Surname	StemUp Model Solution	Centre Number	Candidate Number
First name(s)			2

GCE A LEVEL

A400U10-1

O20-A400U10-1

MONDAY, 12 OCTOBER 2020 – MORNING

BIOLOGY – A level component 1
Energy for Life

2 hours

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**20**	
2.	**10**	
3.	**14**	
4.	**18**	
5.	**8**	
6.	**21**	
7.	**9**	
Total	**100**	

A400U101
01

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen. Do not use correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The assessment of the quality of extended response (QER) will take place in question **7**.

The quality of written communication will affect the awarding of marks.

OCT20A400U10101

© WJEC CBAC Ltd.

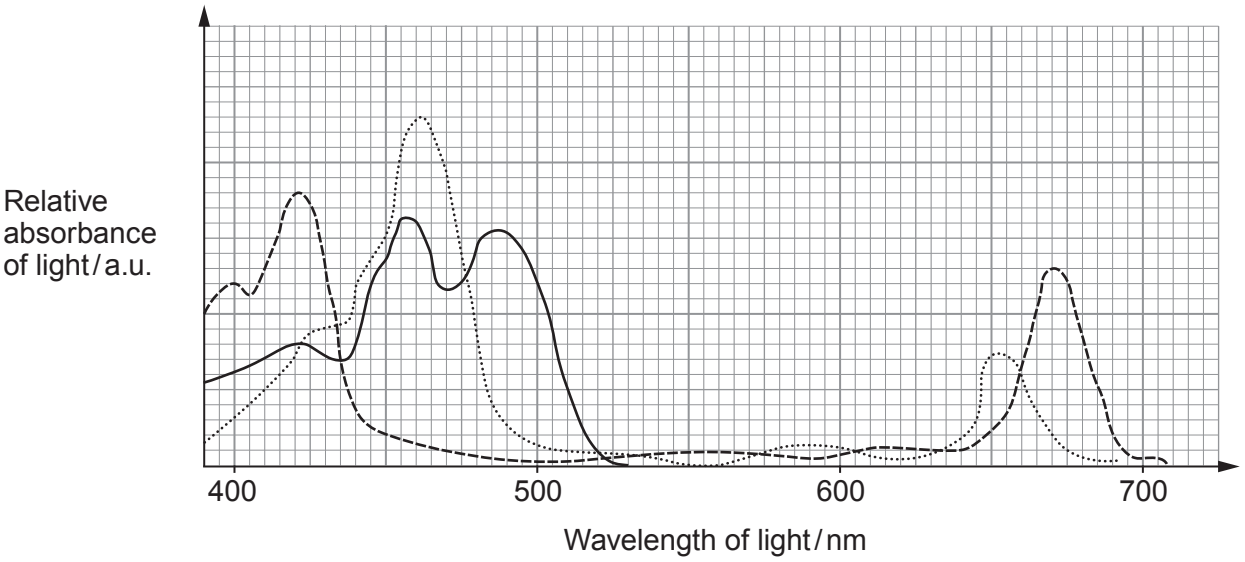
stemup.co.uk

Examiner only

Answer **all** *questions.*

1. Photosynthetic cells are transducers converting light energy into chemical energy. Several photosynthetic pigments are involved in the absorption of light energy. **Image 1.1** is an absorption spectrum showing the relative absorbance of different wavelengths of light energy by different pigments.

Image 1.1



(a) (i) Using information in **image 1.1**, describe the absorption spectrum of **chlorophyll a**. [2]

Chlorophyll a has absorption peaks in the blue (about 425 nm) and red (about 675 nm) regions. There is minimal absorbance in the green region, between 480 and 650 nm.

(ii) Suggest the advantage to photosynthetic cells of having several different light absorbing pigments. [1]

Light is absorbed over a greater range of wavelengths, so the rate (efficiency) of photosynthesis is increased.

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

Prochlorococcus is a species of cyanobacterium and is the most abundant photosynthetic organism on Earth. Cells of *Prochlorococcus* contain molecules of chlorophyll a and b embedded in photosynthetic membranes.
Image 1.2 and **image 1.3** show a molecular model of a chlorophyll molecule and the arrangement of chlorophyll molecules in the photosynthetic membrane.

Image 1.2

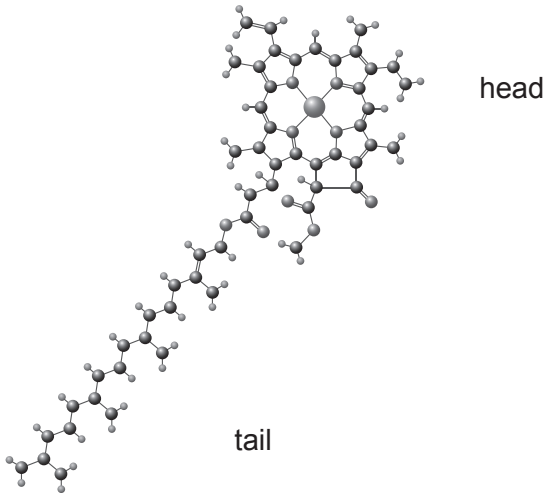
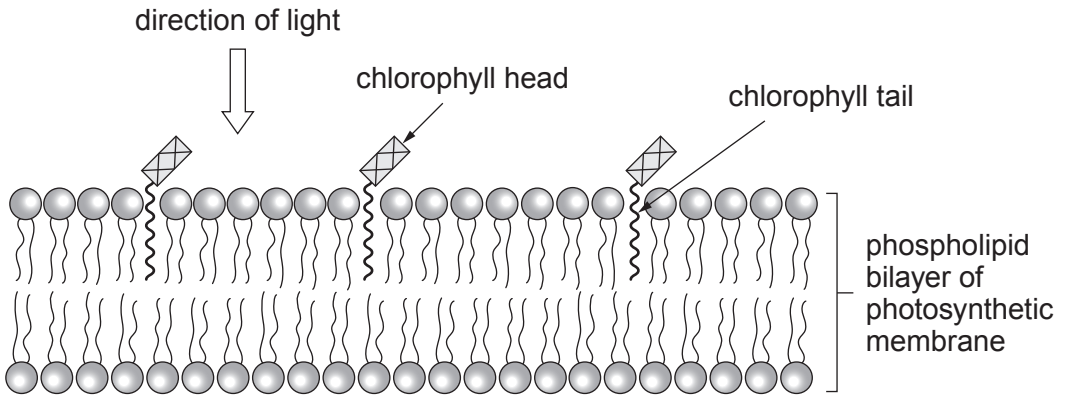


