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Centre number

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Surname

StemUp Model Solution

Forename(s)

Candidate signature

I declare this is my own work.

A-level BIOLOGY

Paper 3

Monday 15 June 2020

Morning

Time allowed: 2 hours

Materials

For this paper you must have:

- a ruler with millimetre measurements
- a scientific calculator.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions in **Section A**.
- Answer **one** question from **Section B**.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Show all your working.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for the questions are shown in brackets.
- The maximum mark for this paper is 78.

For Examiner's Use

Question	Mark
1	
2	
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6	
7	
TOTAL	



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Section A

Answer **all** questions in this section.

You are advised to spend no more than 1 hour and 15 minutes on this section.

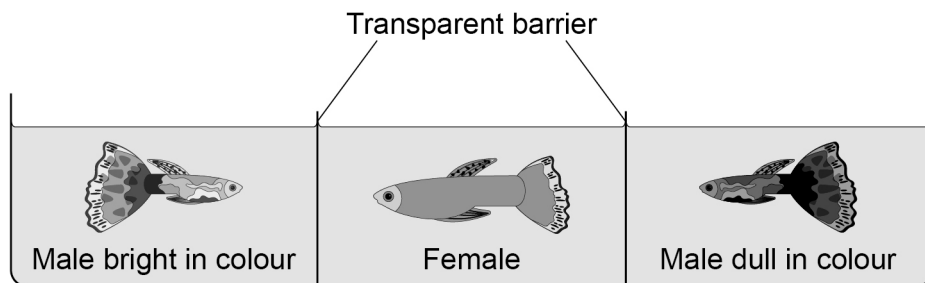
0 1

Guppies are small fish. Female guppies are dull in colour. Male guppies can be bright or dull in colour.

Scientists investigated the effect of female brain size on choosing a mate. They used laboratory-bred female guppies with large brains and with small brains.

They set up a fish tank as shown in **Figure 1**.

Figure 1



They observed each female for 10 minutes and recorded which male they were attracted towards. They repeated this with 45 large-brained females and 45 small-brained females.

0 1 . 1

Suggest **three** possible limitations of this investigation.

[3 marks]

- 1 *The females were bred in a laboratory, so they might not choose a mate in the same way as wild female guppies (not representative).*
- 2 *The transparent barrier might not allow normal courtship behaviour or interaction; choice may also involve chemical signals, not just colour.*
- 3 *10 minutes might not be long enough for each female to make a final choice. Also we do not know if the guppies were used in previous experiments.*



Guppies with large brains are better at identifying predators.

The scientists found that **only** female guppies with large brains were attracted to male guppies bright in colour.

0 1 . 2

Suggest and explain the advantage of this behaviour to the population of guppies.

[3 marks]

Large-brained females will mate with males that are bright in colour, so their male offspring are more likely to be bright in colour (inherit the alleles for bright colour).

These bright offspring will in turn attract large-brained females, so over generations the population could evolve to have larger brains.

So more of the population will be better at identifying and avoiding predators, so more survive and reproduce.

0 1 . 3

Describe how the behaviour of female guppies could result in sympatric speciation.

[3 marks]

The two groups of guppies are not geographically isolated: they live in the same area.

Large-brained females only mate with bright males and small-brained females only mate with dull males, so the groups become reproductively isolated and their gene pools are kept separate.

Mutations, different selection pressures and genetic drift cause changes in allele frequencies in each group, until eventually they cannot interbreed to produce fertile offspring, so they are separate species.



0 2

In northern India, there is a conflict of interests between farmers of livestock (eg cows) and people trying to conserve ibex (a type of wild goat).

When livestock are given extra food, their populations can grow too large and compete with ibex.

0 2 . 1

Name the type of competition between livestock and ibex.

[1 mark]

Interspecific competition

Livestock will outcompete ibex if they:

- are in the same habitat
- eat a similar diet.

Scientists investigated this conflict of interests.

Table 1 summarises some of the scientists' findings.

Table 1

Type of livestock	Difference between livestock food and ibex food*	Difference between livestock habitat and ibex habitat*
Cow	1.0	1.5
Horse	0.5	0.0
Yak	0.0	2.0

* A score of 0.0 indicates that the food or habitat is the same.



0 2 . 2

There must be a balance between the need for conservation of the ibex and the need for farmers to keep livestock.

Using **all** the information, suggest and explain **three** actions that the farmers could take to achieve this balance.

