Unit 3—Sustainability and Interdependence

Key Area 1 :   Food supply, plant growth and productivity

(a) Food Supply

Food security is the ability of human populations to **access** food of sufficient **quality** and **quantity**.

Increase in human population and concern for food security leads to a demand for increased food production.

Food production must be **sustainable** and must not have a negative impact on the ecosystem and natural resources.

More food needs to be produced for the same area of land so increased plant productivity and genetic diversity will be required in order to maintain a sustainable food supply.

Plant growth

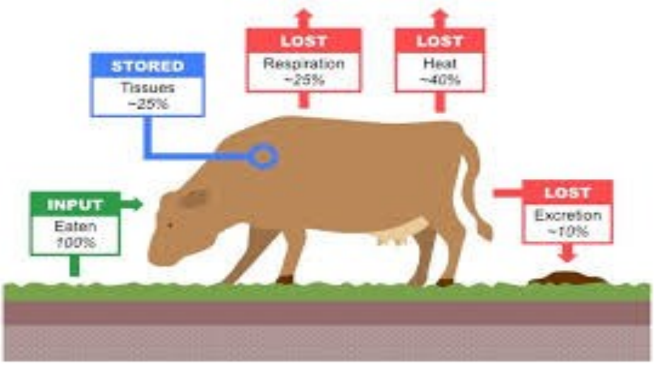
Agricultural production depends on factors that control **photosynthesis** such as;

- light intensity
- carbon dioxide concentration
- chlorophyll concentration
- availability of water
- temperature.

The area to grow plants is limited and so increased food production will depend on factors that control plant growth such as ;

- Breeding of higher yielding cultivars (*cultivated varieties*)
- Use of fertiliser
- Protecting crops from pests, diseases and competition.

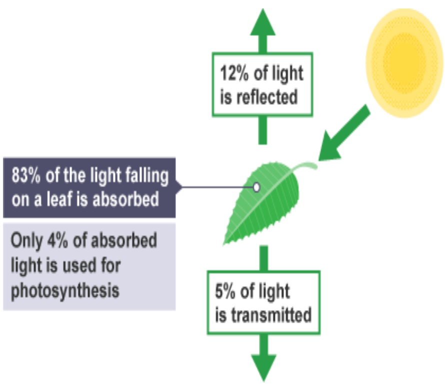
Livestock produce less food per unit area than crop plants due to **loss of energy at trophic levels**.



Livestock production is often suitable in areas unsuitable for growing crops .

(b) Photosynthesis

Photosynthesis is the process by which green plants trap light energy to make carbohydrates.



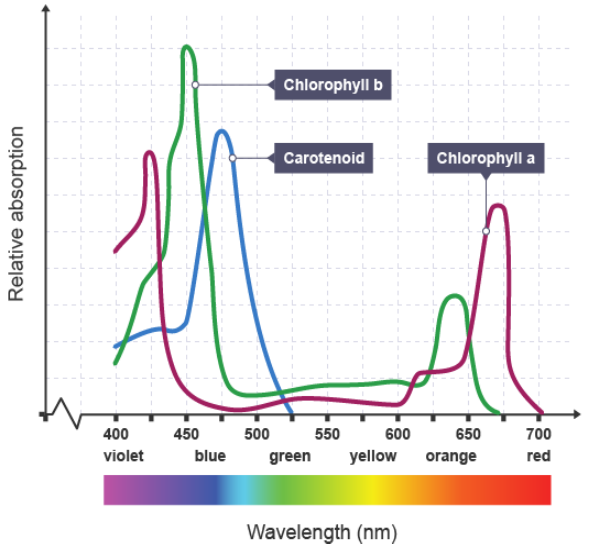
Light hitting the leaf of a plant can be;

- Absorbed
- Transmitted
- Reflected

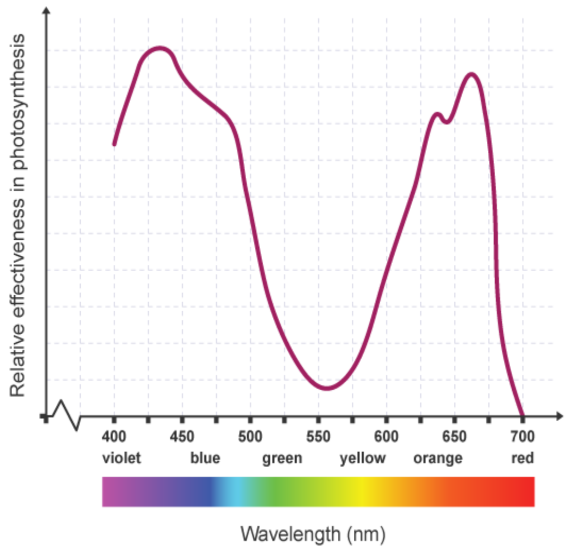
Light energy is absorbed by photosynthetic pigments to generate ATP for photolysis.

Each pigment absorbs a different range of wavelengths of light.

- **Chlorophyll**—absorbs mainly in the **red** and **blue** regions of the spectrum .
- **Caretenoids** are accessory pigments that **extend the range of wavelengths absorbed** and pass the energy to chlorophyll for photosynthesis.



The absorption spectra shows the wavelengths of light absorbed by different pigments in a leaf.

