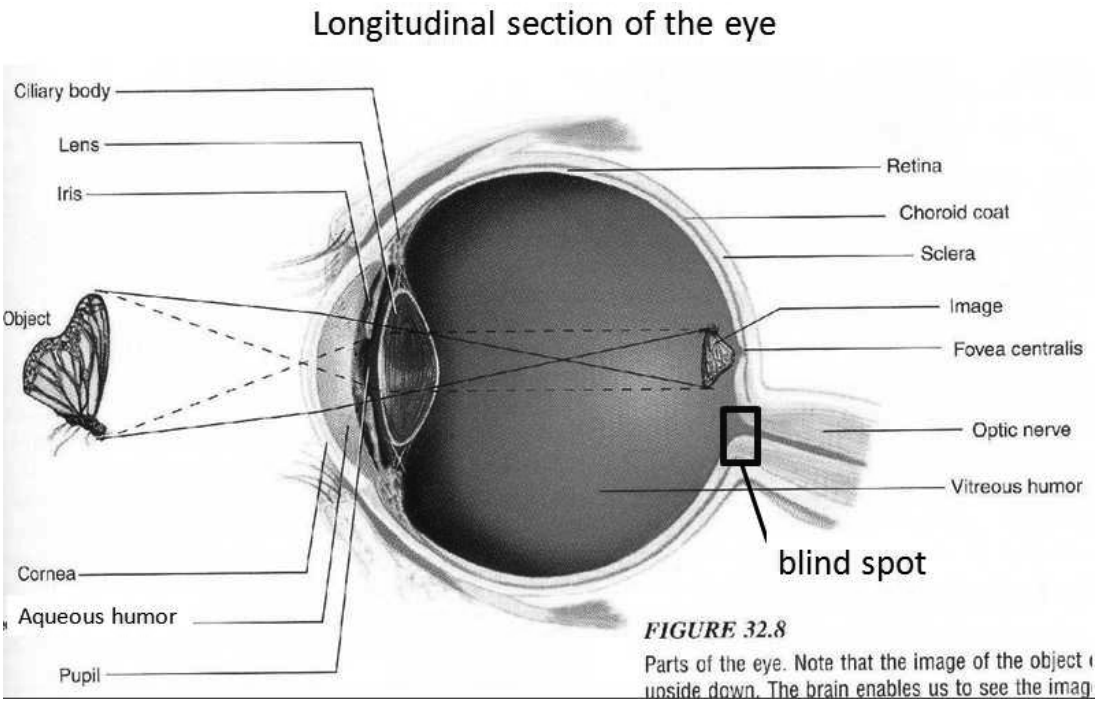
Observation

At a certain moment the triangle disappears from view.

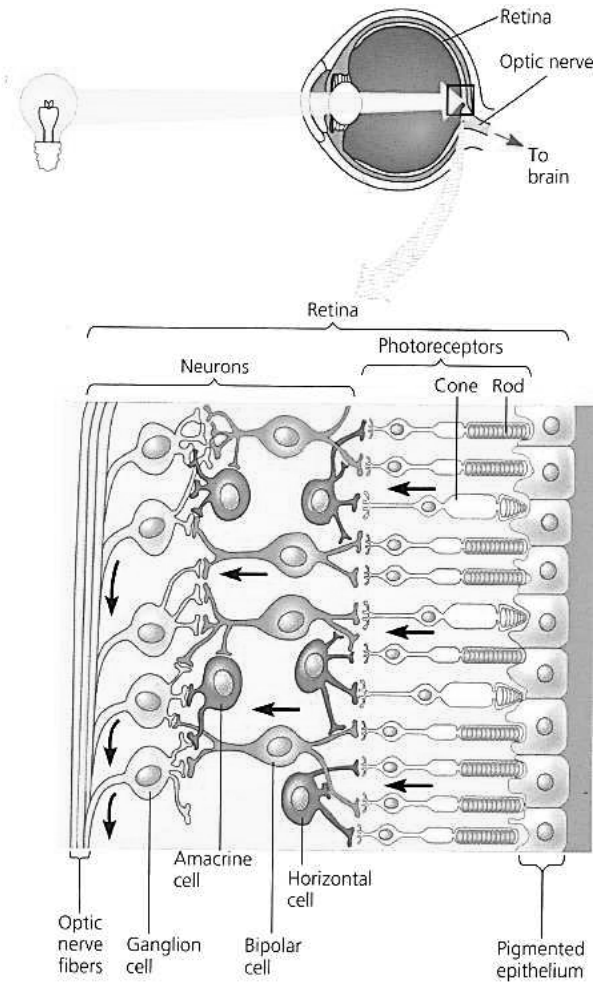
Explanation

The retina is built of several cell layers. The middle layer contains the photoreceptor cells. These cells convert light in an electric impulse. There are two types, called rods and cones. Rods provide black-and white vision in dim light and enable us to see at night. Cone cells detect colour. Rods and cones synapse with neurons, which form another layer of the retina. The fibres of the neurons form the optic nerve which leads to the visual cortex in the brain. When the eye focuses on an object, the light beams coming from that object touch the retina on the fovea centralis. This spot in the retina is situated right opposite the lens. There

is also one “blind” spot on the retina without photoreceptor cells. This spot without receptor cells is the place where all nerve fibres of the retina come together and form the eye nerve that goes to the brain.



Source: Life. Ricki Lewis



Source: Campbell and Reece, 2005

Conclusion

The image is formed on the fovea centralis. At the moment we can't see the triangle, because its image is formed on the "blind" spot on the retina. In that spot, there are no rods and cones. All the nerves from the retina come together at that point.

5.5 Location on the retina of the different types of photoreceptors

Objectives

- Students can explain how human vision works;
- Students can make observations from an experiment on their own body;
- Students can interpret experiment results;
- Students can interpret an abstract scheme of the retina.
- Students can explain the different role of cones and rods in their own words.

Position in curriculum

Grade 12, Chapter 3, lesson 2, 2010

Materials needed

- coloured bar or colour pencil (one of the two persons is not allowed to look at the bar because he/she mustn't know its colour)
- measuring stick

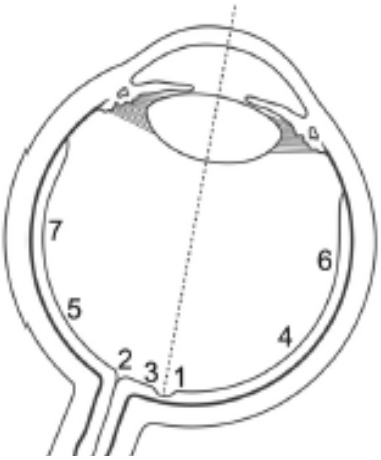
Procedure

- Discuss the research question: Where are the rods and single-cone cells located in the retina?
- Close your left eye. Look with your right eye to a letter on a white paper, like this letter X.
- The person that sits on your left moves the coloured bar from the left side towards the letter X. Start with a distance from at least 50 cm.

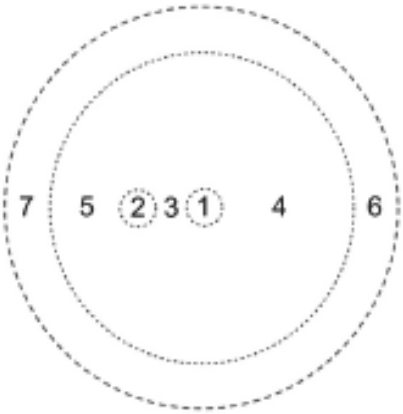
Observation

- From which distance do you see the bar? ……cm
- From which distance do you see the colour of the bar?.....cm

Zones of the retina



Horizontal cut through the right eye, seen from above



The retina of the right eye, seen through the lens

Where does the ray of light coming from the coloured bar touch the retina first?
Mark the right sequence from the following possibilities:

Starts with:

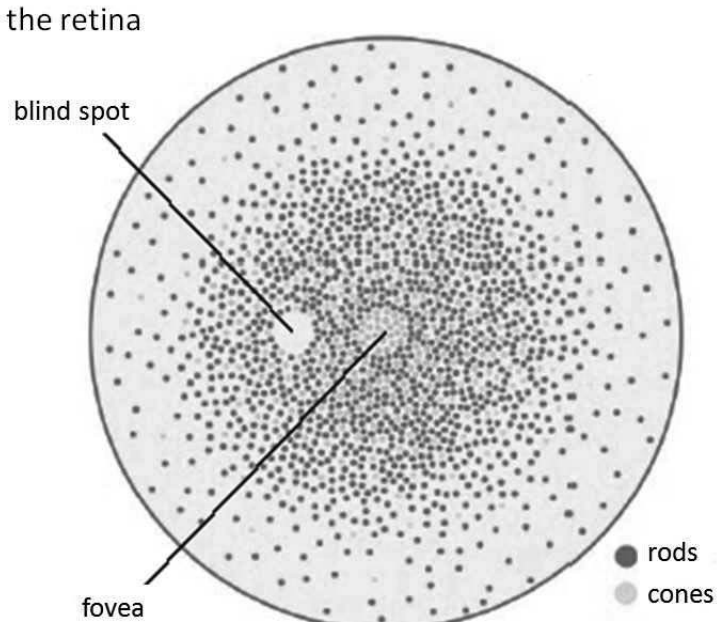
- 7 - 5 - 2 - 3 – 1 or 6 - 4 – 1 (correct)

Then thouches:

- 1 - 3 - 2 - 5 - 7 (correct) or 1 - 4 – 6

Explanation

The retina is built of several cell layers. The middle layer contains the photoreceptor cells, the rods and cones. Rods provide black-and white vision in dim light and enable us to see at night. Cones cells detect colour. The picture shows the distribution of rods and cones on the retina. Rods are concentrated around the edges of the retina and cones around the centre. The fovea centralis, a zone in the retina directly opposite the lens, only contains cones. The distribution of rods and cones helps explain why human vision works as it does. To see detail in bright light, it is best to look directly at the object because this focuses light on the central retina area that is dense with cones. At night we can see an object more clearly from the corner of the eye. From this perspective, the light bouncing off the object stimulates the rod-rich region of the eye. Only rods are sensitive enough to respond to dim light. More background information is given in the “Blind” spot experiment.



Conclusion

As rods provide black-and white vision and cone cells detect colour, this experiment shows that rod cells are concentrated around the edges of the retina and cone cells are located toward the centre of the retina.