Image 1.3



(b) (i) State **one** element, other than carbon, hydrogen and oxygen, that is found in the chlorophyll molecule. [1]

Magnesium (Mg)

(ii) Use **image 1.2** and **image 1.3** to explain how the properties of the head and tail of the chlorophyll molecule result in its position in the photosynthetic membrane. Suggest an advantage of the position of the chlorophyll molecules. [3]

The tail is hydrophobic (non-polar), so it is held among the hydrophobic fatty acid tails in the membrane.

The head is hydrophilic (polar), so it sits at the membrane surface.

This holds the head in the optimum position, facing the light, for absorption of light.

A400U101 03

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

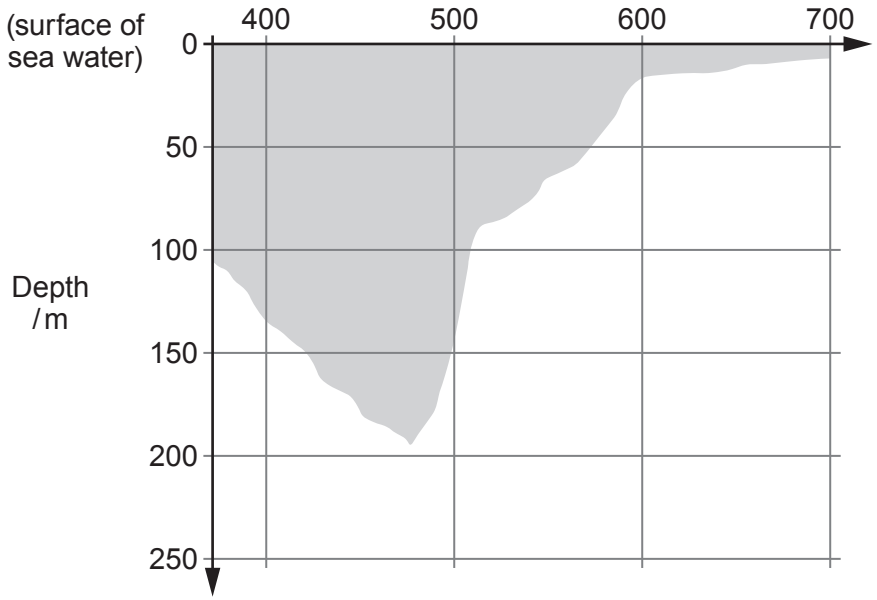
(c) In the light dependent stage of photosynthesis, molecules of chlorophyll a emit electrons. Describe how these electrons are replaced in non-cyclic photophosphorylation. [2]

They are replaced by the photolysis of water at photosystem II, using light energy:

$2H_2O \rightarrow 4H^+ + 4e^- + O_2$; the electrons released replace those lost by the chlorophyll.

(d) *Prochlorococcus* is found at depths between 0 and 200 m in oceans around the world. Different proportions of chlorophyll a and chlorophyll b are produced by *Prochlorococcus* at different depths. **Image 1.4** shows the depth to which different wavelengths of light penetrate seawater.

Image 1.4



Using **image 1.1** and **image 1.4**, explain why *Prochlorococcus* cells found at depths between 150 metres – 200 metres produce chlorophyll b but not chlorophyll a. [2]

Only blue light (about 450 to 500 nm) penetrates to 150 to 200 m, so there is no light for chlorophyll a to absorb.

Chlorophyll b absorbs in the blue region of the spectrum, the only light to penetrate to this depth.

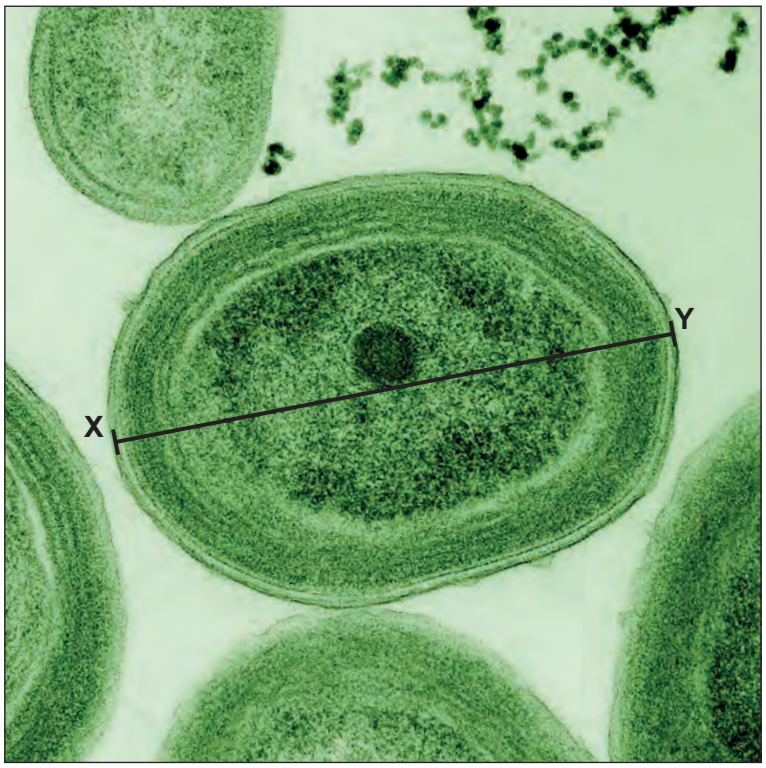
© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(e) *Prochlorococcus* is found in enormous numbers even in nutrient poor waters. **Image 1.5** shows a photomicrograph of a *Prochlorococcus* cell.

