EUROPEAN UNION SCIENCE OLYMPIAD

TASK 2

Theme: Crime Scene Investigation

Gothenburg, Sweden

Thursday 15th April, 2010

General instructions

Wear a laboratory apron and safety glasses at all times within the laboratory.
Eating and drinking is prohibited in the laboratory.

Disposable gloves are provided and must be worn when handling chemicals.

All paper used, including rough work paper, must be handed in at the end of the experiment.

All results must be entered into your answer book.

Your graphs must be handed in along with the answer book.
Only the calculator provided is allowed.

Only the final answer book, and attached graphs, will be marked.

The tasks may be carried out in whatever order you wish.

Cover story - Who killed Erik Lundberg?

It was a gloomy Sunday morning in the beginning of October. The strong wind made the rain drops hit the windows, creating an intensive sound.

Inside the police station, on the other hand, a robust smell of coffee made the environment very inviting. Although it was a Sunday, quite a few officers were in. The reason for this was the murder of Erik Lundberg, which had taken place very recently. The two suspected murder locations were the victims home and a local pub, "The Crown".

Inspector Carin Larsson entered the forensic laboratory and approached Dr. Mary Blade, chief of the Crime Scene Investigators (CSI). Before inspector Larsson even had time to ask about the cause of death, Dr. Blade spontaneously declared: "A typical case of copper sulfate poisoning. Erik Lundberg has been poisoned with copper sulphate pentahydrate."

Inspector Larsson got all the information from Dr. Blade before returning to her office where she started to summarise what they knew so far.

Erik Lundberg had been found in his home late Saturday morning. The maid had found him lying on his bed, apparently dead. The police officers who first arrived at the crime scene secured the location and awaited the arrival of the investigators and the forensic team.

The forensic team had arrived at noon and immediately started their documentation of the crime scene. They directly measured the body temperature of the corpse, to be able to estimate the time of death. They noted that the bedroom window was open and that the room temperature was 10.0°C (assume that the room temperature was constant during the night and remains constant). It took the forensic team another 9 hours to complete the investigation of the crime scene (photographing and securing evidence, looking for possible traces of the killer, etc.) and before the body was removed, the team measured the temperature of the body a second time.

Inspector Larsson had also been informed that Erik Lundberg had received an anonymous death threat three days earlier. Its author had cut letters from various journals and newspapers to form the following message:

On FRiDay yOU shaLl DiE!!!

This letter was analysed in detail by the forensic investigators, who found a large amount of unknown particles, which probably were of biological origin. No fingerprints were found. Samples of the particles were preserved for microscopic analysis.

It did not take long for the investigators to realise that there were four prime suspects who could have been involved in the murder of Erik Lundberg.

They were:

A) Nils, 52, colleague of Erik Lundberg.
B) Anders, 45, cousin
C) Malin, 37, ex-wife
D) Linda, 43, former business partner

Who killed Erik Lundberg? The continued story

The police interviewed the suspects and close to forty witnesses. They also checked receipts, credit card use and surveillance cameras. As a result of this, the police was able to establish the following facts:

Erik Lundberg met Linda for lunch at 12 o'clock. Erik drank two glasses of beer.

After lunch, at approximately 1 PM, he met with Anders. At that meeting Erik drank one cup of coffee.

In the afternoon he met Malin for supper at 6 PM. Erik drank three glasses of wine.

At around 7 PM Erik met Nils in a bar. Both had one glass of whiskey.

Summary of the body temperature analysis

- Bedroom temperature: 10,0 ^{o}C
- Body temperature at 12 noon Saturday: 28,0 ^{o}C
- Body temperature at 9 pm Saturday evening 22,0 ^{o}C

About Erik Lundberg

- Age: 46 year old
- Weight: approx. 70 kg
- Total volume of blood: 5,00 L
- Poisoned with Copper(II) sulphate pentahydrate ($CuSO_4 \cdot 5H_2O$).
- Other signs on the body: none

Chemical reference information

- $CuSO_4 \cdot 5H_2O$
- Density ρ=3,7 g/mL

Volume of the drinks (per drink)

- Beer: 0,40 L
- Coffee 0,15 L
- Wine 0,15 L
- Whiskey 0,06 L

A forensic team investigated the flora inside the suspect's homes, and also the surrounding areas. Their results are summarised in "**Report from the Forensic Botany Team**".