Questions

1. When do we see an object most clear at night: directly before us or more in the corner of our eye?
   (At night we can see an object more clearly from the corner of the eye. From this perspective, the light bouncing off the object stimulates the rod-rich region of the eye. Only rods are sensitive enough to respond to dim light.)
2. If you already did the experiment “Blind spot”, point the number in the figure which represents the blind spot. *(Number 2 is the blind spot (number 1 is the fovea centralis)).*

5.6 Investigating how our eyes judge distances

Objectives

- Students can explain how human vision works;
- Students discover that the judgment of distance is obtained by comparing images coming from both eyes, that are combined in the visual cortex of the brain;
- Students can make observations from an experiment on their own body;
- Students can interpret experiment results;

Position in curriculum

Grade 12, Chapter 3, lesson 2, 2010

Materials needed

- The page with picture of the star.

Procedure

- Discuss research question “how can both of your eyes judge distance of an object?”
- Hold this paper 40cm in front of you.
- Close your left eye and hold your thumb 10cm before your right eye so you can’t see the sun anymore.
- Close your right eye and open your left eye.

Observation

When we open the left eye, we can see the star again.

Explanation

Since our eyes are located near each other in front of our heads, the area that each eye covers (called the visual field) overlap. Each eye sees an object from a slightly different angle. The image made in the left eye is thus slightly different at the one made in the right eye. When both eyes function, the visual cortex of the brain interprets and integrates the information from each eye. The image of the left eye and that of the right eye are combined together in the brains. The result is a three-dimensional perception of the object. This knowledge can be found by the students by doing the 3 experiments about the judgement of distance.

Conclusion

The image formed in the left eye is different at the image formed in the right eye.

Questions

Link the observations and conclusions of the 3 last experiments. With this information, you should be able to explain how judgment of distance is obtained.
(Read the explanation for more information about how judgment of distance is obtained.)

5.7 Visualisation by our eyes

Objectives

- Students can explain how human vision works;
- Students discover that the image that the eyes see is corrected by/ changes in the brain;
- Students can make observations from an experiment on their own body;
- Students can interpret experiment results;

Position in curriculum

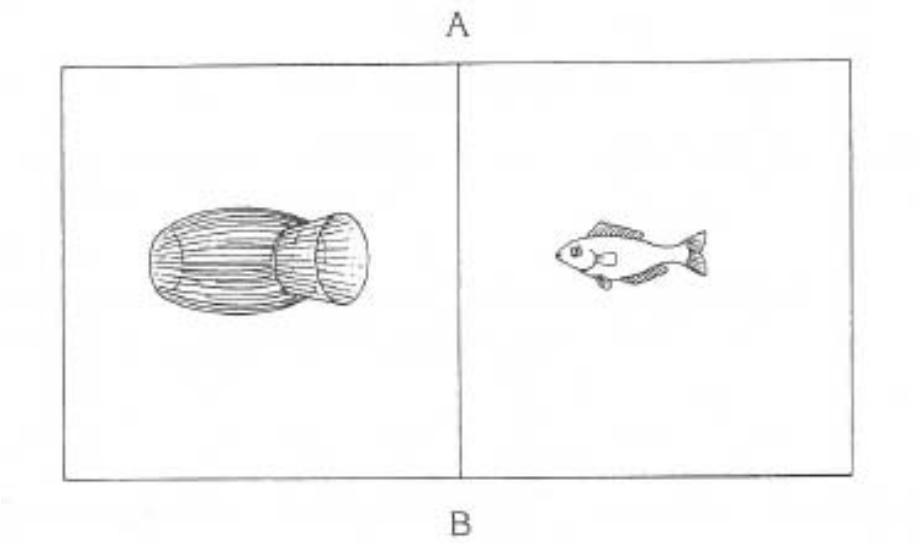
Grade 12, Chapter 3, lesson 2, 2010

Materials needed

- Ruler or book

Procedure

- Put a ruler on the line AB on the figure.
- Let your forehead rest on the ruler.
- Close the right eye, look with the left eye and fill in the table what you see (observations).
- Close the left eye and now look with the right eye. Write your observation in the table.
- Try again with both eyes open. Write your observation in the table.



Observation

Left eye	We see a fish pot
Right eye	We see a fish
Both eyes	We see a fish in a fish pot

Explanation

Since our eyes are located near each other in front of our heads, the area that each eye covers (called the visual field) overlap. Each eye sees an object from a slightly different angle. When both eyes function, the visual cortex of the brain interprets and integrates the information from each eye. The image of the left eye and that of the right eye are combined together in the brains. The result is a three-dimensional perception of the object. The objective of this experiment is to discover that the images of both eyes merge in the brain.

Conclusion

The image we see with our two eyes together is different of the image seen with the left and right eye separately. The image formed in the left eye and the one formed in the right eye are combined together in the brain, generating a three-dimensional image, allowing us to estimate distances quite accurately.

5.8 Advantage of having two eyes

Objectives

- Students can explain how human vision works;
- Students discover that the advantage of seeing with 2 eyes is judgment of distance;
- Students can interpret experiment results;

Position in curriculum

Grade 12, chapter 3, lesson 2, 2010

Materials needed

- Two ballpoints

Procedure

- Close one eye.
- Hold in each hand a ballpoint and stretch both arms before you.
- Move both ballpoints towards each other and try to let the two points touch with each other.
- Try this again with both eyes open.

Observation

It is easier to touch with the two points correctly if we use both eyes.

Explanation

Since our eyes are located near each other in front of our heads, the area that each eye covers (called the visual field) overlaps. Each eye sees an object from a slightly different angle (called parallax). When both eyes function, the visual cortex of the brain interprets and integrates the information from each eye. The image of the left eye and that of the right eye are combined together in the brains. The result is a three-dimensional perception of the object. The objective of this experiment is to let students discover that the advantage of seeing with 2 eyes is the judgment of distance.

Conclusion

We can judge distance when we look with two eyes. We call this judgment of distance.

5.9 Judgment of distance

Objectives

- Students will enable to know about the sensitivity of the eye and without eye to judge on the same objects.
- Students recognize the importance of two eyes in the assessment of distances.

Position in curriculum

Grade 12, Chapter 3, lesson 2, 2010

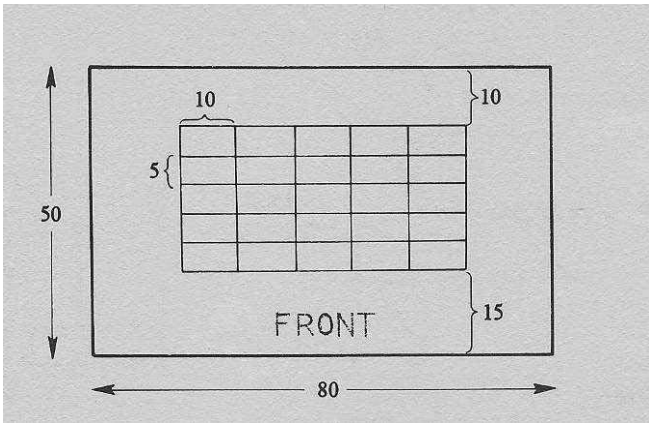
Materials needed

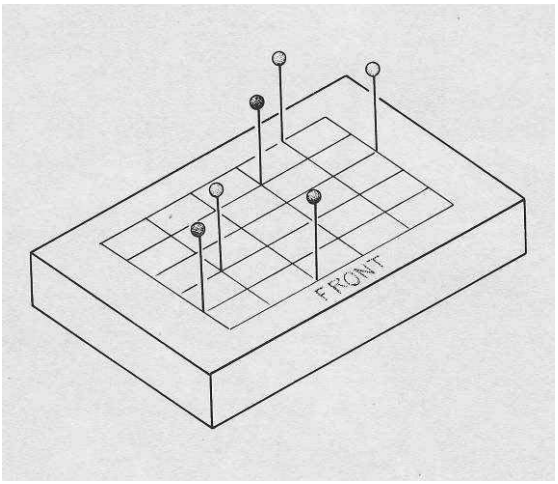
- Board of polystyrene or cardboard
- Fine felt-tip pen
- 6 pins with head (8cm height) in different colours (e.g. toothpicks with flags)

Procedure

- Work in teams of two, an experimenter and a subject.
- Use a fine felt-tip pen to mark out grids on the board (see figure).
- Make little holes on the intersections and remove the grid lines.
- The experimenter, without allowing the subject to watch, sticks the coloured pins upright into the marked block. Each pin is placed at an intersection of the lines so that no two pins are on the same line whether the block is viewed from the side or the front (See Figure). Avoid making a regular pattern as far as possible.
- The subject closes one eye and keeps it closed.
- The experimenter passes the block to the subject, tilting the block away from the subject so that he/she cannot see the marked grid. The subject holds the block quite steady about 30 cm away, tilted so that he or she can see the front edge of the block and the pins but not the marked grid on the top of the block or either of its sides.
- The subject now calls out the colours of the pins, in order from the front to the back and the experimenter writes this down.
- Still holding the block in the same position, the subject opens both eyes and calls out the order of the pins again from front to back.
- The correct answers are marked.
- The experimenter changes the position of the pins and the experiment is repeated twice more.

- Calculate an average value of the data.
- The average number of correct answers for one eye and both eyes are compared.
- The subject and experimenter change roles.





Observations

Compare the results for one eye and both eyes. Which experiment resulted in the highest scores?

Explanation

Students will probably find it quite difficult to decide the order when using only one eye, but should have little difficulty when using both eyes. Using one eye, the only clue to distance (in the absence of parallax) will be the relative size of the pins. Since the diameter of the heads varies slightly, this will be unreliable. The design of the apparatus prevents overlap of objects, which would normally be an important clue. Using both eyes, the degree of convergence of the eyes when concentrating on each pin will be a source of sensory information. This information must come from stretch receptors in the external eye muscles.

Conclusion

It is difficult to assess distances with only one eye. With one eye, the only clue to distance (in the absence of parallax) is the relative size of the pins.

Questions

How can you explain the difference in test results between one eye and both eyes?

5.10 We see with our eyes... and our brain

Objectives

- Students understand that what we see is determined by the brain, not only by the eye.

Position in curriculum

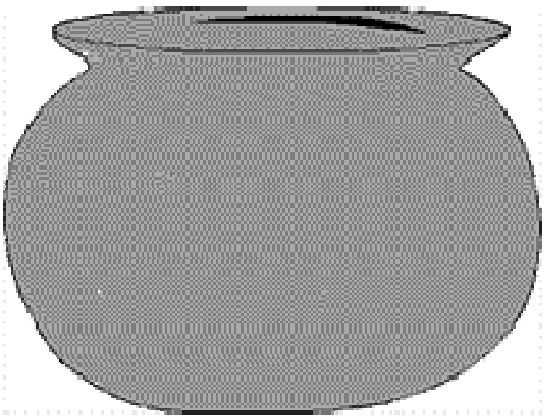
Grade 12, chapter 3, lesson 2, 2010

Materials needed

- Four large sheets of white paper
- Pieces of bright red, blue and green card
- A black marker pen
- Scissors
- Glue

Procedure

- Draw a fishbowl on one of the large sheets of white paper with the black pen.
- Cut out three identical fish shapes (large ones, but smaller than the bowl you have drawn) from the three coloured pieces of card.
- Use the glue to stick these to the three remaining sheets of white paper, one on each.
- Hang all four sheets of paper on the wall of a bright room.
- Stare at the red fish for about 30 seconds, then stare at the fishbowl. What do you see?
- Look away, let your eyes return to normal and repeat what you have just done with the green fish.
- Repeat again with the blue fish.