[3 marks]

- 1 *Do not give the livestock extra food (or keep only small numbers of livestock), so their populations do not grow large enough to compete with the ibex.*
- 2 *Do not farm horses, as horses have the same habitat (0.0) and very similar food (0.5) to the ibex; farm cows instead, as they have the least similar food and a different habitat.*
- 3 *If horses are kept, keep them in fenced, enclosed areas separate from the ibex. Yaks could also be farmed, as despite eating the same food they live in a very different habitat (2.0).*

4

Turn over for the next question

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0 3

In Europe, viruses have infected a large number of frogs of different species. The viruses are closely related and all belong to the Ranavirus group.

Previously, the viruses infected only one species of frog.

0 3 . 1

Suggest and explain how the viruses became able to infect other species of frog.

[2 marks]

A mutation occurred in the viral DNA (genome), which changed the base sequence and so the tertiary structure of the viral attachment protein (antigen).

The altered attachment protein became complementary to, and could bind to, receptors on the cells of other frog species.

0 3 . 2

Name **two** techniques the scientists may have used when analysing viral DNA to determine that the viruses were closely related.

[1 mark]

- 1 *DNA (genome) sequencing, comparing the base sequences*
- 2 *Polymerase chain reaction (PCR) and gel electrophoresis*

0 3 . 3

Determining the genome of the viruses could allow scientists to develop a vaccine.

Explain how.

[2 marks]

From the genome, scientists could identify the proteins that the viral genes code for (the proteome).

They could then identify potential antigens, such as the attachment proteins on the virus surface, to use in the vaccine.



0 3 . 4

Describe how the B lymphocytes of a frog would respond to vaccination against Ranavirus.

You can assume that the B lymphocytes of a frog respond in the same way as B lymphocytes of a human.

Do **not** include details of the cellular response in your answer.

[3 marks]

A B cell with a specific, complementary receptor (antibody) on its surface binds to the viral antigen in the vaccine.

This B cell is stimulated to divide by mitosis to form a clone of identical B cells (clonal selection and expansion).

Some of the clones become plasma cells, which produce and release monoclonal antibodies against the virus.

Others become memory cells, which remain in the blood and give a faster, larger secondary response if the frog is infected.

8

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0 4

Table 2 shows information about two types of medicine.

Table 2

Name of medicine	Mass of medicine in one tablet / mg	Maximum dose of medicine an adult is allowed	Mass of sodium in one tablet / g
Aspirin	300	0.6 g every 4 hours	0.15
Paracetamol	500	1.0 g every 6 hours	0.43

0 4 . 1

A journalist studied the data in **Table 2**. She made the following suggestion.

‘If an adult takes the maximum number of tablets allowed for **either** of the medicines, then the person would have more than the RDA of sodium.’

The RDA (recommended daily allowance) of sodium for an adult human is 2.4 g per day.

Is the journalist’s statement true for **both** of the medicines in **Table 2**?

Use suitable calculations to support your answer.

Show your working.

[2 marks]

Aspirin: 0.6 g = 2 tablets every 4 hours, so 6 doses = 12 tablets per day

12 × 0.15 g = 1.8 g of sodium, which is less than 2.4 g

Paracetamol: 1.0 g = 2 tablets every 6 hours, so 4 doses = 8 tablets per day

8 × 0.43 g = 3.44 g of sodium, which is more than 2.4 g

No. It is true for paracetamol (3.44 g, which is 1.04 g more than the RDA) but not for aspirin (1.8 g, which is 0.6 g less than the RDA).



Doctors investigated the link between high sodium concentrations in medicines and hypertension (high blood pressure).

They analysed medical records of patients. 1 292 337 of these patients had taken medicines containing high sodium concentrations. Each of these patients was paired with a patient from a control group.

0 4 . 2

Give **two** factors that should have been the same for each pair of patients and **one** factor that should have been different.

[2 marks]

Same factor 1 Age and sex

Same factor 2 BMI and other previous medications

Different factor Control has no sodium in the (same) medicine

0 4 . 3

Doctors found:

- 4.73% of the patients who had taken medicines containing high sodium concentrations suffered from hypertension
- there were 7.18 times fewer control patients with hypertension.

Calculate how many of the control patients had hypertension.

Show your working.

[2 marks]

Patients with hypertension: $1\,292\,337 \times 0.0473 = 61\,127.54$

Control patients: $61\,127.54 \div 7.18 = 8513.6$

Answer 8514 patients

Question 4 continues on the next page

Turn over ►



0 4 . 4

A high concentration of sodium in the blood can affect blood volume and cause hypertension.