Reference data for identification of the particles discovered on the anonymous letter can be found in "**Manual for Forensic Palynologists**".

(Non-)Fact Sheet

In this fictitious story we use a substance that in real life has different properties than those we award it here. The reason is that we need to use something YOU can work with, without dying. The following statements are not true, <u>but will be considered facts in this story</u>:

$CuSO_4.5H_2O$ is a lethal poison. Ingestion of any amount over 20mg/kg will lead to certain death.

$CuSO_4.5H_2O$ is easily dissolved in any of the liquids drunk by the subjects in this story, and also becomes invisible in those drinks.

All the liquids can hold a maximum of 25 mg/mL of the poison. If more is mixed into a drink nobody will drink it because of the awful taste that is only perceived above that amount.

This poison has some strange properties that delay all symptoms for 7-8 hours after ingestion. When symptoms finally occur, death is almost instant.

Inspector Larsson knew that a body cooling curve over time constructed by the forensic physics analysts would probably give her a relatively accurate time of the murder, another piece of circumstantial evidence, which could possibly be used to exclude some of the suspects.

When the victim was found the forensic team took the whole blood because Inspector Larsson realised that if someone could determine the concentration of the poison in the blood sample, based on results from the forensic laboratory and complementary analyses by you, she could hopefully exclude one or two of the four suspects, based on what Erik Lundberg drank during his last day in life.

It is time for you to solve this murder case. Please, observe that it is necessary to utilise information based on the chemical, biological and physical analyses done by the forensic team or by you to be definitely sure of who poisoned Erik Lundberg this Friday afternoon or evening.

GOOD LUCK!

Task 1. Forensic physics. Determine the cooling curve of the dead body.

A long time ago, before potatoes were imported to Sweden, the "turnip" or "swede" (known as "rutabaga" in the US), was a base ingredient in Swedish food, and an important source of vitamin C. In this experiment, however, you will focus on the cooling of the swede, as a way to deepen your understanding of how bodies cool, and also to find out at what time Erik died, and his body started cooling. As you will notice, the cooling is quite slow, so you will need to follow the cooling for a considerable amount of time. The starting temperature of the swede directly taken from the heat bath is about 50-60 °C. Note the following experimental details:

- Be careful not to burn your hands. Use protective eyeglasses and gloves when you take the swede out of the heat bath.
- Put the hot swede on a table and keep away from other objects that may influence the cooling process.
- Measure the temperature in the centre of the swede as it varies with time. The sensor of the thermometer is located at the tip of the metallic shield.

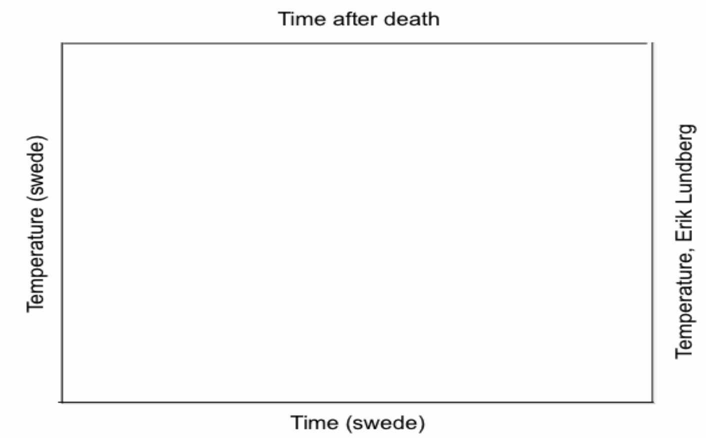
Fill in your answer book as you go along in your investigation

1.1. Collect your data in a Table as you do the measurements. Do not forget to include the Table in your answer book.

1.2. Draw a graph showing how the temperature of the swede varies with time! In addition, draw a horizontal line in the graph corresponding to the room temperature.

1.3. Assume that the cooling of a dead body follows the same type of relationship between temperature and time as the cooling of a swede. You can then use your experimental graph to estimate the time of death of Erik Lundberg. Since the swede obviously cools down faster than a human body, and the temperatures are different, you will have to rescale the axes, and change the time and temperature scales to fit with the relevant information given in the “story text” regarding the death.

The figure to the right shows an example of how to include the alternative coordinate axes, corresponding to the cooling of the dead body. In your diagram, add the axes (including scales) corresponding to the time after death and to the temperature of Erik Lundberg's body, assuming that his body temperature at the time of death was 37.0°C.