Observations

- You should see a green-blue fish in the bowl.
- You should see a reddish-blue fish in the bowl.
- You should see a yellow fish in the bowl.

Explanation

Sometimes you can see something which is no longer there and see it in a different colour!

The retina of the eye is covered with light-sensitive cells called rods and cones. The rods, of which there are more than 100 million, pick up on shading and levels of light and dark, while the cones register colour. There are fewer cones than rods, only around 7 million, but they are concentrated especially in the central area of the retina known as the fovea. There are three types of cones, each sensitive to a different range of colour: red, green or blue.

The images you see in the bowl after staring at the fish are afterimages. The afterimage is due to the nerve cells in the eye that process the signals from cone cells. When they keep receiving a red signal from the cones, they start to adapt by turning down the 'volume' of the signal they send to the brain. When we look away from the image the red signal from this part of the eye stays muted for a while. However, the blue and green signals are sent at the normal 'volume'. Your brain doesn't appreciate that the red signal has been turned down and interprets this as a normal signal from your eyes. This means that the fish-shaped patch from which the red signal is reduced, is perceived as a genuine object in your field of vision, leading to the afterimage which persists even when the object has been removed.

Normally the eye reacts to this by shifting slightly, so the cones are not constantly exposed to the same image and there is no desensitisation. However, if the image is large enough (like the fish), the small eye movements are not enough to neutralise the effect.

Conclusion

The retina of the eye is covered with light-sensitive cells called rods and cones. Nerve cells in the eye process the signals from the rod and cone cells. The image that we actually 'see' has thus been processed by the brain. Some experiments can therefore make us 'see' things that are not there.

Questions

1. Why do the afterimages appear in a different colour from the one you were looking at?
When you stare at the red fish, the image fall onto one region of your retina and the cells responding to red become desensitised. So, when you turn to look at the fishbowl on the white paper, the red-sensitive cells don't respond as strongly as normal to the red part of the light that is reflected back from the white surface, but the ones that are sensitive to blue and green light do. That's why you see a green-blue fish.

2. Why don't we perceive this effect in daily life?
In daily life continuous small eye movements prevent the cones from being fixed on the same object for a long time.

6. Experiments about the sensory system

6.1 Sensitivity of human senses to temperature

Objectives

- Students can identify the effects of different temperatures on the sensitivity of the nerve system.
- Students can explain how the human sensory system measures temperature changes rather than actual temperatures.

Position in curriculum

Grade 12, chapter 3, lesson 2, 2010

Materials needed

- A supply of hot and cold water ;
- 3 jars or beakers large enough to put a finger in;
- Thermometer (optional).

Procedure

- Collect three jars or beakers of about the same size. Fill one with cold water (10 -15°C), one with hot water (40-50°C) and the third with warm water (about 25 °C).
- Place the first finger of the left hand in the cold water and the first finger of the right hand in the hot water. Leave both fingers immersed for <u>at least one minute</u>.
- After one minute, remove both fingers from the jars and dip them repeatedly but alternately in the warm water for about a second at a time. Notice the temperature sensation in each finger.
-

Observations

What impression did the left finger and the right finger give about the temperature of the warm water?
The finger which has been immersed in cold water will register warmth. The finger previously held in hot water will register coldness.

Explanation

The experiment shows that the thermo-receptors of the human body respond to changes in temperature rather than to any particular temperature. In fact, there is a steady stream of nerve impulses from cold and warmth receptors at all temperatures within certain limits. Sudden changes of temperature cause increased bursts of impulses.

In the experiment the difference in sensations can be attributed to the difference in the temperature of the fingers after one minute's immersion. This can be tested by repeating the experiment with the left-hand finger in the hot water and the right-hand finger in the cold water. The sensation on dipping them both into warm water should be the reverse of the first experiment. An alternative explanation is that the warmth receptors in the hot water become adapted, i.e. after prolonged immersion they no longer send impulses to the brain. Consequently, on transfer to lukewarm water, there are few impulses sent to the brain from the warmth receptors of this finger, whereas the warmth receptors in the cold finger fire normally.

The results illustrate that the fingers detect whether they are gaining or losing heat rather than the actual temperature of an object. Similarly, metal objects at room temperature will feel cold to the touch because heat is conducted away from the fingers, while wooden objects at the same temperature feel less cold.

Conclusion

The thermo-receptors of the human body respond to changes in temperature rather than to any particular temperature.

Questions

1. Why should there be any difference in the sensory information from the two fingers? How could you modify the experiment to test your suggestion?
2. Does the result mean that the skin of your fingers is incapable of judging whether an object is hot or cold?
3. What does the result suggest about the way in which the skin responds to temperature?

6.2 Sensation of touch receptor by stimuli

Objectives

- Students understand the functioning of the human sensory system.
- Students can explain that not every part of the human body has the same sensitivity to sensory stimuli.
- Students can perform an experiment to test the sensitivity of areas of the human skin.

Position in curriculum

Grade 12, Chapter 3, lesson 2, 2010

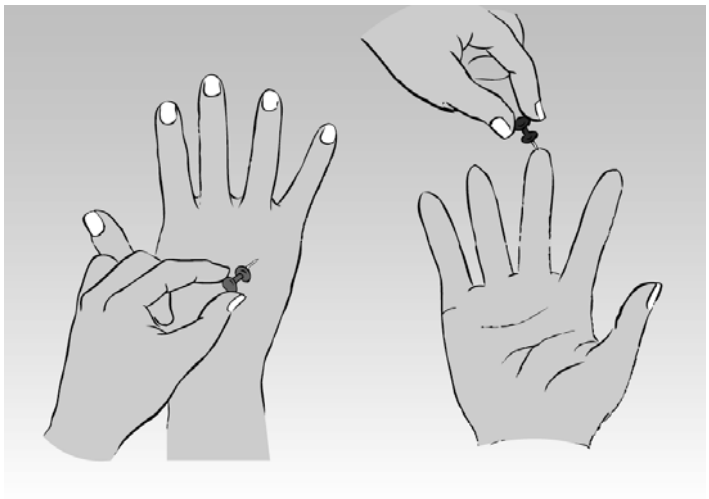
Materials needed

- two sharp pointers, such as toothpicks
- paper to keep track of results

Procedure

There are two or three people in each team:
- the experimenter who applies the stimuli,
- the subject who receives and reports on the stimulus,
- a recorder who notes the subject's responses. If there is no third person the experimenter must keep a record of the results.

The objective is to determine the minimum distance apart for two simultaneous touch stimuli to be recognized as two sensations rather than one; the subject must not know in advance whether he or she is to receive one or two stimuli.



Observations

The experimenter draws up a table and, without showing the subject, writes down a programme of 5 single and 5 double stimuli, randomly distributed. An example is shown below.

Gap between points	AREA TESTED	.....									Total correct
10 mm	type of stimulus	2	1	2	2	1	2	1	2	1	1	
mm	subject's response											

The subject closes his/her eyes or turns his/her head so that he/she cannot see the stimulus being applied. The experimenter makes sure that the two "pointers" are exactly 10 mm apart. He or she then presses the pointer carefully on to the skin on the back of the subject's hand, observing the procedure given below:

- Each stimulus should last for about half a second. Do not merely touch the skin.
- For the double stimulus, both wires must touch the skin simultaneously.
- The stimuli are applied at random over the whole area of the back of the hand.

After each stimulus, the subject must say 'one' or 'two' according to how many stimuli he or she thought they could feel and it is noted in the table how many stimuli were correctly recognized. After 10 stimuli, the correct responses are added up.
Next, the experiment can be repeated as follows:

- Change the distance between the pointers, for example 5mm.
- Repeat the experiment on another location, such as the tip of the finger (treating all four finger-tips as the test area).

Explanation

The feeling of only one stimulus when two are applied can be explained as follows:

(a) Only one point touches a receptor. It is unlikely that, on the back of the hand, a pressure on the skin will not affect at least one receptor.

(b) Both points touch receptors which feed impulses into only one nerve fibre. A single sensory fibre may receive branches from sensory endings covering a region of several square millimetres.

(c) There are two receptors and two sensory fibres but they cannot be discriminated by the brain. Various sensory systems are associated with greater or lesser areas in the brain and the analytic capabilities of the cortex are more limited for some receptors than for others.

Conclusion

The touch receptors on the human body and their connections to nerves are not distributed evenly across the human body. Fingertips have a much higher density of receptors and connections than the back of the hand or the skin of the back. The higher the density of receptors and connectors the more sensitive that part of the human body is for sensory stimuli.

Questions

1. For each region tested, what were the minimum distances between the points which could still be recognized as separate stimuli?
2. What could be the reasons for the different spatial sensitivity of some regions? The explanations should consider the distribution and density of touch receptors and their possible connections to nerves.

6.3 Reaction time in seeing the object

Objectives

- Students can explain the functioning of the sensory system;
- Students can perform an experiment involving multiple measurements and calculate an average value.
- Students can explain why there is no difference in reaction time between the two experiments.

Position in curriculum

Grade 12, Chapter 3, lesson 2, 2010

Materials needed

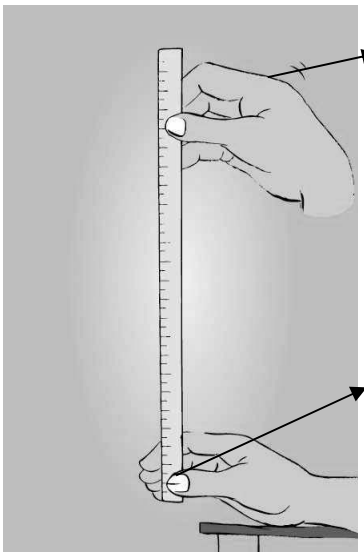
- 50 cm ruler
- Stopwatch
- Pen/pencil

Procedure

It is necessary to work in pairs for this experiment.

- The subject marks a pencil line down the centre of his thumb-nail and sits sideways at a bench or table with the forearm resting flat on the bench and the hand over the edge (See Figure).
- The experimenter holds a ruler vertically between the subject's first finger and thumb with the zero opposite the line on the thumb but not quite touching either the thumb or fingers.
- The subject watches the zero mark and, as soon as the experimenter releases the ruler, the subject grips it between finger and thumb to stop it falling any further. The distance on the ruler opposite the mark on the thumb is recorded in an observation table.
- This is repeated 4 times and the average distance calculated.
- The experiment is then repeated with the same subject but this time the subject lets the ruler rest lightly against the thumb or fingers, with closed eyes, and grips the ruler as quickly as possible after he or she feels it begin to fall.
- The experiment is repeated 4 times and the results are recorded in an observation table. Calculate the average distance again.
- The speed of the subject's reaction is a function of the distance the ruler falls before it is stopped.