Image 1.5



X-Y = 0.6 μm

(i) Calculate the surface area : volume ratio of a *Prochlorococcus* cell which has a radius of 0.3 μm.
Express your ratio to the nearest whole numbers. [3]

Surface area of a sphere = $4\pi r^2$.

Volume of a sphere = $\frac{4}{3}\pi r^3$

π = 3.14

SA = 4 × 3.14 × 0.3^2 = 4 × 3.14 × 0.09 = 1.1304 μm^2

Volume = 4/3 × 3.14 × 0.3^3 = 4/3 × 3.14 × 0.027 = 0.11304 μm^3

Ratio = 1.1304 : 0.11304

= 10 : 1

Surface area : volume ratio = 10 : 1

A400U101
05

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(ii) With reference to the **size of the organism**, explain how *Prochlorococcus* is able to gain sufficient minerals from nutrient poor waters. [3]

Prochlorococcus is very small (diameter 0.6 μm), so it has a very large surface area to volume ratio (10 : 1). This gives a large area, relative to its volume, over which minerals can diffuse (and be actively taken up) into the cell. Its small diameter also means a short diffusion distance, so minerals quickly reach all of the cytoplasm, even at low concentrations.

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(f) *Prochlorococcus* stains red when using the Gram staining technique.

(i) **Complete the flow chart** below which shows the stages in the Gram staining technique. [2]

Fixation

↓

Stain with crystal violet

↓

Iodine treatment

↓

Washed and decolourised with alcohol (ethanol)

↓

Counterstain

(ii) Explain what this staining technique indicates about the structure of the cell wall of *Prochlorococcus*. [1]

It is Gram negative: thin peptidoglycan wall with an outer lipopolysaccharide layer.

20

A400U101
07

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

2. RuBisCO is the most abundant enzyme on Earth. Each RuBisCO molecule is made of eight **identical** long chain polypeptides and eight **identical** short chain polypeptides.

(a) (i) RuBisCO shows all four levels of protein structure. Briefly describe what is meant by the following terms: [2]

Primary structure *the sequence of amino acids in a polypeptide chain, joined by peptide bonds.*

Secondary structure *the chain coils into an α-helix or folds into a β-pleated sheet, held by hydrogen bonds.*

Tertiary structure *the polypeptide is folded further into a specific 3D (globular) shape, held by ionic, disulphide and hydrogen bonds.*

Quaternary structure *two or more polypeptide chains joined together (in RuBisCO, eight long and eight short chains).*

The genetic code for the long chain polypeptides is found in the chloroplast genome and the genetic code for the short chain polypeptides is found in the nucleus.

(ii) State **two** features of the genetic code. [2]

Triplet code (three bases code for one amino acid) and degenerate (more than one triplet codes for the same amino acid).

(iii) State how many genes code for the polypeptides found in a RuBisCO molecule. [1]

2

(b) RuBisCO is responsible for carbon fixation in the Calvin cycle.

(i) State the names of the **two** substrates that form an enzyme-substrate complex with RuBisCO. [2]

RuBP (ribulose bisphosphate) *CO_2 (carbon dioxide)*

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(ii) State the names of the following molecules:

I. the first 3-carbon phosphorylated **sugar** produced by the Calvin cycle; [1]

triose phosphate (TP)

II. **one** organic molecule formed from the product of the Calvin cycle with the addition of nitrogen **and** phosphorus; [1]

nucleotide (e.g. ATP, DNA)

III. **one** organic molecule formed from the product of the Calvin cycle with the addition of nitrogen **and** sulphur. [1]

amino acid (e.g. cysteine), forming protein

10

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

3. *(a)* Metabolism is a combination of anabolic reactions which build up molecules and catabolic reactions which break them down. Give **one** example where ATP is used in: [2]

an anabolic reaction; protein synthesis (forming peptide bonds)

a catabolic reaction. phosphorylation of glucose in glycolysis

(b) With reference to the production of ATP:

(i) state what is meant by substrate level phosphorylation; [2]

ATP is formed using energy derived directly from a reaction (the breakdown of a substrate), by transferring a phosphate group to combine ADP and Pi, e.g. in glycolysis and the Krebs cycle.

(ii) outline the process of chemiosmosis in an animal cell. [3]

Energy from the electron transport chain pumps H^+ from the matrix into the intermembrane space, creating a proton gradient.

H^+ flow from the intermembrane space to the matrix through protein channels in the stalked particles.

This flow provides energy to ATP synthase, which combines ADP + Pi → ATP.

(c) High levels of ATP within a cell cause the non-competitive inhibition of several enzymes involved in ATP synthesis.

Explain how an ATP molecule could act as a non-competitive inhibitor. [2]

ATP binds to an allosteric site on the enzyme, not to the active site. This changes the tertiary structure and so the shape of the active site, so the substrate cannot bind and fewer enzyme-substrate complexes form.

© WJEC CBAC Ltd.

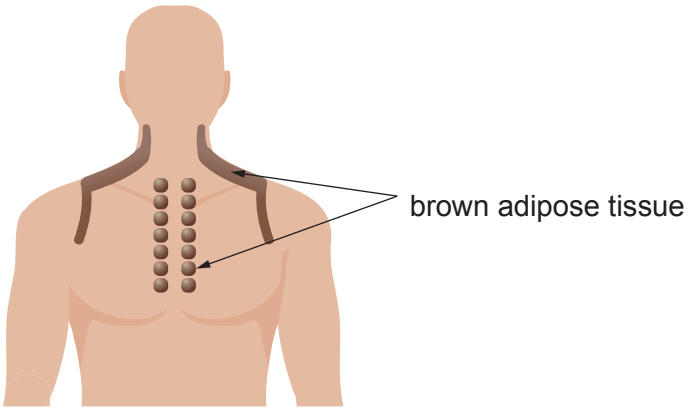
stemup.co.uk

Examiner only

(d) There are two types of adipose (fat) tissue in humans, white adipose tissue and brown adipose tissue (BAT).