1.4 Now you can determine the time when Erik Lundberg died. Write your answer in box 1.4

1.5 From the time of death obtained above you can conclude that some of the suspects cannot have murdered Erik Lundberg. Which of the suspects remain? Mark your results in the answer book.

Supplementary Questions

1.6 The cooling of the swede follows a curve which can be described by one of the following alternatives:

A. $T = (T_{start} - T_{ambient}) \cdot a^t$
B. $T = T_{start} - a \cdot t$
C. $T = T_{start} - a \cdot t^2$
D. $T = T_{start} - a \cdot t^{0.5}$
E. $T = (T_{start} - T_{ambient}) \cdot a^t + T_{ambient}$
F. $T = T_{start} - a \cdot t - T_{ambient}$
G. $T = T_{start} - a \cdot t^2 - T_{ambient}$
H. $T = T_{start} - a \cdot t^{0.5} - T_{ambient}$

where T denotes temperatures measured in °C and t denotes the time from the start of the measurement, expressed in a suitable time unit, e.g. minutes or hours or any other unit of your choice. The value of the parameter *a* obviously depends on your choice of time unit. Choose the correct expression and write your answer in box 1.3

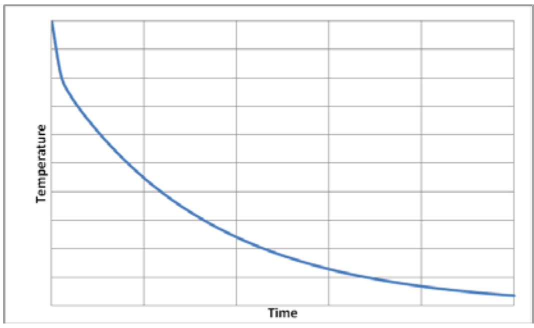
1.7 Determine the parameter *a* for the swede for your choice of time unit. Write your value for *a* and your choice of time unit in box 1.7

1.8 For your choice of formula for the cooling in 1.6 determine the parameter *a* for Erik Lundberg's dead body, using the data supplied in the cover story. Use a suitable time unit and find the parameter *a* for this choice. Write your value for *a* and your choice of time unit in box 1.8.

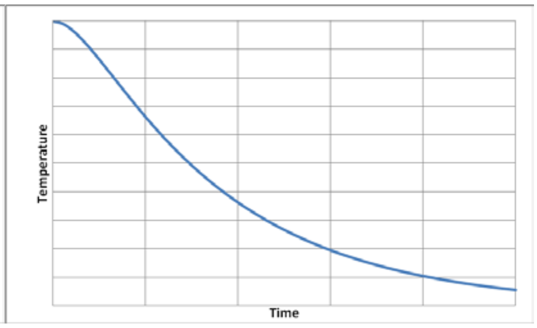
1.9 At what time would Erik Lundberg's dead body have cooled to 11 °C (assuming that the ambient temperature remains unchanged)? Write your answer in box 1.9.

1.10 If your cooling graph for a swede can be used as a model for a dead body, it can also be used to describe other objects. The time scales are different and the parameter values for *a* in 1.4 and 1.6 above depend on the choice of time unit. However, in both cases, you can identify a time, t_{50}, when the temperature difference has fallen to 50%. You can then introduce a dimensionless variable, $x=t/t_{50}$ which is independent of the time unit used. Now, rewrite the expression you chose in 1.3 in the form $y=f(x)$. The variable y should be dimensionless and tell what fraction remains of the original temperature difference. Again, this is independent of the temperature scale used. Write down an expression for y in terms of temperatures involved, i.e. T, T_{start} and $T_{ambient}$. Also write down the function $y=f(x)$ in box 1.

1.11 The experimental curve you have used for simulating the cooling process of a dead human body is after all not perfectly realistic. The cooling of a dead body starts from the outside since the heat is transferred through the surface of the body. In a living human the central part of the body is kept at a constant temperature of 37°C, this temperature is maintained by the cell metabolism and the distribution of the heat by the circulation of blood. As soon as the death occurs, the heat production of the cell metabolism and the circulation stops. The temperature is measured deep inside the body. Which one of the following graphs would be the most realistic for what happens?