Table			
Speed of response to sight		Speed of response to touch	
1		1	
2		2	
3		3	
4		4	
Total		Total	
Average		Average	



Explanation

The experiment compares reaction times from the eyes to the brain and from the fingertips to the brain. The shorter sensory pathway from eyes to brain might lead one to expect a reduced reaction time. However, the average class results will probably not show any significant difference. The main reason is that the speed of conduction is so rapid that very large differences in distance would be needed to produce a measurable difference in reaction time by our crude methods. Other possibilities are that touch receptors respond more rapidly than the retinal (eye) receptors and so compensate for the longer nervous pathway to be traversed. Finally, the reaction time is also influenced by other factors than the speed of conduction of nervous impulses, particularly the time taken for the muscles to contract on receiving an impulse.

Conclusion

There is not a significant difference in reaction time from the eyes to the brain and the fingertips to the brain. Conduction speeds are so high that the small difference in distance can be neglected.

Questions

1. Was there a significant difference in reaction times using sight and touch (a) for your own results, (b) for the class results when averaged?
2. What differences in results did you expect?
3. Did the class results fulfil this expectation? If they did not, discuss possible reasons for this.

6.4 Eye – and hand coordination

Objectives

- Students can explain the importance of sensory and motor co-ordination in daily life;
- Students can perform an experiment to test the importance of sensory and motor co-ordination in daily life;
- Students can process the experiment results in a graph;
- Students can interpret experiment results.

Introduction

The experiment is a reminder of how much sensory and motor co-ordination we have had to learn and now take for granted. This experiment can also be used to develop the students' data gathering and graph constructing skills.

Position in curriculum

Grade 12, Chapter 3, lesson 2, 2010

Materials needed

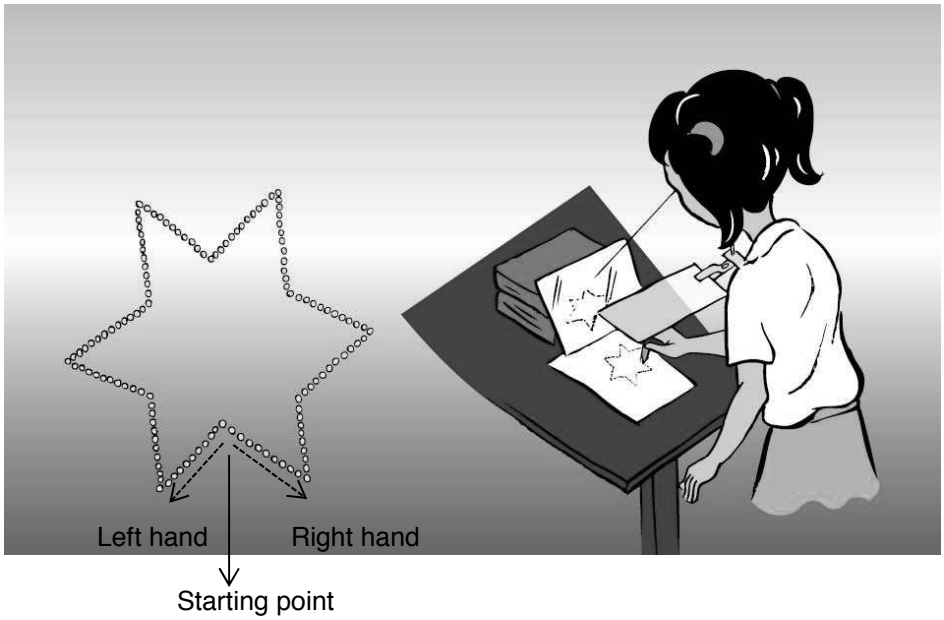
- Small mirror (15 x 15 cm)
- Paper with picture of the star
- Pencil
- Two books or wooden block (to support the mirror)
- Stopwatch
- Book or piece of paper (to prevent the view on the drawing)

Procedure

It is best to work in pairs; a subject to conduct the trials and an observer to time them. It is possible, however, to do the experiment on your own. If there is no clamp stand available the observer can hold the cardboard to prevent the subject to see the 'star' directly.

- Place the mirror vertically and support it, if necessary, with a clamp or book placed behind it.

- Arrange the ‘star’ and the piece of paper in such a way that you can see the star and your hand in the mirror, but not by direct vision.
- Use the right hand if right-handed, or left hand if left-handed, and place the pencil point on the 'start here' circle.
- The observer notes the time or starts the stop-clock and the subject, moving in the direction indicated by the arrow, traces round the outline of the star, looking only at the mirror image and making the line, however erratic, pass through every circle. When the outline is completed, the observer notes the time taken and enters it in an observation table.
- The pencil line is rubbed out, or the sheet replaced, and the same subject repeats the trial but with the opposite hand, and the observer notes and records the time as before.
- The trials are repeated at least twice more for each hand, running the trials consecutively, i.e. 2 trials with the right, followed by 2 trials with the left, and the times noted and recorded in the observation table.



Observations

Record your data in a table. What conclusions can you draw from your observations?

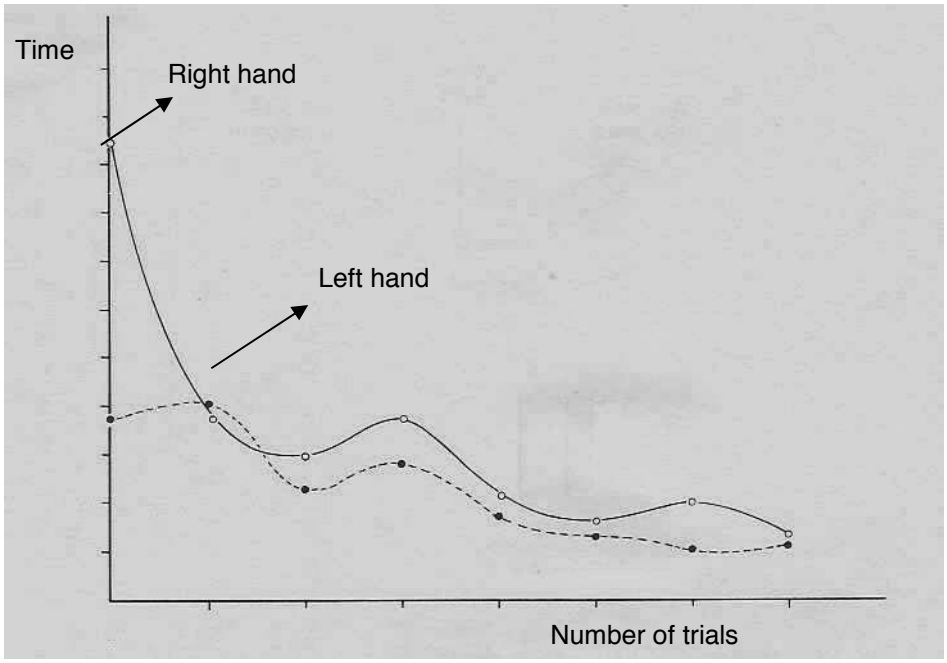
Explanation

The experiment shows that generally speaking, the preferred hand is considerably slower at the first trial than the other hand. The possible reasons are:

1. that the previously learned experience with the preferred hand interferes with the ability to acquire a different set of motor skills at odds with those already established,

2. that since the preferred hand is tested first, the other hand is benefiting from that first trial, i.e. there is some transfer of the newly tried skill from, say, the right to the left hand.

The best way to study the results, if there are enough of them, would be to plot a graph (see figure). There is usually a marked improvement in performance with both hands even after only 2 or 3 trials but the improvement with the preferred hand is usually more spectacular, since it is initially so much slower than the other. On average, the time for the second trial with the preferred hand will be about 40% less than that for the first. The other hand shows less improvement so that by about the third trial there is little difference in the times.



Conclusion

The experiment shows that generally speaking, the preferred hand is considerably slower at the first trial than the other hand. After a few trials though, both hands do the experiment in approx. identical times.

Questions

1. Considering only the times for the first trial of each hand, does there appear to be a significant difference between them?
2. Suggest possible explanations for any differences.
3. As the trials proceeded, was there a decrease in the time taken to complete them? If so, was there a difference in the rate of improvement for the different hands?
4. Two explanations can be given for the results (see background information). Can you think of any way to test the validity of both explanations?

7. Experiments about the heart

7.1 The dissection of a pig heart

Objectives

- Students can recognize the main parts of a pig (and human) heart
- Students can do a dissection carefully and skilfully
- Students understand how the structure of the heart supports its function.

Position in curriculum

Grade 11, chapter 6, lesson 1, 2009

Materials needed

- Heart of a pig (fresh, price approx. 5000 riel)
- Dissection scalpel or scissors
- 2 small bars (like chopsticks)
- Tweezers
- Towel or napkin
- Dissection shelf (optional)
- Gloves (optional)

Procedure and observations

1. External anatomy

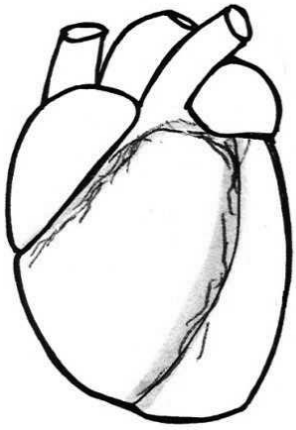
Rinse the heart with water and dry it with the paper or towel. It will render the dissection less bloody.

Situate the heart in the body:

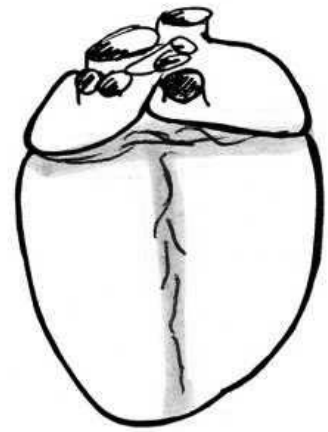
- Where in the body is the heart located?
- Which side of the heart is the front and back?
- Which side of the heart is the left and right?

→Left and right side or like they appear <u>in the body</u> of the animal or human.