The function of BAT is to generate heat. In adult humans it is found in the neck, shoulders and chest, as shown in **image 3.1**.

Image 3.1



In the inner mitochondrial membrane of BAT cells there is a protein which makes the membrane permeable to protons. When there is a fall in body temperature the concentration of this protein in the membrane increases and more heat is generated.
Capsaicin is a chemical found in red chili peppers. It makes the inner mitochondrial membrane of BAT cells more permeable to protons.

(i) Explain how capsaicin reduces ATP production by BAT cells. [2]

Protons leak back into the matrix through the membrane instead of through ATP synthase, so there is less of a proton gradient. Therefore fewer protons flow through ATP synthetase, so less ATP is produced (the energy is released as heat).

(ii) Using all the information provided, suggest why eating red chili peppers causes sweating and reddening to the neck, shoulders and chest. [3]

Peppers increase the release of heat energy, raising body temperature. BAT cells are found in the neck, shoulders and chest, so heat is produced in these areas. Sweating increases to reduce body temperature by evaporation. Vasodilation increases blood flow to the skin there, causing reddening.

A400U101
11

14

© WJEC CBAC Ltd.

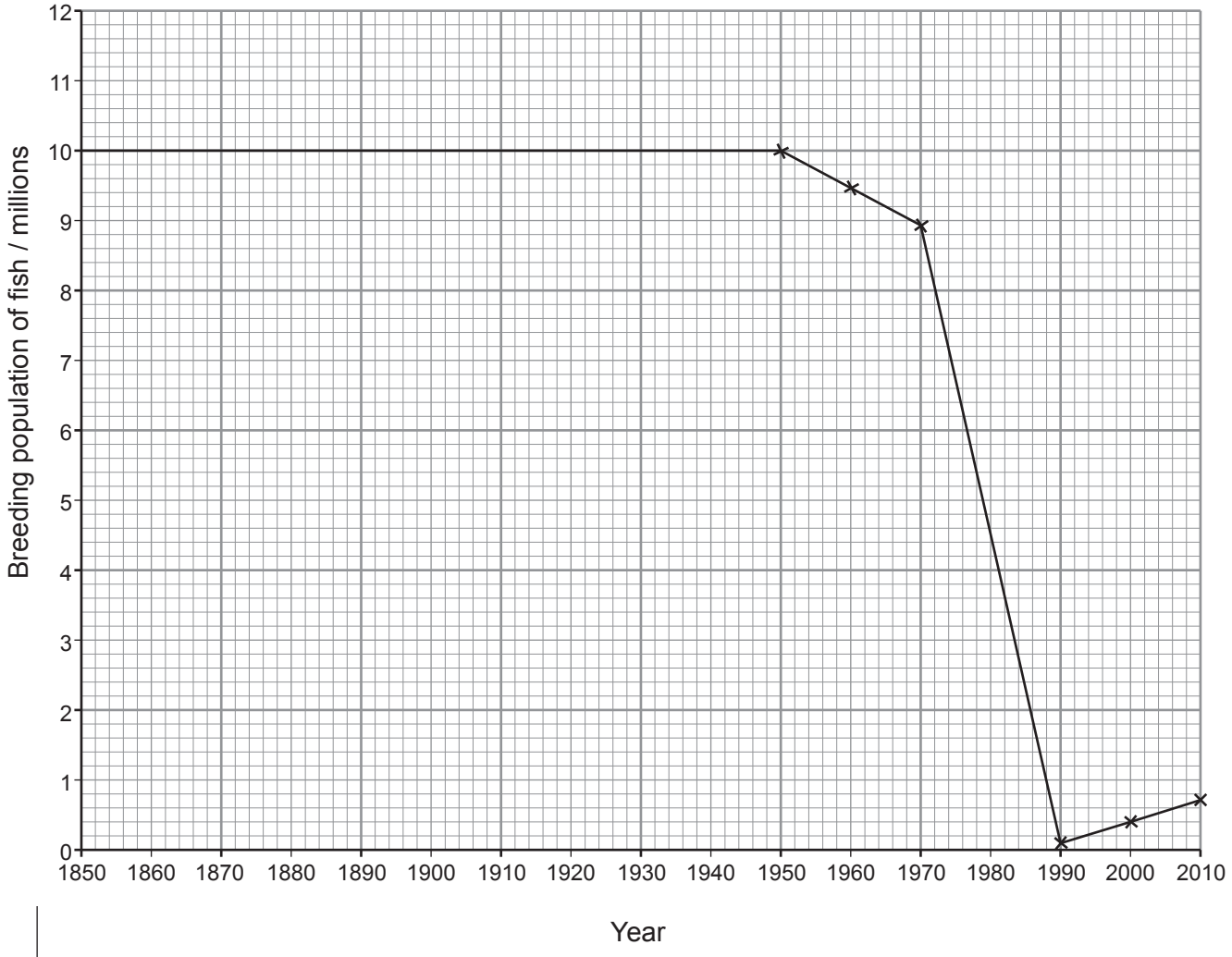
4. The Grand Banks is an area of sea off the coast of Newfoundland in Canada. Cod have been fished in the area for hundreds of years.

During the 1900s there were significant improvements in fishing techniques. By 1968, the number of cod caught had increased and 800 000 tons of cod were landed in that year alone. This represented 60% of the total cod population of reproductive age.

By 1992 the population had dropped to less than 1% of earlier levels and cod fishing was banned in the Grand Banks by the Canadian Government.

Image 4.1 shows the estimated breeding population of cod in the Grand Banks between 1850 and 2010.

Image 4.1



© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(a) With reference to **human activity**, explain the shape of the estimated population graph shown in **image 4.1** between the following dates: [3]

1850 to 1950;

Stationary phase at about 10 million (carrying capacity) because fishing was sustainable, with less efficient techniques.

1970 to 1990;

Rapid decline (population crash) from 9 to under 1 million because of overfishing with improved techniques.

1990 to 2010.

Slow population recovery (increase) because cod fishing was banned in 1992, so the fish could breed.

© WJEC CBAC Ltd.