Use your knowledge of water potential to suggest how high sodium concentrations in the medicines taken could affect blood volume.

[3 marks]

The sodium ions from the medicines are absorbed into the blood, which lowers (makes more negative) the water potential of the blood.

So water moves into the blood by osmosis from the cells and tissue fluid, down a water potential gradient (and more water is reabsorbed by the kidneys).

This increases the blood volume, which raises blood pressure.

9



0 5 . 1

In the UK in 2016, there were 525 048 deaths. Cancer caused 30.4% of all deaths. Throat cancer caused 5% of all deaths from cancer.

Calculate the mean number of people who died of throat cancer per month in 2016.

Show your working.

[2 marks]

$$\text{Cancer deaths: } 525\,048 \times 0.304 = 159\,614.6$$

$$\text{Throat cancer deaths: } 159\,614.6 \times 0.05 = 7980.7 \text{ per year}$$

$$\text{Per month: } 7980.7 \div 12 = 665.06$$

Answer 665 people per month

Increased methylation of the promoter region of a tumour suppressor gene causes one type of human throat cancer.

In this type of throat cancer, cancer cells are able to pass on the increased methylation to daughter cells. The methylation is caused by an enzyme called DNMT.

Scientists have found that a chemical in green tea, called EGCG, is a competitive inhibitor of DNMT. EGCG enables daughter cells to produce messenger RNA (mRNA) from the tumour suppressor gene.

0 5 . 2

Suggest how EGCG allows the production of mRNA in daughter cells.

[3 marks]

EGCG is a similar shape to the substrate, so it binds to the active site of DNMT, so DNMT cannot methylate the promoter region of the tumour suppressor gene in the daughter cells.

With less methylation, transcription factors can bind to the promoter region and stimulate RNA polymerase, so the tumour suppressor gene is transcribed into mRNA.

Question 5 continues on the next page

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The scientists investigated the effect of different amounts of EGCG on the growth rate of the throat cancer cells grown *in vitro*. Their results are shown in **Figure 2**.

Figure 2

This figure has been removed due to third-party copyright restrictions.

0 5 . 3

A reporter who reviewed all of this work concluded that drinking green tea could be a cure for cancer.

Suggest **three** reasons why his conclusion might **not** be valid.

[3 marks]

1 *It was only investigated in throat cancer cells, so it might not work for other types of cancer; also not all cancers are caused by increased methylation.*

2 *The cells were grown in vitro, so cells in the body might respond differently. Also we do not know how much EGCG is in green tea.*

3 *EGCG only reduced the growth rate of the cancer cells (significantly only at the higher concentrations), so there is no evidence of cancer being cured.*

8



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0 6 . 1

Describe the advantage of the Bohr effect during intense exercise.

[2 marks]

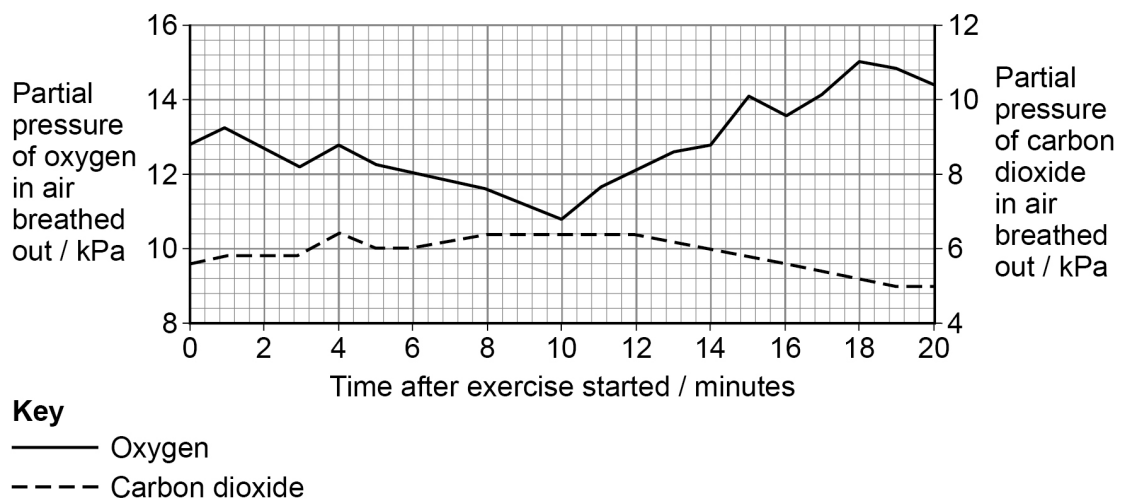
During intense exercise more CO_2 is produced, which lowers the pH and decreases the affinity of haemoglobin for oxygen, so more oxygen dissociates (is unloaded) at the muscles.