Make following **observations**:

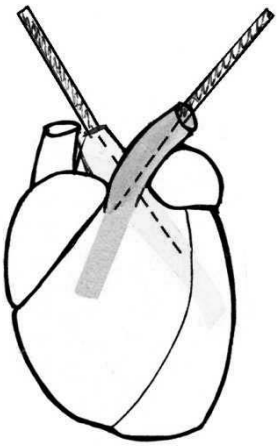


Lay down the heart with the front site in your direction. You recognize the front site by the beige line that goes from left above to right under. This line is the **connective tissue**. Observe the veins from the heart near the surface and the coronary arteries that lie deeper. The connective tissue forms also the division between the 2 ventricles. The coronary arteries give the heart oxygen and nutrients, whereas the veins remove the waste materials.



The connective tissue passes round the heart, right under the atria. At the back site of the hearth, the connective tissue goes almost straight to the **heart point**.

Indicate the **2 atria** and the **2 ventricles**.



Put the small bar in the thickest blood vessel (white colour, stands open and bends to the left. This is the **aorta**.

- *Where does the bar end?*

→ In the left ventricle.

Put the bar in the second thickest blood vessel. This is the **pulmonary artery**.

- *Where does the bar end?*

→In the right ventricle

- *Can you move the bar from the first ventricle to the other?*

→*No.*

- *Is there a connection between the left and right ventricle?*

→*No.*

- *If you leave both bars in the arteries, how do they lay against each other?*

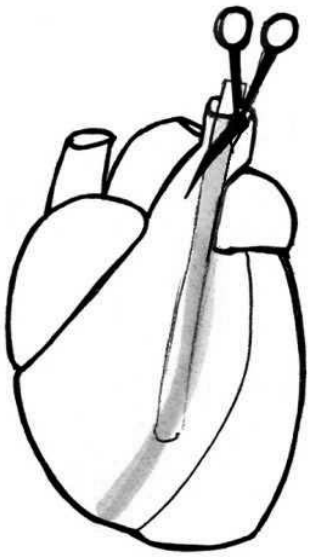
→ The bars make a cross, so the arteries cross too.

Search the veins (flaccid (weak), red blood vessels or just an opening). Put the small bar in it.

- *Where does the bar end?*

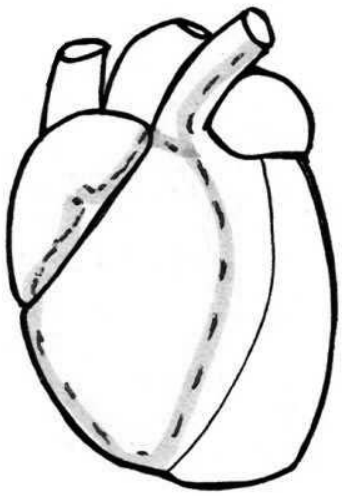
→In the atria. The **superior vena cava** and **the inferior vena cava** end in the right atrium. The **4 pulmonary veins** end in the left atrium. Veins bring the blood to the heart. Arteries carry away the blood from the heart.

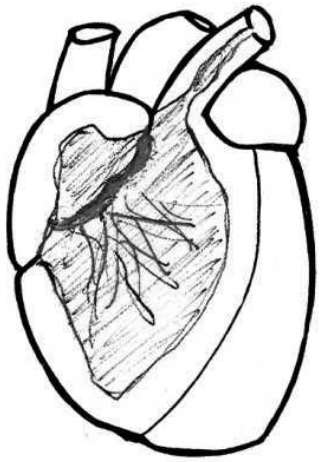
2. Internal anatomy



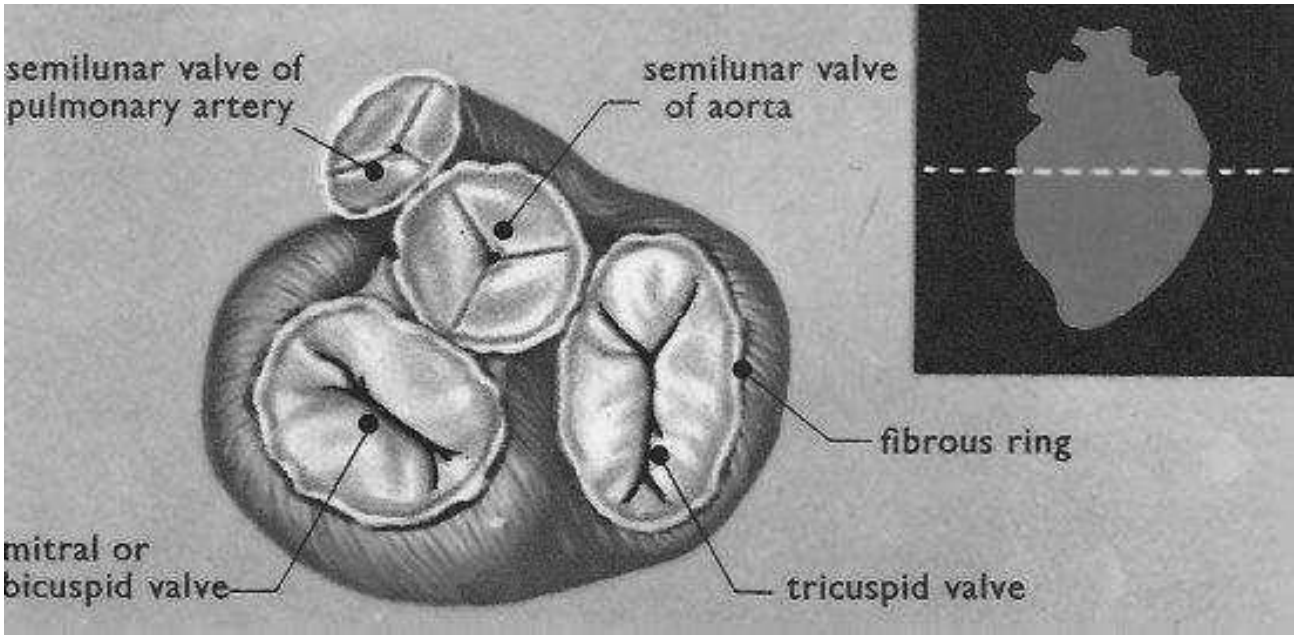
Cut the wall off the pulmonary artery as in the figure. Use the bar to guide you.

You see the **semi lunar valve** at the junction to the ventricles. You can find them by gliding with the bar or tweezers along the wall of the artery. You will end in a “bucket”. This is a valve. Search the 2 other “buckets”. The 3 “buckets” together form the semi lunar valve and prevent that the blood coming from the heart, flows back to the heart.



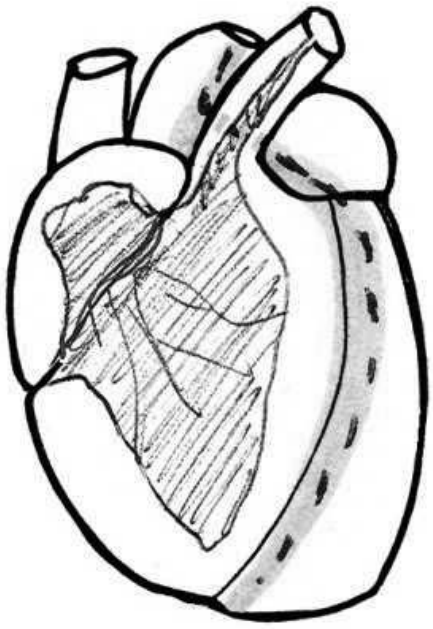


Cut the right ventricle open as in the left figure above. You see the bicuspid valve with tendons. The blood flows from the atrium to the ventricle. The bicuspid valve prevents that the blood flows back in the atrium.

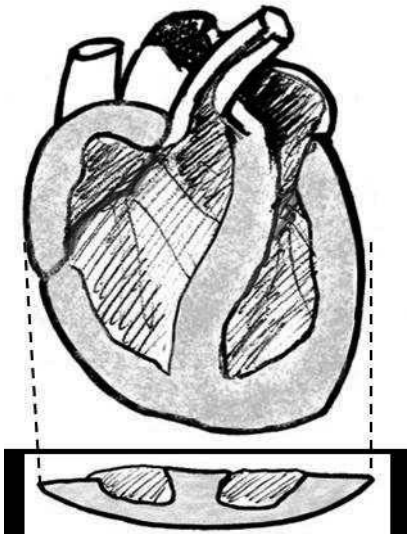


Cut the wall off the aorta. You see again the **semi lunar valve** at the junction to the ventricles. You can find at the “buckets” a small hall in the wall of the aorta. This is the beginning of the coronary artery.

Keep on cutting through the wall of the aorta. You will cut the mitral valve. This valve prevents that blood from the left ventricle flows back into the left atrium. Mention the difference in thickness of the ventricle walls (left and right ventricle) and the volume of the ventricle.



Cut along a lateral line and remove all the front parts of the heart. You made a “cross section” of the heart, just like in the figure.



3. How to use this activity?

After the dissection it is important to repeat the main terms and show them on the heart.

- Left and right part
- Coronary arteries and coronary veins
- Atria and ventricles
- Semilunar valves between the arteries and the ventricles
- Valves with tendons between the ventricles and the atria
- The thick wall of the left ventricle and the thinner wall of the right ventricle
- The fact that the right and left part of the heart are completely separated.
- The direction of the blood

Afterwards, the terms that the students/pupils encountered in the dissection have to be repeated in a schematic way in order to help them remember them better. Begin with a model or poster of the heart and review all the terms with the students.

Conclusions

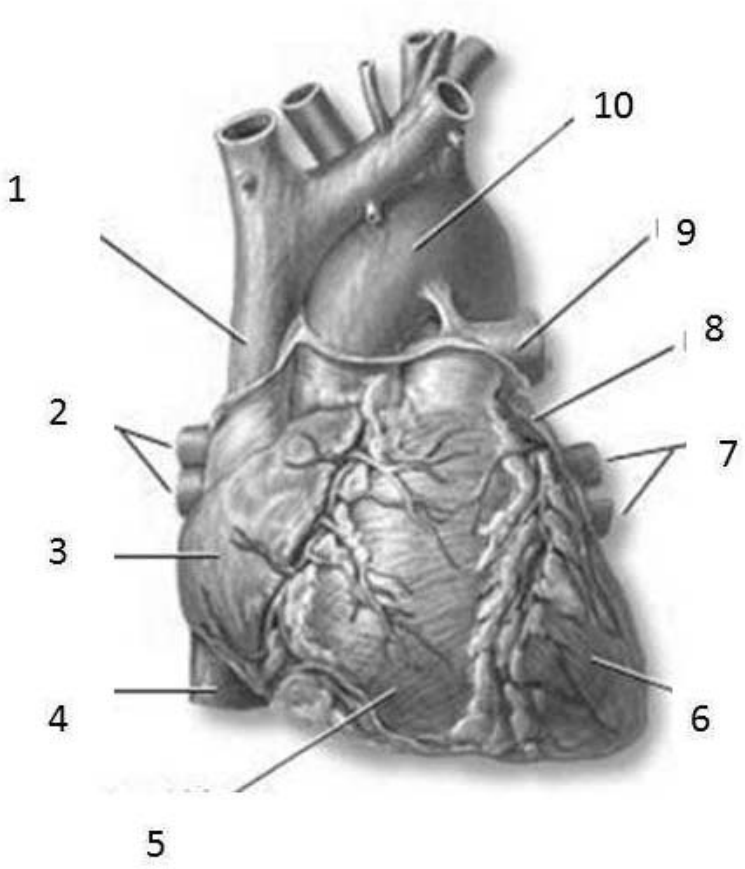
A dissection of a heart of a pig (or cow) is an excellent student activity to start the instruction on the structure of the heart. The heart of a pig is more or less as big as the heart of a human being.