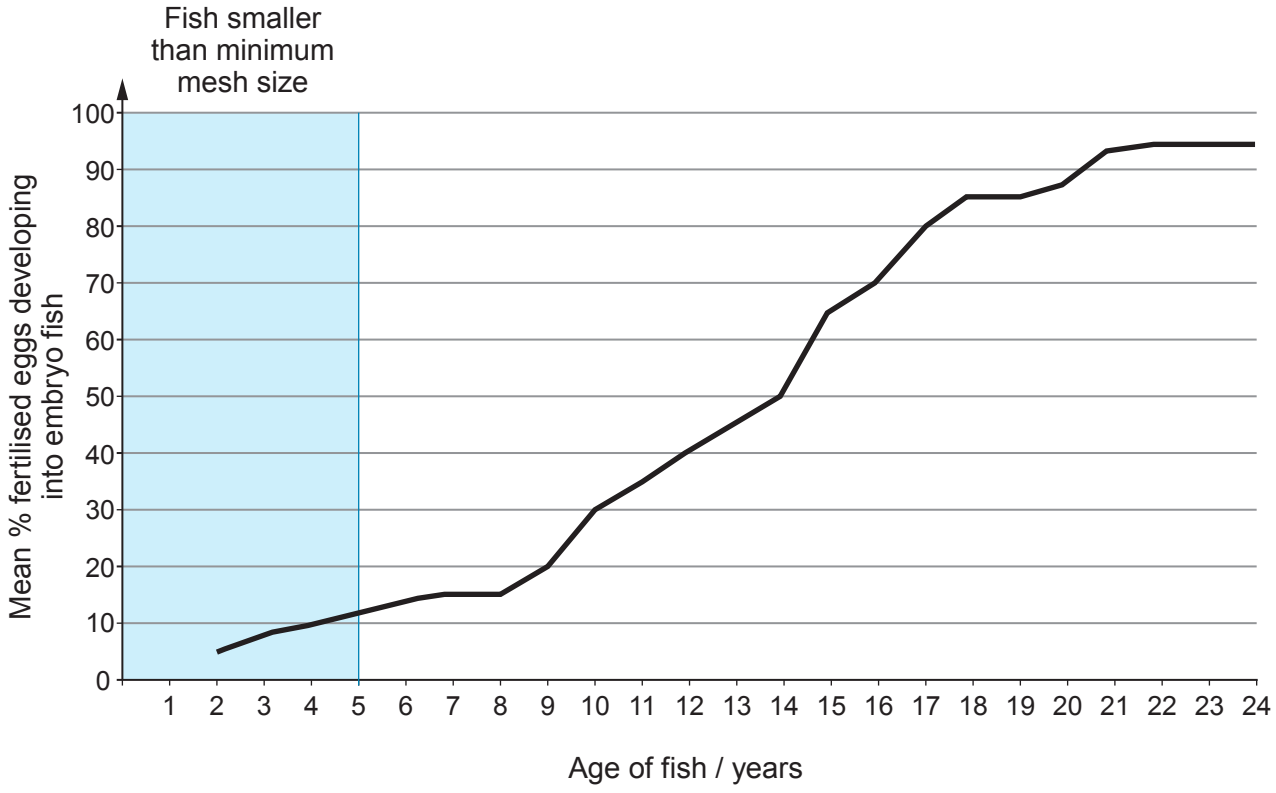
stemup.co.uk

(b) Cod continue to grow throughout their lives. The older the cod, the larger they will be. **Image 4.2** and **image 4.3** show how the age of cod affects the number of eggs released and the mean percentage of fertilised eggs developing into embryos.

Image 4.2



Image 4.3



© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

There is a minimum mesh size for the nets used for trawling for cod so that only larger fish are caught.

(i) Evaluate the effectiveness of using this minimum mesh size in allowing the recovery of the cod population. [4]

It would have very little effect. Fish under 5 years release under 4 million eggs and about 10% develop.

The bigger mesh still catches older fish, which produce far more eggs: a maximum of 12 million at 12 years.

Eggs from older fish are far more likely to develop into embryos (over 90% at 21 years).

(ii) Other than restricting the mesh size of nets, give **two** methods which are used to prevent overfishing. [1]

Fishing quotas (limiting the size of the catch) and seasonal restrictions (closed seasons).

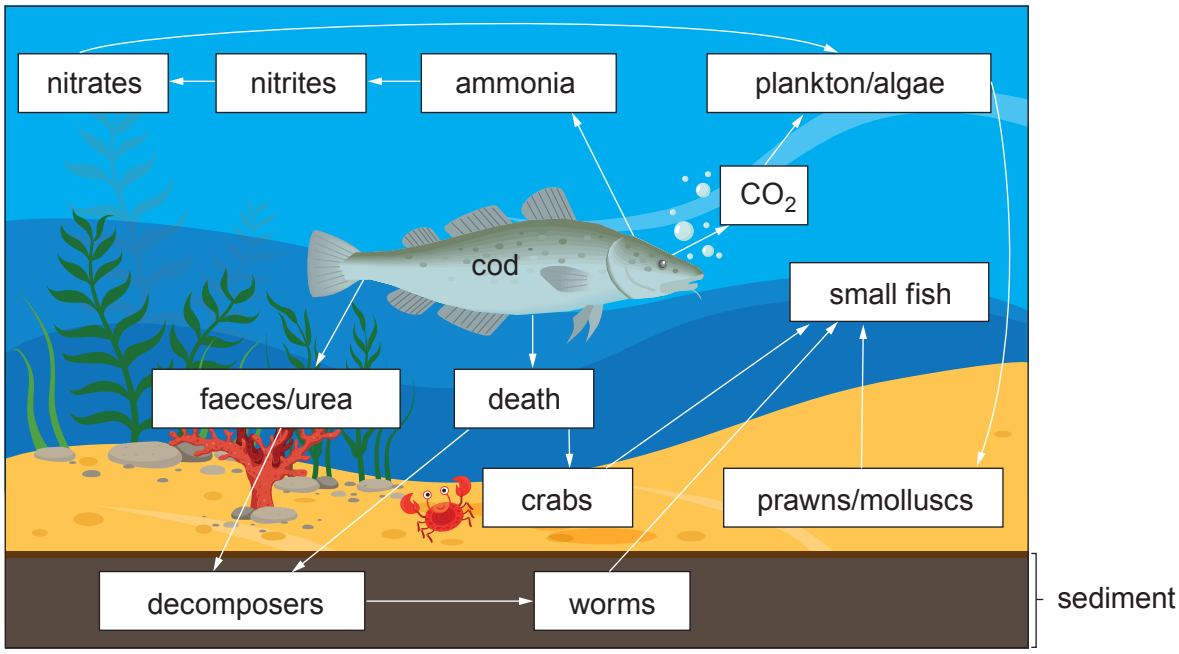
© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