This provides more oxygen for aerobic respiration in the muscles, so anaerobic respiration is delayed and less lactate is produced.

A cyclist completed a fitness test on an exercise bike. The intensity of the exercise was increased every 10 seconds. The test finished when he was unable to cycle any further. The partial pressure of oxygen (pO_2) and of carbon dioxide (pCO_2) in air breathed out was measured.

Figure 3 shows the results of the cyclist's fitness test.

Figure 3



Ventilatory threshold (VT) is a measure of the point when anaerobic respiration increases because aerobic respiration alone can no longer maintain muscle contraction.



0 6 . 2

VT can be identified as the **first** point when there is an increase in pO_2 breathed out, without an equivalent increase in pCO_2 breathed out.

Use **Figure 3** to determine the **time** after the exercise started when the cyclist reached VT.

Calculate the **ratio** of pO_2 to pCO_2 in breathed-out air at this time.

Show your working.

[2 marks]

At 10 minutes: $pO_2 = 10.8 \text{ kPa}$, $pCO_2 = 6.4 \text{ kPa}$

Ratio = $10.8 \div 6.4 = 1.6875$

Time when the cyclist reached VT = 10 min

Ratio of pO_2 to pCO_2 at VT = 1.69:1

0 6 . 3

An increase in the intensity of exercise produces an increase in the volume of carbon dioxide produced.

However, **Figure 3** shows that the pCO_2 in air breathed out did **not** show a large increase during the exercise.

Suggest **one** physiological change that would cause this result. Explain how the physiological change would allow for the removal of the increase in the volume of carbon dioxide produced.

[2 marks]

Physiological change Increase in breathing rate (more breaths per minute)

Explanation Each breath has a similar pCO_2 , but there are more breaths per minute, so a larger total volume of carbon dioxide is breathed out (removed) each minute.

Question 6 continues on the next page

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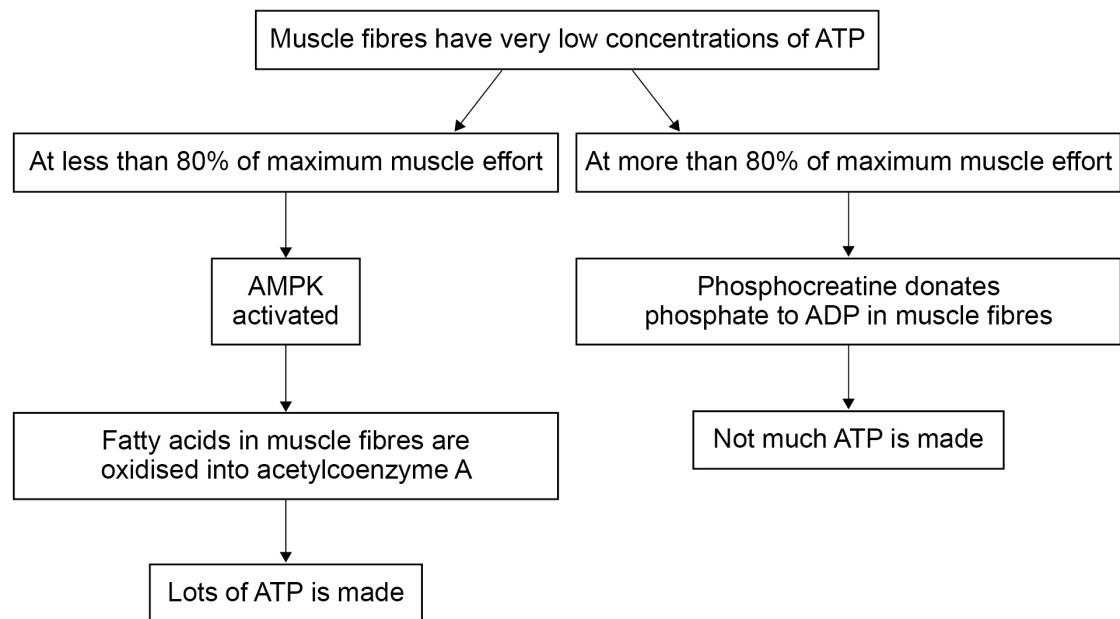


When muscle fibres have very low concentrations of ATP, they may get ATP in the following ways.