Questions

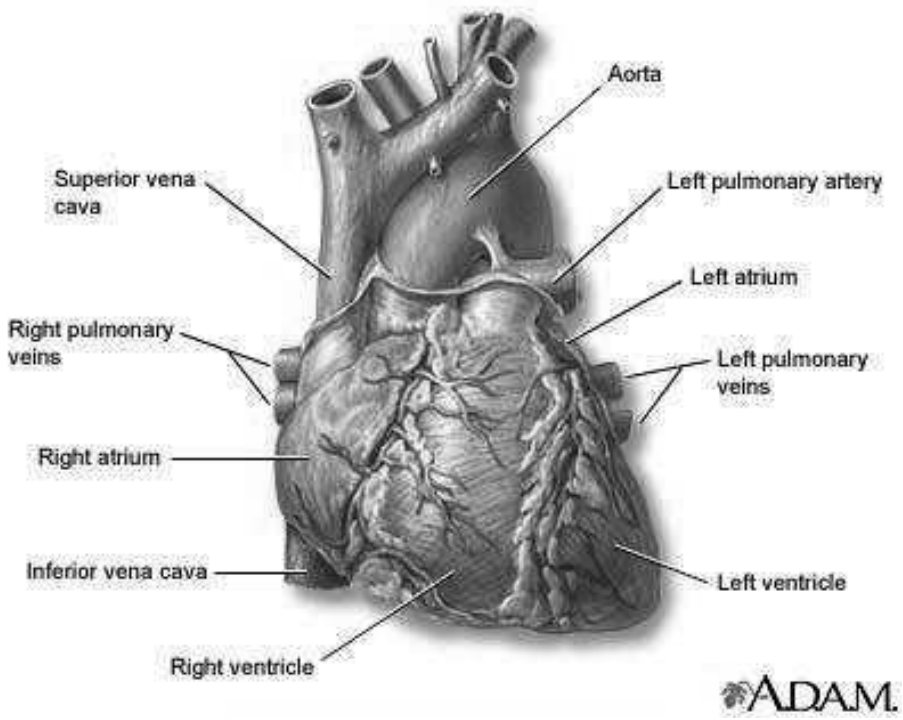
1. Exercise on the external structure of the heart

Present your students/pupils(or pairs of students/ pupils) the following exercise on a sheet of paper. The extra questions are pure abstract phase: the student has no figures or concrete material to help him finding the answer.

Put the right names next to the numbers from the figure in the table.



Solution:



Source: **http://www.nlm.nih.gov/medlineplus/ency/imagepages/1056.htm**

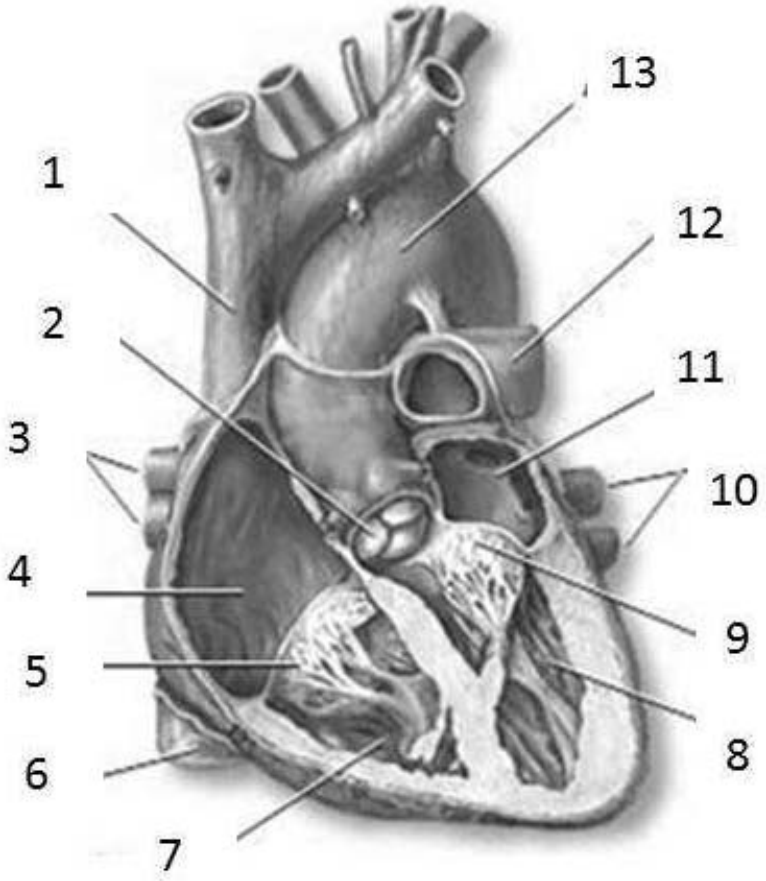
- Which blood vessels give the heart muscle nutrients?
- Which blood vessels drain off the waste materials from the heart muscle?

Colour the figure:

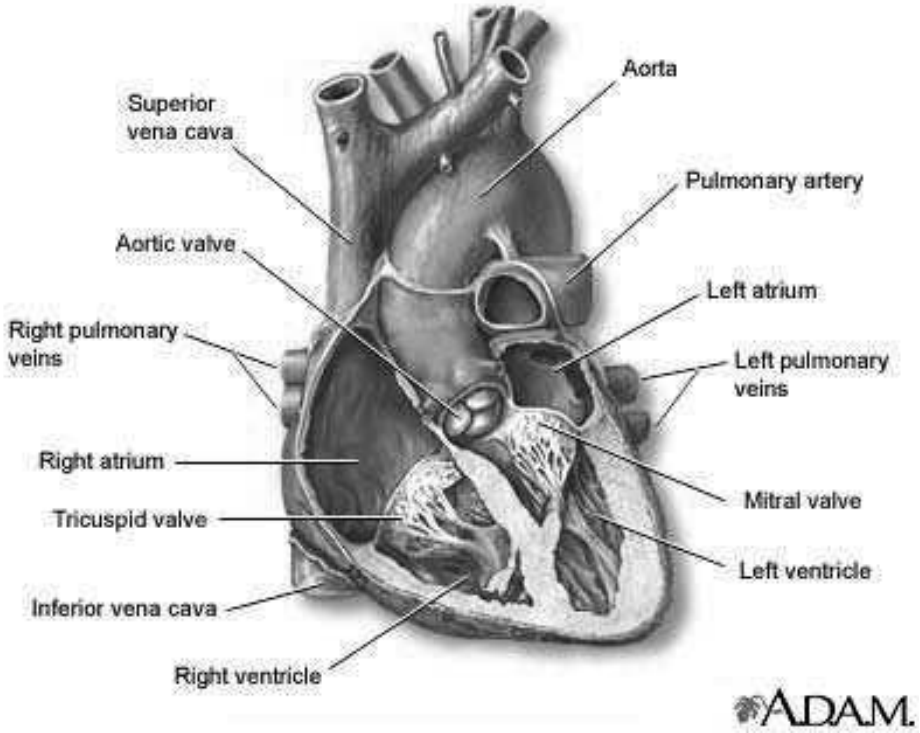
- The left atrium in pale red
- The right atrium in pale blue
- The left ventricle in dark red
- The right ventricle in dark blue

2. Exercise on the internal anatomy of the heart?

Put the right names next to the numbers from the figure in the table.



Solution



Source of figures: **http://www.nlm.nih.gov/medlineplus/ency/imagepages/1056.htm**

- What is the function of the valves?
- Which ventricle is most muscular?
- What will be the consequence of that?

7.2 Constructing a model of the heart valves

Introduction

This model aims at showing students how valves prevent the blood flowing in the “wrong” direction in the heart. They should be able to explain the functioning of the atrioventricular valves using a simple model.

Two pairs of heart valves keep blood flowing in a single direction. The atrioventricular valves are located between each atrium and ventricle. These thin flaps of tissue move in response to pressure changes that occur when the ventricle contracts. When the ventricle contracts, the pressure increases. This pushes the flaps upwards and prevents blood from moving back into the atrium.

The semilunar valves consist of three flaps that look like a pocket. The flaps form a ring in the arteries just outside each ventricle. Blood leaving the ventricle can pass these valves easily. Blood moving backward toward the ventricle, fills these pockets and causes the valves to bulge. This prevents the blood from flowing back.

Objectives

- Students can explain the functions of the heart valves.
- Students can make and use heart valves.

Position in curriculum

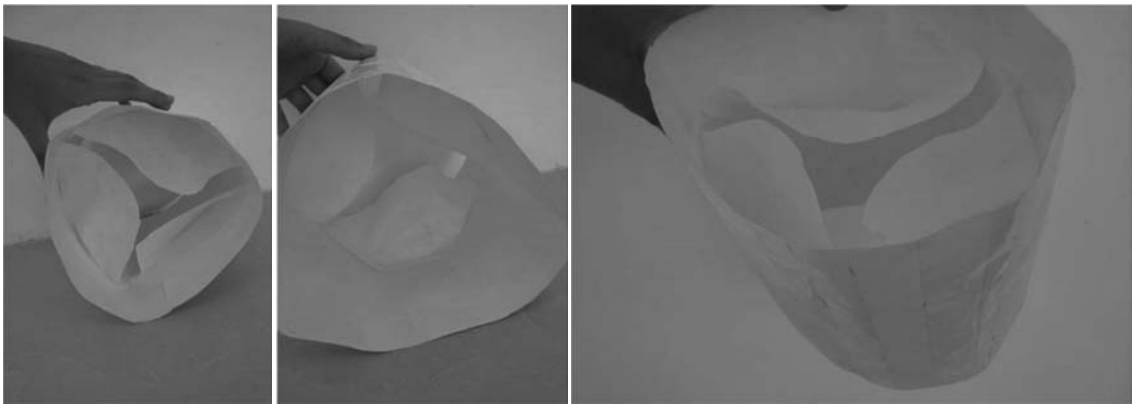
Grade 11, chapter 6, lesson 1, 2009

Materials needed

- Scissors
- A4 paper
- Coffee filters

Description and use of the model

The model shows the function of the semi lunar valves. Stick two sheets of paper to form a tube (represents the artery). Stick at this tube tree times one side of three coffee filters (representing the “pocket” flaps).