A)



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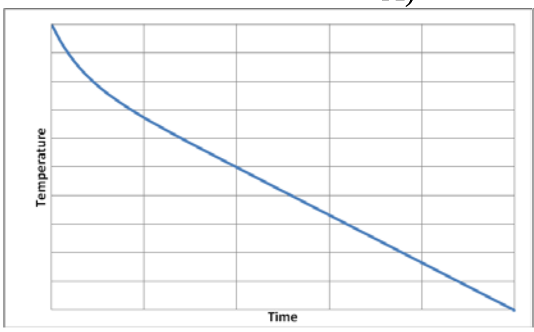
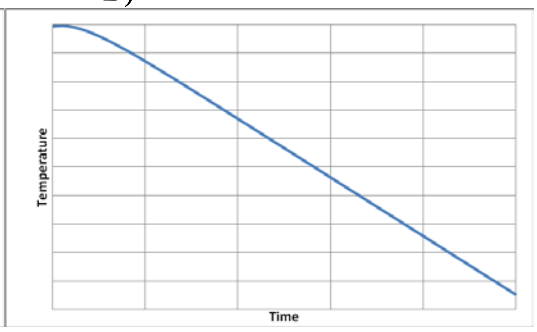


C)



D)

GOOD LUCK!

Task 2. Forensic chemistry

Please note! The following section provides important background information, but you do not need to perform this experiment, yourselves!

This scheme has been followed by the forensic laboratory (Dr Blake) to determine electrolytically the mass of copper on the cathode. This mass is a measure of copper in the test sample from the blood sample of the victim.

Dr Blake's method (not to be done but to be read) !! This method describes the handling of the electrolytical cell and the sample preparation including a concentration and filtering step that must be considered by you, to be able to calculate a correct result at the end of this analysis.

The sample of whole blood from the victim was purified from red blood cells and concentrated 5 times to the volume of 1.00 L before the analysis begun. This new sample is marked "blood serum". The analysis started and 10.0 mL of this blood serum sample was pipetted into a 250 mL beaker and diluted with distilled water so that roughly 90% of the cathode was covered by the solution. In addition, 1 mL of concentrated H_2SO_4 was added to the solution in the beaker.

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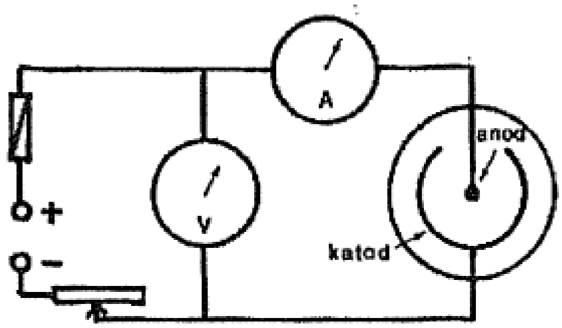
Before the cathode (a copper piece) was placed in the electrolytical solution, it was cleaned by quickly dropping it into the diluted H_2SO_4 cleaning solution. The copper piece was then washed several times with distilled water. Then it was dried and its mass was measured on the scale to highest precision. The obtained mass is stated on the plastic bag, which contains the copper cathode.

The analytic cell was constructed according to this picture. The cell was started by using the power from the power supply and it was run for ca 1.5 hours. At this point all copper was deposited on the electrode. In this way, solid copper layers were added to the original copper plate in this reaction.



Finally the process was stopped by lifting the electrodes up from the cell, however with the power from the power supply on and constantly spraying the cathode with distilled water for about 30 seconds. Then the power supply unit was released from the electrodes. The cathode was then dried and placed in the plastic bag.

2.1 NOW CONTINUE AND FILL IN THE ANSWER BOOK BASED ON THIS DESCRIPTION AS YOU GO ALONG!

Your task now!!

Information provided by the electrolysis analysis

The copper electrode is now available for you. It has been dried by the forensic laboratory and its original mass before the electrolysis experiment is stated on the covering plastic bag. Please, determine its current mass on the high-precision scale and fill out the answer sheet from here on concerning the electrolytic analysis.

Please, be aware of the dilution used by the forensic laboratory!