As the wild cod numbers are decreasing, cod are now being farmed, which can have major impacts on their local ecosystems. **Image 4.4** below shows the relationship between the cod and its natural environment.

Image 4.4



(c) Use **image 4.4** and your knowledge of fish farming to conclude how fish farming can impact the ecosystem in the surrounding areas. [5]

Fish farming keeps many more cod in a restricted area, producing large amounts of faeces and urea.

Excretion increases levels of ammonia in the water, which decomposers convert to nitrites and then nitrates.

Nitrates (and CO_2) increase the rate of growth of algae and plankton, causing eutrophication (an algal bloom).

Respiration of the cod and of decomposers breaking down dead algae increases CO_2 levels, decreases pH and causes oxygen depletion.

Death, faeces and extra nutrients therefore change the numbers of organisms in the food chain, e.g. fewer small fish, crabs and prawns.

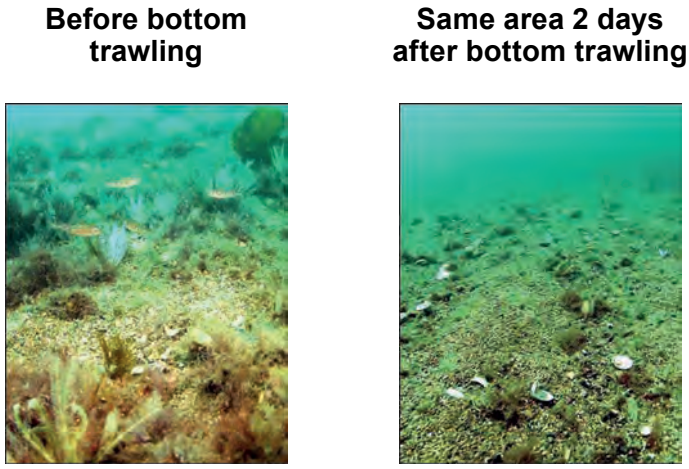
© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(d) Bottom trawling involves dragging very large weighted nets along the sea bed. The heavy equipment used in bottom trawling destroys the seabed, as shown in **image 4.5**.

Image 4.5



Following bottom trawling, organisms repopulate the area. Identify the type of succession that results in the repopulation **and** give **two** reasons for your answer. [3]

Secondary succession.

Sediment (organic matter) is still present, so pioneer species are not needed to form a substrate.

Larval stages, seeds and roots of organisms are still present in the sediment, so recolonisation is rapid.

(e) Planetary boundaries attempt to quantify and set a safe limit for the environmental impact of human activity. The boundary limit for CO_2 in the atmosphere was set at 350 ppm by volume, the current value is in excess of 400 ppm by volume.
State **and** explain **one** effect that increased CO_2 has had on the **marine** environment. [2]

Acidification: more CO_2 dissolves in sea water, forming carbonic acid, lowering the pH.

This dissolves calcium carbonate, so corals die and mollusc shells and crustacean exoskeletons are weakened.

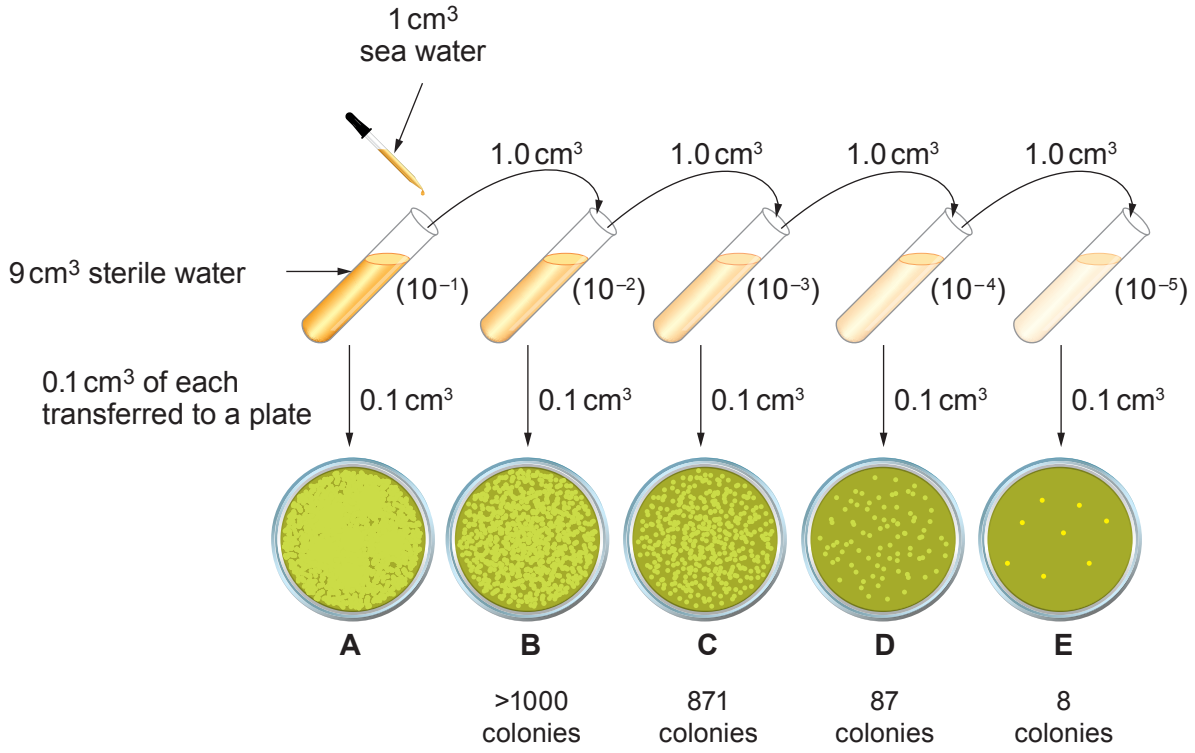
18

© WJEC CBAC Ltd.