The picture shows the use of the model. An arm can only enter in one direction. In the same way, the blood can also just flow in that direction, which is away from the heart.

Remark the model of the heart lying on the table. The model is very useful to explain the anatomy of the heart, after the students did the dissection.

Conclusion

Two pairs of heart valves keep blood flowing in a single direction: the atrioventricular valves and the semilunar valves.

8. Other experiments

8.1 Extraction of DNA

Objectives

- Students understand the function of DNA in living organisms;
- Students can extract DNA from banana or tomato.

Position in curriculum

Grade 12, chapter 5, lesson 1, 2010

Materials needed

- 1 Banana or tomato
- 1 Small plastic bag
- 1 Plastic bottle (1/2 cut)
- 1 Plastic bottle
- 1 Funnel
- 1 Toothpick or tweezers
- 1liter of pure drinking water
- 50ml of cool alcohol
- 50ml of buffer
- Salt
- Detergent (or washing liquid)
- 1 box of paper tissue
- 1 Test tubes

Procedure

- Squash a small piece of banana (2-3 cm) with a fork
- Pour 12 ml extraction buffer[1] into a ½-cut plastic bottle- this buffer contains salts necessary for the precipitation of the DNA.
- Add 3ml detergent which will break open the cells
- Add the banana pulp and mix well
- Put two layers of paper tissue into a funnel and moisten them with water. Pour the banana mixture into the funnel and, collect the filtrate in a plastic bottle. Throw away the filter paper with the remains of the banana pulp.
- Put 1ml of the filtered banana juice into a plastic tube

- Add 1ml of distilled water and mix well
- Carefully pour 8 ml cold alcohol down the side of the tube so that the alcohol remains in a layer above the juice
- Let the solution sit for 2-3 minutes.

Observations

You can watch DNA precipitate out into the alcohol layer. A white substance will become visible at the interface where the two liquids meet. This is the DNA.

If the experiment is successful there will be enough DNA to be lifted out of the tube with a toothpick or tweezers.

Explanation

Cells store and use information to guide their functions. The genetic information stored in DNA is used to direct the synthesis of the thousands of proteins that each cell requires. In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kinds (A, G, C, and T). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular "letters") and replicated (by a templating mechanism). Each DNA molecule in a cell forms a single chromosome.

Francis Crick, James Watson and Maurice Wilkins received the Nobel Prize in 1962 for determining the molecular structure of DNA in1953.

Conclusion

The genetic information stored in DNA within cells is used to direct the synthesis of the thousands of proteins that each cell requires. In all organisms, instructions for specifying the characteristics of the organism are carried in DNA.

Questions

1. What is the purpose of using salt and detergent in DNA extraction?
2. What does the cool alcohol function?
3. What happens when alcohol is added to the filtrate of banana juice?
4. Make you observation on the extracted DNA in the tube containing alcohol.

8.2 What is the effect of a solution on bacteria growth?

Objectives

- Students can explain how bacteria can live.
- Students can relate the growth of bacteria to the presence of different nutrients.
- Students can describe characteristics of bacteria.

Position in curriculum

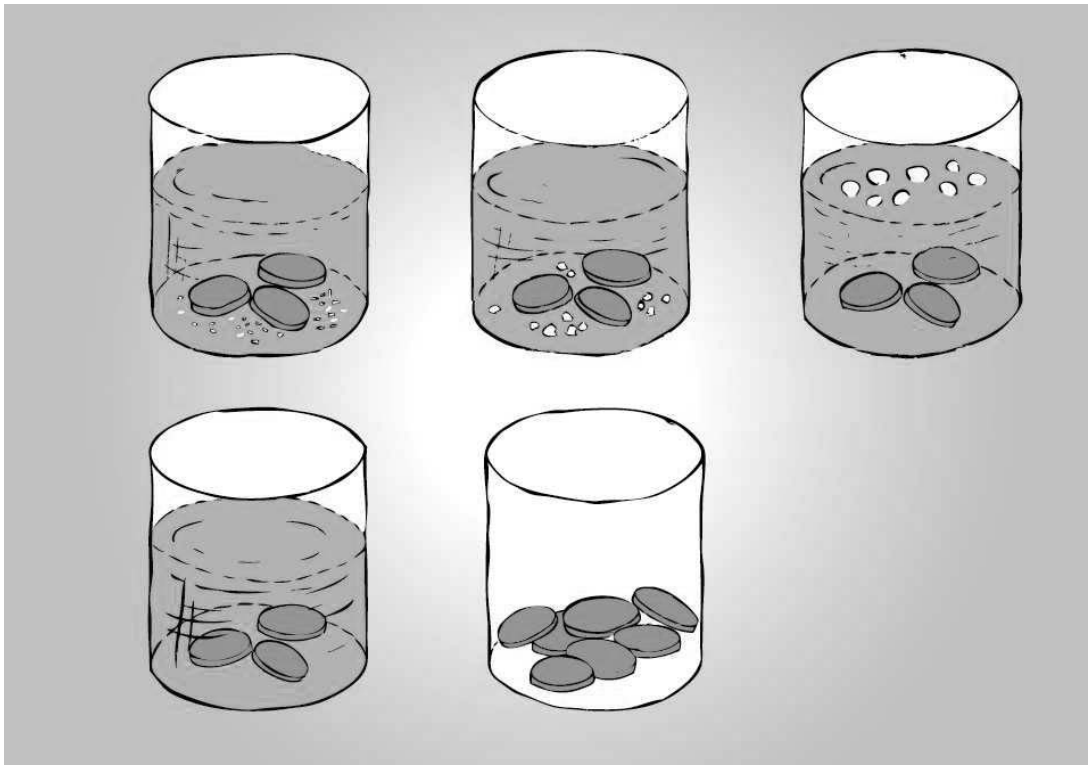
Grade 10, chapter 1, lesson 2, 2008

Materials needed

- Water
- Carrot
- Salt
- Sugar
- Soap
- 10 baby plates
- Cooking stove
- Pot

Procedure

- Take some water and add small pieces of carrot. Make sure that the pieces are fully submerged in the water.
- Prepare the following solutions in each plate:
    - Plate 1: add sugar (maximum concentration)
    - Plate 2: add salt (maximum concentration)
    - Plate3: add soap (one tea spoon)
    - Plate4: only water
    - Plate5: only some pieces of carrot, no water
- Cover all the plates
- Place all the plates in the sunlight.
- Repeat the procedure but put the glasses in a dark space.



Top (left to right): water, carrot and sugar; water, carrot and salt; water, carrot and soap
Bottom (left to right): water and carrot; carrot.

Observations

- Observe the plates after 24 hours.
- Observe also the smell of each solution.
- Repeat your observations every 2 days.

Samples	Number of days			
	1	3	5	7
In sunlight				
Out of sunlight				

Explanation

Bacteria are all around us. Given good growing conditions, a bacterium grows slightly in size or length, a new cell wall grows through the centre forming two daughter cells, each with the same genetic material as the parent cell. If environment is optimum, the two daughter cells may divide into four in 20 minutes. Then why isn't the earth covered with bacteria?

The primary reason is that conditions are rarely optimum. Scientists who study bacteria try to create the optimum environment in the lab: a culture medium with the necessary energy source, nutrients, pH, and temperature, in which bacteria grow predictably.

Bacteria need to feed on something that gives them energy and allows them to grow. These are called nutrients for bacteria. Bacteria can grow on meat, milk and other foods causing a bad odour and diseases for people who consume bacteria infected food. Since there are different types of bacteria, their needs to the food may also vary. By knowing the type of food or nutrients that each specific bacteria needs, we can control the environment in order to stop the growth of unwanted bacteria and promote the growth of bacteria that we need. Also for bacteria growth experiments in laboratories, good nutrients are the key to a fast and useable result.

Conclusion

Bacteria feed on nutrients that provide them with energy and allow them to grow. By knowing the nutrients each bacteria needs, we can control the environment in order to stop the growth of unw bacteria and promote the growth of bacteria that we need.

Questions

1. In which solutions do bacteria and fungi grow well?
2. Why does this happen?
3. How can you explain the strong smell in some of the solutions?
4. Do bacteria and fungi need light to grow?
5. Do you think the observed bacteria are producers or consumers? Explain why.
6. Try to think of other solutions to test bacterial growth. Would bacteria grow well in these solutions?
7. You can repeat the experiment, but using boiled water instead of normal water. What results do you expect?

8.3 Models for the digestive system

Objectives

- Students can explain process of food digestion by using these models
- Students can make and use these models
- Students can keep their digestive system healthy

Position in curriculum

Grade 7, chapter 4, lesson 3, 2009
Grade 11, chapter 4, lesson 2, 2009

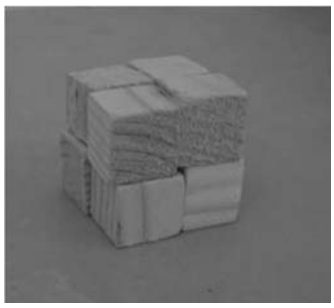
1. Cube model for surface area

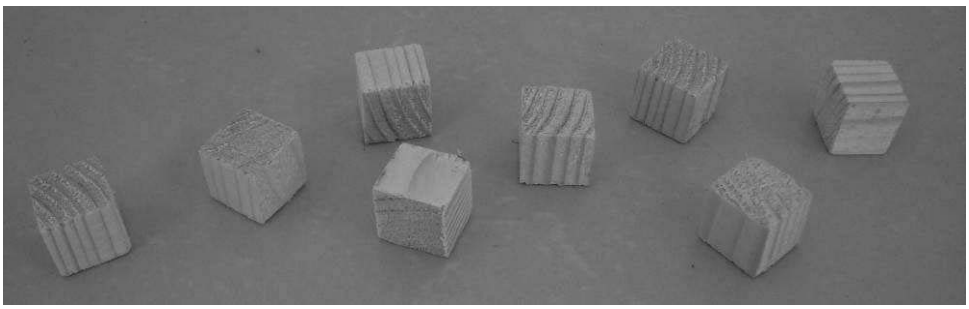
Background knowledge

This model illustrates the role the teeth play in the digestive system. By cutting the food in small parts they increase the surface of the food particles.
The teeth tear food into small pieces and increase the surface area available for chemical digestion.

Description and use of the model

Make several cubes of the same size. Lay the cubes together to form a big cube (photo left). This big cube represents a food bite (for example: 1 piece of meat). After a time of biting, the big piece of meat will change in a few smaller pieces of meat, shown by the small cubes (photo right). The total surface of all the small cubes is higher than the surface of the big cube.