2.2 Titration analysis

The concentration of Cu^{2+} in an unknown solution can also be determined by a standard titration method using KI(s) as a reducing agent for Cu^{2+} and $S_2O_3^{2-}$ as a titrand in the successive titration experiment according to the following reactions:

$2Cu^{2+} + 4I^{-} \rightarrow 2CuI(s) + I_2$
$I_2 + 2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2I^{-}$

E**xperimental**

- Pipette 10.00 mL copper solution each from the stock solution (the blood serum) into three clean but not necessarily dry Erlenmayer flasks.

- Fill the macro burette as shown to the zero level (it is automatically adjusted). Sometimes the zero level is somewhat lower than zero. Please, write down this level, which is specific to your burette.

- Add to all three flasks 2.0 g solid KI, and 1.0 mL acetic acid. Then titrate with $S_2O_3^{2-}$ until the solution is pale yellow. At this point you add 0.5 mL of starch indicator using the small pipette. Then continue titrating until the blue colour disappears.
- Titrate the three Erlenmayer flasks to the end point and read off the titration value on the burette.

- The concentration of the $S_2O_3^{2-}$ solution in the burette is 0.100 M (molar).

If you need extra solution, please ask for it!

Fill in your answer book! Solve the murder case using the information presented in the cover story. If the results are inconclusive from the chemical analysis, compare the results with information obtained from the other two tasks related to physics and biology

GOOD LUCK!

Task 3. Forensic biology

Determine the nature and origin of the particles on the anonymous letter. These can be studied on the microscopic slide you have received. Examine the reports by the forensic biologists and use the information available to answer the first two questions, then answer the remaining questions.

3.1 Which species of plant did the particles originate from? Write your result in the answer book

3.2. Which suspect(s) appear most likely to have written the anonymous letter? Mark your answer in the answer book (1 pt each. NB! 1 point will be subtracted for each answer that is not supported by botanical evidence)

3.3: Veterinarian CSI officer, part I SUMMER:

For which of the following animals can the cooling curve that you have constructed be applied to determine the time of death. Mark your answers in the answer book.

SPECIES	**CLASS**
Brown Rat (*Rattus norvegicus*)	Mammalia /mammals
Common Starling *(Sturnus vulgaris)*	Aves / birds
Common Viper, Adder (*Vipera berus*)	Reptilia / reptiles
Common European Toad (*Bufo bufo*)	Amphibia / amphibians
European carp (*Cyprinus carpio*)	Actinopterygii / fishes

3.4: Veterinarian CSI officer, part II WINTER:

You are asked to come to a very different crime scene. Somebody has killed (within the last 13 hours) a brown bear (*Ursus arctos*) and an European hedgehog (*Erinaceus europaeus*) during the winter. Both animals were killed in their winter quarters where the air temperature was 8 °C and the question is now: Can a cooling curve similar to the one you constructed for Erik be applied to determine the time of death for these two animals? Mark your answers in the answer book.