- AMPK (an enzyme) oxidises fatty acids.
- Phosphocreatine donates phosphate to ADP in anaerobic conditions.

Figure 4 shows how these chemicals work.

Figure 4



0 6 . 4

At more than 80% of maximum muscle effort, ATP can only be made for a limited time.

Use **Figure 4** to suggest **one** reason why.

Tick (✓) the correct box.

[1 mark]

ATP cannot move into muscle fibres at a fast-enough rate.

☐

Muscle fibres have a limited amount of phosphocreatine.

☒

Muscle fibres produce too much lactate.

☐

Muscle fibres quickly run out of ADP.

☐


0 6 . 5

GW1516 is a performance-enhancing drug. GW1516 activates AMPK **and** develops slow muscle fibres at rest.

Use **Figure 4** to justify why professional athletes are **not** allowed to take GW1516.

Do **not** include details of chemiosmotic theory in your answer.

[4 marks]

GW1516 activates AMPK, so more fatty acids are oxidised into acetylcoenzyme A even when the athlete is at rest.

More acetylcoenzyme A would enter the Krebs cycle, so the Krebs cycle generates more reduced coenzymes (reduced NAD and reduced FAD).

So more reduced coenzymes pass their electrons to the electron transfer chain, so more ATP is produced by oxidative phosphorylation.

Because GW1516 develops slow muscle fibres at rest, athletes could build slow muscle fibres without exercising or training.

Having more slow muscle fibres and more ATP from aerobic respiration would increase endurance, delaying the onset of anaerobic respiration and fatigue.

This gives an unfair advantage over athletes who do not take the drug, so it is banned.

Question 6 continues on the next page

Turn over ►



EPO is another performance-enhancing drug. It can increase the haematocrit (the percentage of red blood cells in blood).

0 6 . 6

A heart attack is caused by a lack of glucose and oxygen being delivered to cardiac muscle via the coronary arteries. The overuse of EPO can increase the risk of a heart attack.

Suggest how.

[2 marks]

EPO increases the haematocrit, so the blood becomes thicker (more viscous).

The thickened blood flows more slowly and could cause clots (a thrombus) that block the coronary arteries, so less glucose and oxygen reach the cardiac muscle.

0 6 . 7

The normal haematocrit for human males is $47(\pm 5)\%$. For professional male cyclists, the maximum haematocrit allowed is 50%.

A student suggested that professional male cyclists should be allowed to use EPO until their haematocrit is 50%.

Give **two** reasons why this suggestion is **not** valid.

[2 marks]

1 *Some cyclists would gain a bigger advantage than others, e.g. a cyclist at 42% could gain an 8% increase but one naturally at 50% would gain nothing.*

2 *There are health risks of taking EPO, such as increased risk of blood clots, strokes and heart attacks.*

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Section BAnswer **one** question.

You are advised to spend no more than 45 minutes on this section.

0 7Write an essay on **one** of the topics below.**Either****0 7 . 1**

The functions of enzymes and their importance in organisms.

[25 marks]**or****0 7 . 2**

The causes and importance of variation and diversity in organisms.

[25 marks]*07.2 The causes and importance of variation and diversity in organisms*

Variation is the differences between individuals of the same species, and diversity is the range of different alleles, species and habitats. Variation is caused by both genetic and environmental factors, and it is important because it is the raw material on which natural selection acts, allowing populations to adapt, survive and evolve into new species.

The ultimate cause of all genetic variation is mutation. A gene mutation is a change in the base sequence of DNA, for example a substitution, addition or deletion of a base, which often happens randomly during DNA replication. The rate of mutation is increased by mutagenic agents such as ionising radiation and some chemicals. Because the genetic code is degenerate, some substitutions code for the same amino acid and have no effect, but others change the primary structure of a polypeptide. This changes the position of hydrogen, ionic and disulfide bonds, so the tertiary structure of the protein changes. If the protein is an enzyme, the active site may no longer be complementary to its substrate.

Turn over ►

Deletions and additions cause a frame shift, changing every codon after the mutation. In this way, mutation creates new alleles. Chromosome mutations, such as non-disjunction in meiosis, change the number of chromosomes, as in Down's syndrome. Most mutations are harmful or neutral, but a few are beneficial, and these are important because they give individuals an advantage in a changing environment.