Examiner only

5. The quality of bathing water at designated coastal resorts is monitored. The number of bacteria present is assessed by using serial dilutions of sea water, plating, incubating and counting the colonies as shown in **image 5.1**.

Image 5.1



(a) (i) Use the number of colonies on plate **D** to calculate how many bacteria there are in 1 cm³ of the original sample of water. [1]

$87 \times 10 \times 10^4 = 8\ 700\ 000$ per cm³

Number of colonies = 8.7×10^6

(ii) Explain why the number of colonies on plates **C** and **E** would not be used to calculate the number of bacteria. [2]

C too many colonies, so the colonies overlap (merge) and cannot be counted individually.

E too few colonies, so a small error in the count causes a large % error; the count is statistically unsound (unreliable).

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(b) Explain why it is essential that the plates are all cultured using exactly the same culture medium and incubation period. [2]

Different nutrients would affect the growth rate; different incubation periods would give different colony sizes or risk merging. Variation of these controlled variables would affect the DV.

(c) At the end of the investigation all plates were autoclaved. State **one** condition produced by the autoclave which results in the sterilisation of the plates. [1]

A temperature above boiling point (121 °C, under high pressure).

(d) Water quality can be determined by the number of human gut bacteria present. Suggest **two** suitable conditions for incubation in order to culture human gut bacteria. [2]

Incubate at 37 °C (body temperature).

Under anaerobic conditions.

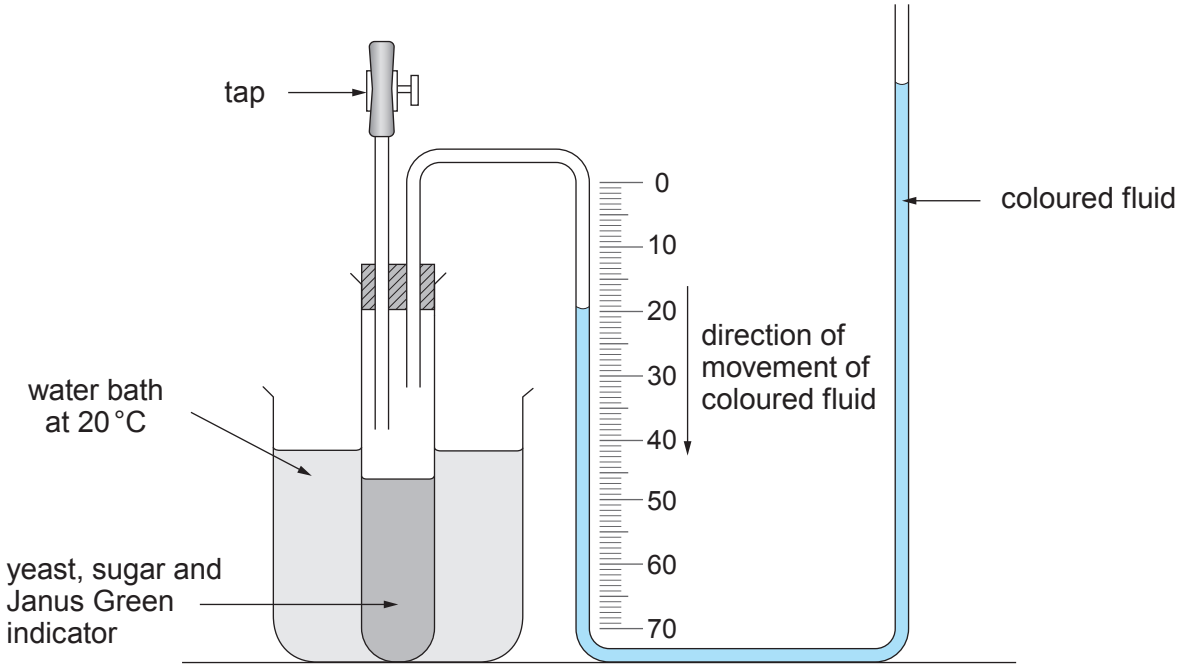
8

© WJEC CBAC Ltd.

stemup.co.uk

6. **Image 6.1** shows the apparatus which can be used to measure the production or absorption of gases during respiration. The apparatus relies on changes in pressure to move the coloured fluid along the tube.

Image 6.1



A student used this apparatus to compare the rate of **anaerobic** respiration in yeast using different sugars as the respiratory substrate.

Janus Green indicator is blue if oxygen is present and pink if no oxygen is present.

- Janus Green indicator is added to the yeast and sugar in a test tube as shown above.
- The apparatus is left with the tap open for 5 minutes.
- After this time the tap is closed.
- Once the solution turns pink, the time for the meniscus to move 10 mm is recorded.
- The time for the meniscus to travel 10 mm is repeated a further four times.
- All controlled variables are the same for each sugar and for each repeat.

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(a) Explain the following:

(i) The tap is open when the apparatus is assembled. [1]

To prevent the coloured fluid being pushed out of the tube by pressure changes during assembly.

(ii) The tap is not closed until 5 minutes after setting up. [1]

To allow the pressure inside the apparatus to equilibrate (and the apparatus to acclimatise to 20 °C).

(iii) No readings are taken before the Janus Green indicator changes to pink. [1]

To ensure all the oxygen is used up, so that only anaerobic respiration is taking place.

(b) Explain why you would expect the meniscus to move in the direction of the arrow. [2]

In anaerobic respiration the yeast releases CO_2 but uses no oxygen, so CO_2 levels (gas volume) go up.