Supplementary questions

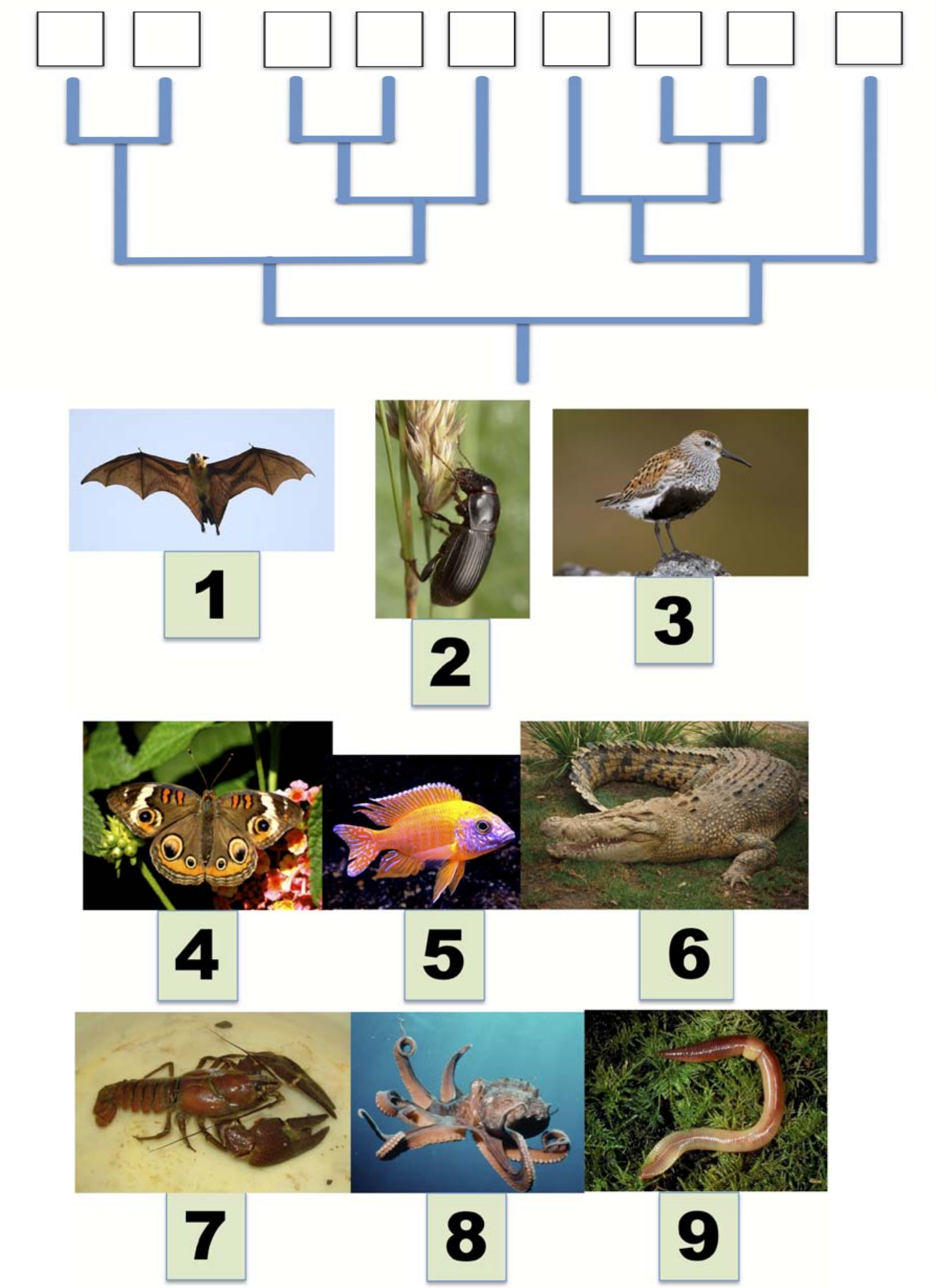
3.5. Suppose a tree grows and increases its mass by 100 kg.

What is the origin of the majority of the increase in mass
Mark only ONE alternative in the answer book.

A) Earth/soil and water
B) Water and air
C) Water (H_2O) and minerals
D) Earth/soil and minerals

3.6. Place the animal species in the tree diagram, in a way that is consistent with their

evolutionary relationship. Write the number associated with each animal in the appropriate box instead of names. Do not forget to copy the results into the answer book.