Meiosis and fertilisation shuffle existing alleles into new combinations. In prophase I, homologous chromosomes pair up and crossing over occurs at chiasmata, exchanging sections of chromatids and producing new combinations of alleles on each chromosome. In metaphase I, independent segregation means the homologous pairs line up randomly, so with 23 pairs in humans there are 2^{23} possible combinations of chromosomes in the gametes. Random fertilisation of any one gamete by any other then multiplies this variation. This is why sexual reproduction produces genetically different offspring, even from the same parents, which is important because a population with high genetic diversity is less likely to be wiped out by a single disease or change in climate.

Variation is also caused by the environment and by changes in gene expression. Many characteristics, such as height, are controlled by many genes (polygenes) and are also affected by environmental factors such as diet, so they show continuous variation and a normal distribution.

Epigenetic changes, such as increased methylation of DNA or decreased acetylation of histones, prevent transcription factors binding and switch genes off without changing the base sequence. This allows cells with identical DNA to differentiate into different cell types, giving variation between cells within one organism, but it can also cause disease: increased methylation of tumour suppressor genes can lead to



uncontrolled cell division and cancer.

The most important consequence of variation is natural selection. Within a population there is variation caused by different alleles. When there is a selection pressure, such as predation, disease or competition, individuals with advantageous alleles are more likely to survive and reproduce, and pass these alleles on to their offspring. Over many generations the allele frequency in the gene pool changes. For example, antibiotic resistance in bacteria arises by random mutation, perhaps in a gene coding for an enzyme that breaks down penicillin. When antibiotics are used, resistant bacteria survive and reproduce, so the frequency of the resistance allele increases. This can be directional selection, as here, or stabilising selection, as in human birth mass, where babies of average mass are most likely to survive. Without genetic variation, natural selection could not happen and populations could not adapt.

Variation within populations can also lead to speciation, which creates diversity. When a population is split by geographical isolation, such as a river or mountain range, the two groups experience different mutations and different selection pressures, and genetic drift also changes their allele frequencies, especially in small populations. Eventually the groups become so different that they can no longer interbreed to produce fertile offspring, so they are separate species (allopatric speciation). Speciation can also occur within the same area when, for example, a mutation changes courtship behaviour so that groups become reproductively isolated (sympatric speciation). Courtship behaviour is itself important because it allows individuals to recognise members of their own species and choose a mate that is fertile.

Variation in pathogens is very important in disease and disease

Turn over ►



prevention. The influenza virus has a high mutation rate, so its antigens change shape frequently (antigenic variability). The memory cells produced after a previous infection or vaccination have receptors that are no longer complementary to the new antigens, so the secondary immune response does not happen and the person can catch flu again. This is why a new flu vaccine has to be developed every year, and why it has been difficult to produce a vaccine against HIV, whose antigens also change rapidly.

Diversity at the level of species and communities is also important.

Species richness is the number of different species in a community, and an index of diversity also takes into account the number of individuals of each species, using $d = N(N - 1)$ divided by the sum of $n(n - 1)$. A community with high biodiversity is more stable, because there are more interactions and food webs are more complex, so if one species declines, its predators can feed on other species. Farming reduces biodiversity, for example by removing hedgerows, growing monocultures and using pesticides, so conservation measures such as leaving field margins are needed to balance food production with maintaining diversity. Genetic diversity within and between species can now be measured directly by comparing DNA base sequences, the amino acid sequences of proteins, or by genetic fingerprinting of variable number tandem repeats, which is used to assess the genetic diversity of endangered species in captive breeding programmes so that inbreeding can be avoided.

Beyond the specification, the long-term evolution experiment set up by Richard Lenski in 1988 shows how mutation and selection create new variation. Twelve populations of *E. coli* were grown from a single ancestor in a medium containing glucose and citrate. After more than 30 000



generations, one population evolved the ability to use citrate as a respiratory substrate in aerobic conditions, which *E. coli* normally cannot do. This depended on earlier, neutral mutations followed by a mutation that duplicated a gene for a citrate transport protein and placed it next to a promoter that is active in aerobic conditions. The new variant had a huge selective advantage, and its frequency rapidly increased in the population. This shows that variation arises by chance, but that it is natural selection which determines its importance.

In conclusion, variation is caused by mutation, by meiosis and random fertilisation, and by the environment and epigenetic changes. It is important because it allows natural selection, adaptation and the evolution of new species, which together produce the diversity of life that makes communities stable. It also explains why pathogens such as influenza are so difficult to control, and why maintaining genetic diversity is essential for the survival of species in a changing world.

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25



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