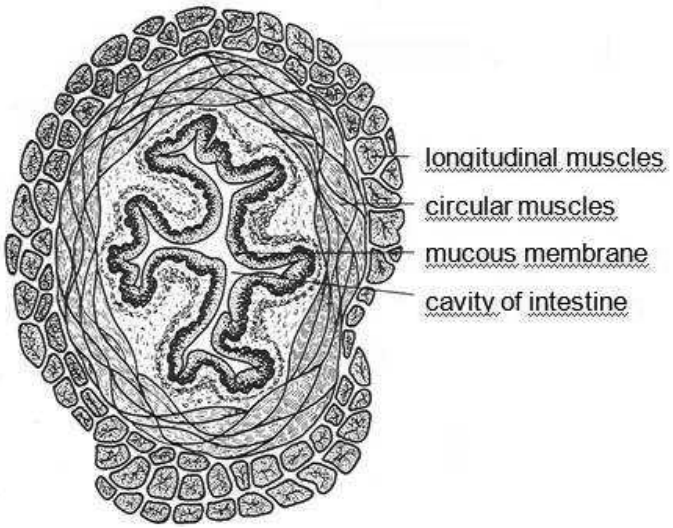


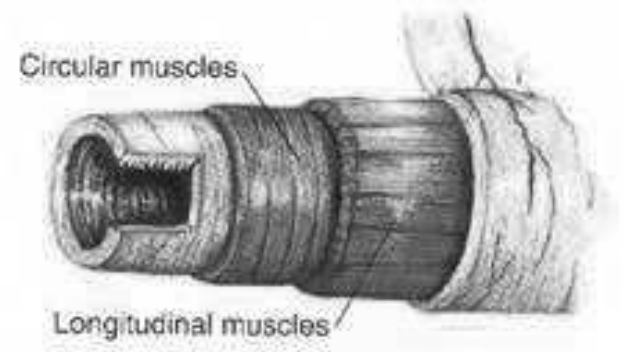


2. Model peristaltic movement

Background knowledge

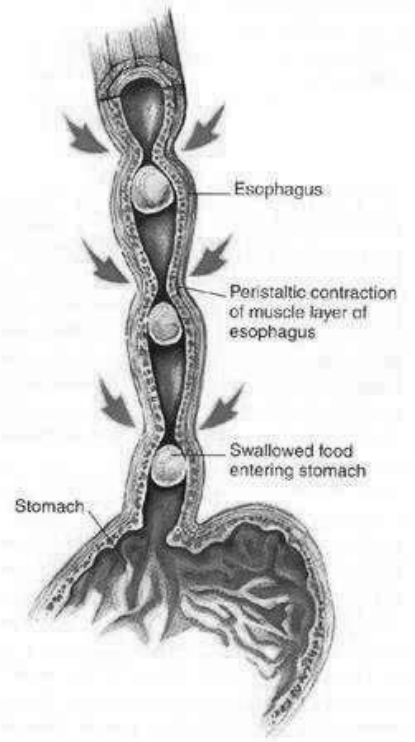
The digestive tract consists of a cavity (tube), a mucous membrane and 2 layers of muscles. The circular muscles of the inner layer circle the tube and constrict the tube when they contract. The longitudinal muscles in the outer layer run lengthwise and shorten and open the tube when they contract. Waves of contraction are called peristalsis and push the food through the digestive tract.





Description

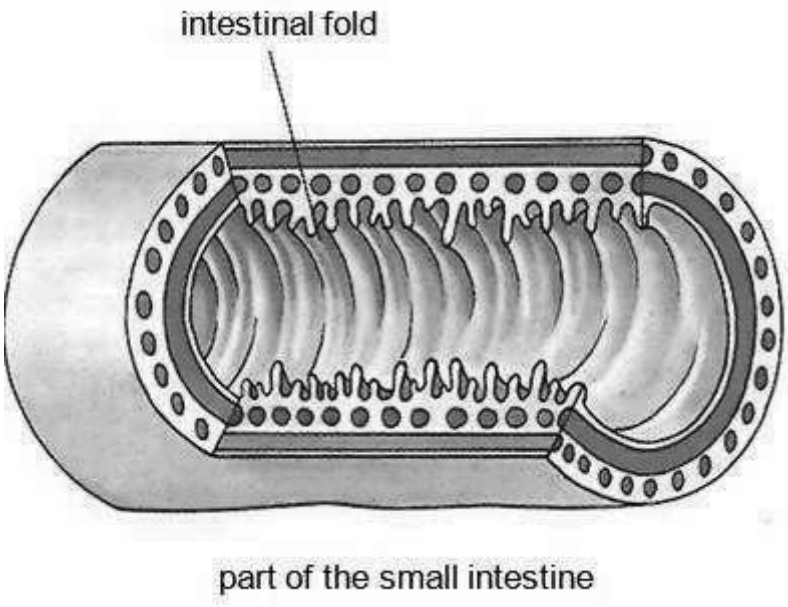
The model consists of a small ball and a panty. The panty represents the digestive track, the ball a food particle. Move the tennis ball by squeezing the panty behind it. The squeezing simulates the contracting movements of the muscles propelling contents through the digestive tract.



3. Model intestinal fold

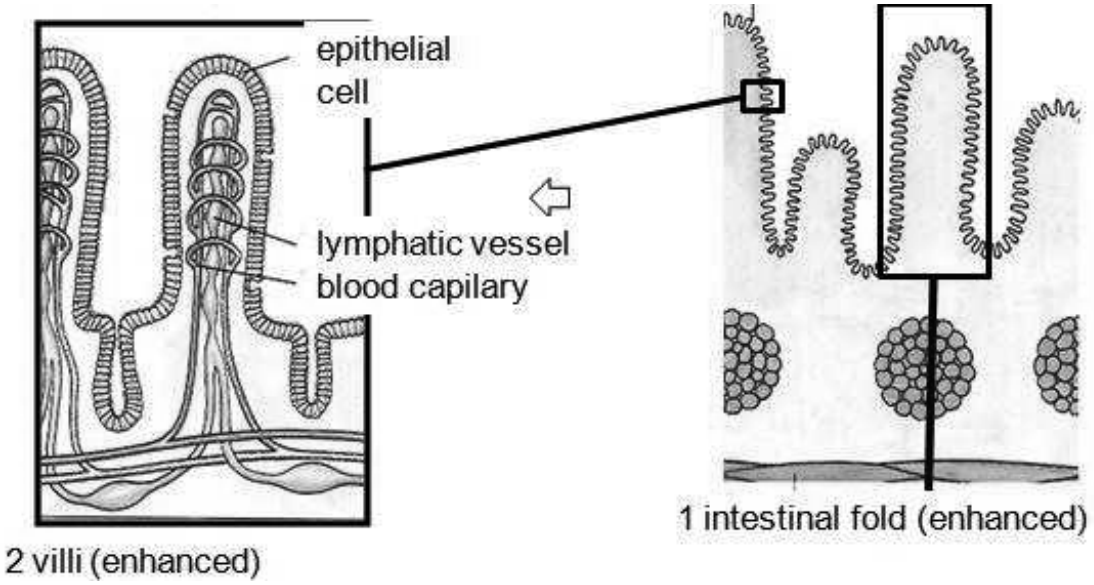
Background knowledge

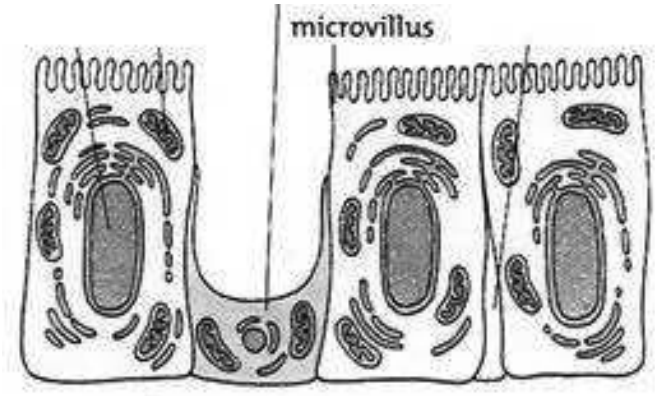
Nutrition absorption must take place at a surface. The small intestine illustrates the maximization of surface area. The organ is very long but is highly folded so it can fit into the abdomen. The inner layer of the small intestine is also extremely folded. The surface consists of intestinal folds (figure left: part of the small intestine). The surface of every fold is also folded: the “hills” are called villi. The tall epithelial cells on the surface of each villus have microvilli. Each villus cell and its 500 microvilli increase the surface area of the small intestine at least 600 times, creating an absorption area of 200 to 300 square meters!



Description and use of the model

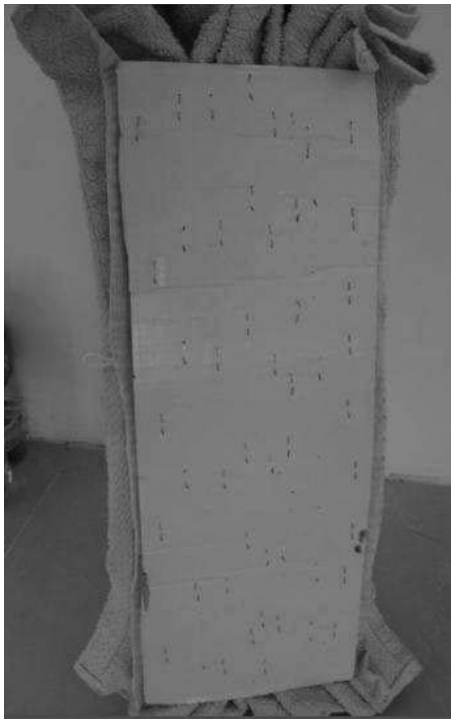
The model is made of a folded towel, fixed with tape to cardboard. The model represents a part of the intestine wall and can be used as demonstration. The big folds represent the intestinal folds, the smaller (part of the tissue) represent the villi.



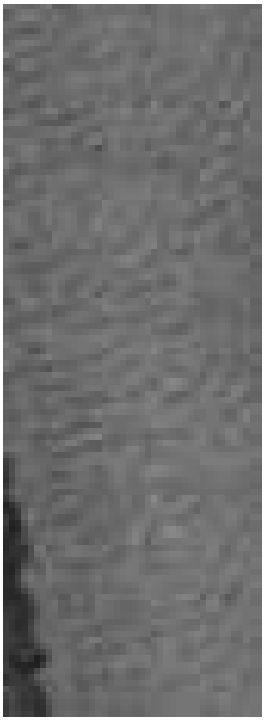


Epithelial cells with microvilli

Front side of model



Back side of model



Detail: the smaller folds represent the villi

Conclusion

These models explain important concepts of digestive systems, particularly the digestive mechanism such as surface area of food particles, peristaltic movement, and intestinal fold.

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