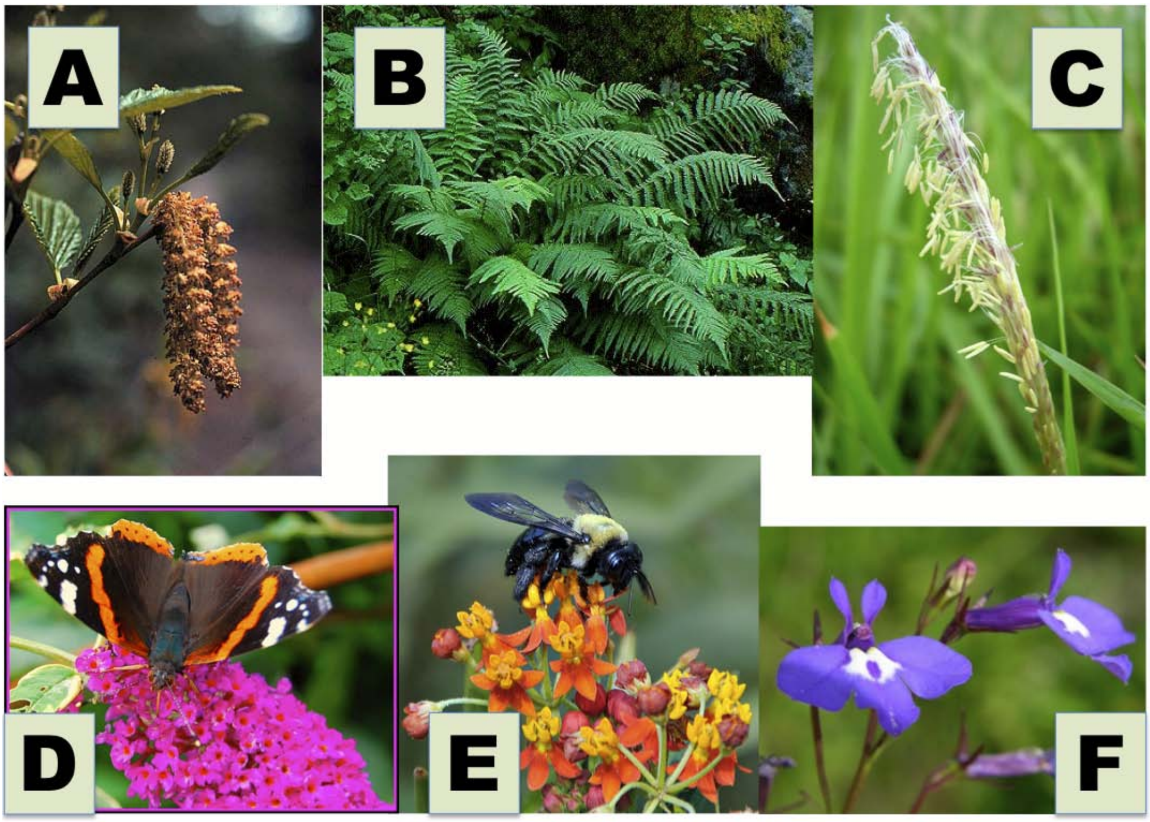
3.7. Suppose that ALL plants, algae, bacteria, fungi and protists on and around an isolated island die. What describes best what will happen to the land-living animals on a long time scale? Mark only ONE alternative.

A) All animals die eventually
B) Many animals die, but those who are meat-eaters survive
C) Some animals that used to eat plants find other things to eat and survive
D) Only the strongest animals survive

3.8. All plants need energy to survive. What is correct about the energy-rich substances that plants that grow on land need. The question only concerns plant species that do not get help from other species to acquire these substances. Mark only ONE alternative.

A) Plants take up e**nergy-rich substances** through their roots
B) Plants take up e**nergy-rich substances** through their leaves
C) Plants take up e**nergy-rich substances** both by the roots and the leaves
D) Plants do not use any of the methods described in alternatives A-C to get energy-rich substances

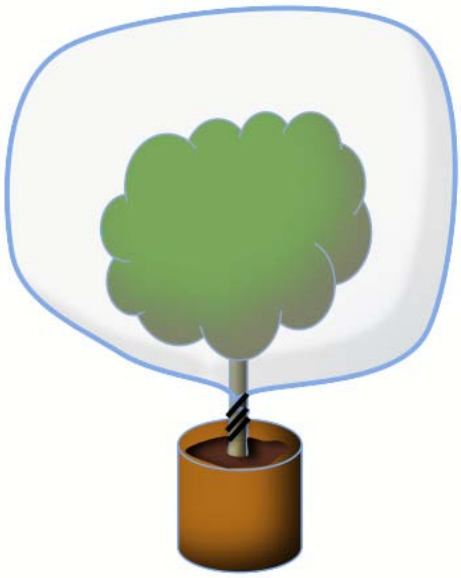
3.9. A person you know suffers from hayfever, but loves gardening. Based on your general understanding of hayfever and plant ecology, the plants below may be predicted to differ in how harmful they are for allergic persons. Which 2 plants below would be the first ones you would tell your friend NOT to plant in the garden?



3.10 . Suppose you cover a plant with a plastic bag, like in the picture below, and put it in the dark for 24 hours. The bag is sealed tight, and nothing can pass between the inside and outside of the bag. At the start of the experiment the bag is filled with air of the exact same composition and properties as the air outside the bag. Only two of the statements below are true for the situation after 24 hours in the dark. Mark the statements that are true.

A. The amount of oxygen (O_2) decreases inside the bag
B. The amount of oxygen (O_2) increases inside the bag
C. The amount of oxygen (O_2) is unchanged inside the bag

D. The amount of carbon dioxide (CO_2) decreases inside the bag
E. The amount of carbon dioxide (CO_2) increases inside the bag
F. The amount of carbon dioxide(CO_2) is unchanged inside the bag



GOOD LUCK!