The pressure in the apparatus goes up, which pushes the coloured fluid down.

(c) Suggest a suitable control experiment **and** explain why a control is necessary. [3]

Repeat with boiled and cooled (dead) yeast, with the same sugar and Janus Green.

Keep all other conditions the same (volumes, sugar concentration, 20 °C).

A control is required to show that the movement is caused by the yeast (respiration) and by no other factor.

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(d) (i) The results when glucose was used as the substrate are shown in the table below. Use the table and formula to calculate the standard deviation for the glucose results. [3]

Time for meniscus to travel 10 mm /seconds	Deviation from mean $x - \bar{x}$	Deviation from mean squared $(x - \bar{x})^2$
254	2	4
246	−6	36
255	3	9
253	1	1
252	0	0
Mean = 252		$\sum(x - \bar{x})^2$ = 50

The formula for standard deviation is:

$$\sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$$ = √(50 ÷ 4) = √12.5 = 3.536

where

x = individual result $\bar{x}$ = mean result

n = number of trials $\sum$ = sum of

Standard deviation = 3.54

(ii) **Complete the following table** which shows the results of the experiment for all three sugars. [3]

Sugar	Time for meniscus to move 10 mm / s						
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Mean	Standard deviation
glucose	254	246	255	253	252	252	3.5
fructose	170	208	214	265	270	225	42.0
sucrose	370	376	388	379	390	381	8.4

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

(iii) State what standard deviation indicates about data **and** comment on the values for the three sugars in this experiment. [3]

Standard deviation indicates the spread (deviation) of the results from the mean.

A smaller SD means more reliable results: glucose (3.5) is the most reliable and fructose (42.0) the least.

Glucose and fructose are not significantly different as their mean ± SD ranges overlap; sucrose is significantly different from the other two.

(e) Explain why the respiratory rate is much slower when yeast uses sucrose as the respiratory substrate. [2]

Sucrose is a disaccharide, so it must first be broken down (hydrolysed) into glucose and fructose before it can be respired.

This extra step slows the rate.

(f) Predict what would happen to the position of the meniscus if the yeast was only carrying out **aerobic** respiration. Explain your answer. [2]

The meniscus would not move.

Equal volumes of CO_2 are produced as oxygen is used (RQ = 1), so there is no net change in volume or pressure.

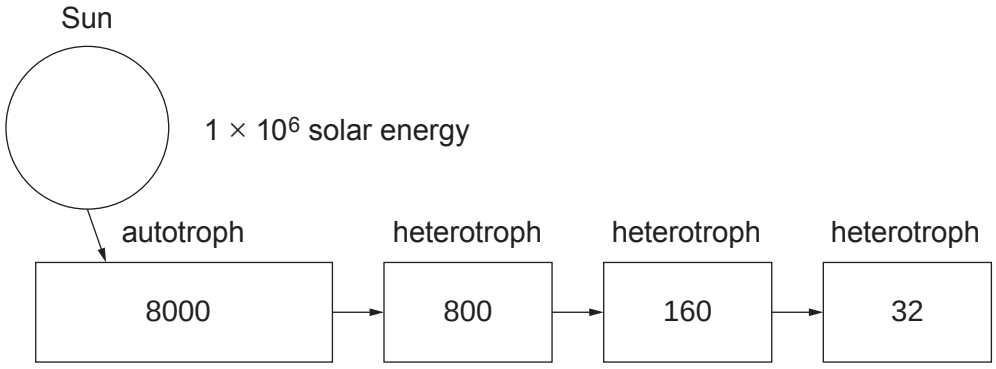
21

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

7. The diagram below shows the flow of energy through an ecosystem.



Figures represent $kJ\,m^{-2}\,yr^{-1}$

Using the diagram, explain what is meant by the flow of energy through an ecosystem and why energy is lost at each stage.

Explain why the efficiency of transfer might change at each stage.

Suggest ways by which farmers can improve the efficiency of the transfer between each level.

[9 QER]

Energy flow is the transfer of energy from the Sun through the trophic levels of an ecosystem. Of the 1×10^6 kJ m^{-2} yr^{-1} of solar energy, only 8000 kJ m^{-2} yr^{-1} (0.8%) is converted by the autotrophs into chemical energy in organic molecules by photosynthesis (GPP).

Most solar energy is lost by plants because it is reflected, passes through the leaf, is the wrong wavelength to be absorbed by chlorophyll or is used as heat of evaporation. Plants also break down sugars in respiration, releasing heat; what remains (NPP) is stored in their tissues.

Energy in organic molecules is passed from one trophic level to the next through the food chain when organisms are eaten: 800 reaches the primary consumers (10%), 160 the secondary consumers (20%) and 32 the tertiary consumers (20%).

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

At each stage energy is lost from animals because not all of the organism is eaten, energy is lost in egestion (faeces) and excretion (urea), and much is released as heat in respiration. Only the energy left in organic molecules that is stored or used for growth is available to the next trophic level.

The efficiency of transfer changes at each stage. From autotroph to herbivore it is low (10%) because cellulose and lignin are not easy to digest, so there is a large loss by egestion. Between carnivores it is higher (20%) because protein and fat are easily digested, so very little energy is lost by egestion, although energy is lost by excretion of urea and in uneaten bone and feathers.

Animals with a high respiratory rate, using energy for movement and to keep warm, lose more energy as heat.

Farmers can improve efficiency by growing varieties of crops with a higher GPP and by breeding animals with a higher conversion efficiency. They can give animal feeds with less cellulose and high energy (protein) supplements.

Reducing movement and keeping animals in warm buildings reduces respiration, so more energy goes into growth. Keeping animals disease free (vaccination) means less energy is wasted, so more biomass is available to the next level, including humans.

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

© WJEC CBAC Ltd.

stemup.co.uk

Examiner only

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

9

END OF PAPER

© WJEC CBAC Ltd.

stemup.co.uk

Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

Examiner only

© WJEC CBAC Ltd.

stemup.co.uk