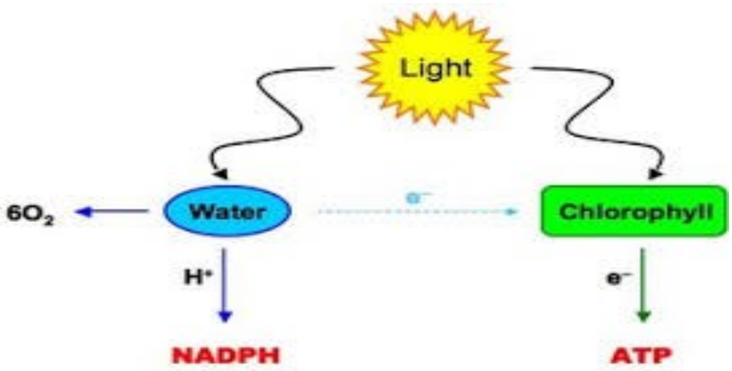


The action spectra shows how effective the different wavelengths of light are for photosynthesis.

The action spectra shows that even when absorbance is relatively low there are still relatively high levels of photosynthesis as the carotenoids are extending the range of wavelengths absorbed and passing the energy to chlorophyll.

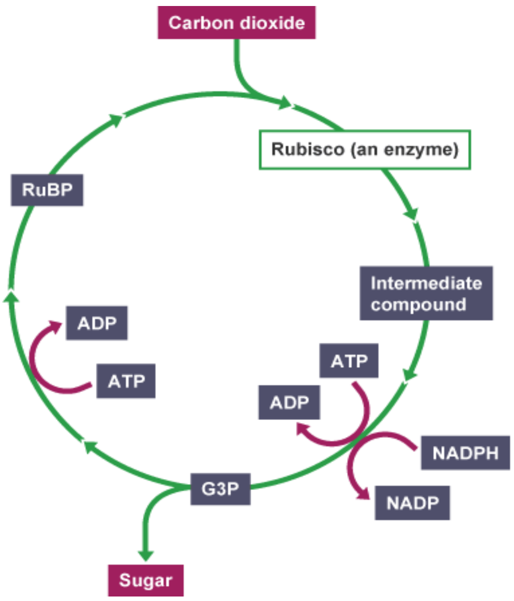
Stages of Photoynthesis

- Absorbed light energy **excites electrons** in the pigment molecule.
- Transfer of these electrons through the **electron transport chain** releases energy to **generate ATP by ATP synthase**.
- Energy is also used for ***photolysis***, in which **water is split** into oxygen, which is evolved, and hydrogen, which is transferred to the coenzyme NADP.



Carbon Fixation

- The enzyme **RuBisCo fixes carbon dioxide** by attaching it to **RuBP** and **3PG** is produced.
- The **3PG is phosphorylated by ATP** and combined with hydrogen from NADPH to form **G3P.**
- **G3P** is used to **regenerate RuBP** and for the **synthesis of glucose**.



<u>Fate of Glucose</u>

The glucose produced in photosynthesis can be used as;

- A substrate for respiration
- Stored as Starch
- Synthesised to Cellulose for cell walls.
- Passed to other biosynthetic pathways to form a variety of substances such as DNA, protein and fat.

Key Area 3—Crop Protection

Weeds compete with crop plants, while other **pests** and diseases **damage** crop plants, all of which reduce the crop yield or productivity.

Weeds

Weeds compete with crop plants for resources such as light, nutrients, water and space and by doing so reduce the growth of the crop and thus productivity.

Type of Weed	Properties
Annual	Rapid growth, short lifecycle, high seed output and long term seed viability
Perennial	Storage organs and vegetative (asxual) reproduction.

Pests

Most of the pests of crop plants are invertebrate animals such as **insects**, **nematode worms** and **molluscs**.

Diseases

Plant disease can be caused by fungi, bacteria or viruses, which are often carried by invertebrates.

Crop Protection

Cultural methods can be used to control weeds, other pests and diseases eg.

- Ploughing
- Weeding
- Crop Protection

Using pesticides

Pesticides can be used to control weeds, pests and diseases.

- **Herbicides** are used to control **weeds**.
- **Fungicides** to control **fungal** diseases.
- I**nsecticides** to kill pest **insects**.
- **Molluscicide** to kill mollusc **pests**.
- **Nematicides** to kill nematode **pests**.

Pesticides can be selective or systemic.

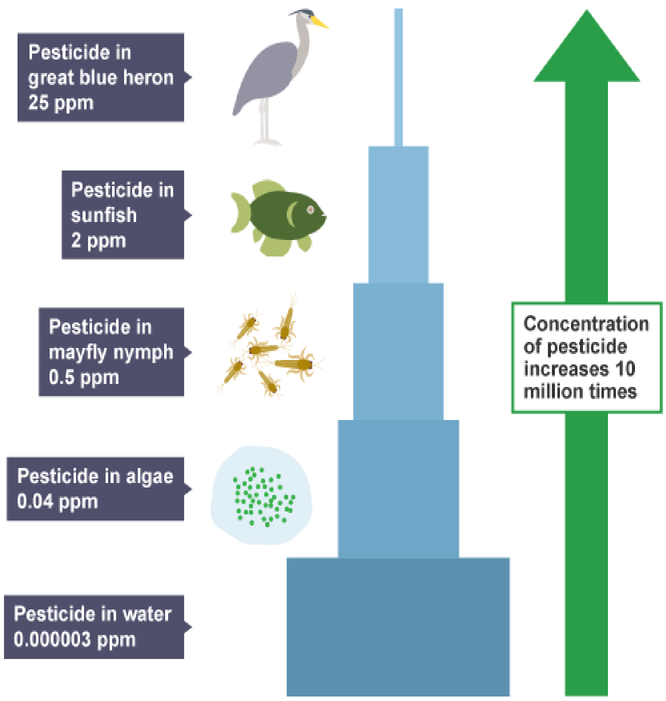
- **Selective** herbicides have a greater effect on **certain** plant species.
- **Systemic** herbicides **spreads through the vascular system** of the plant and **prevents regrowth.**
- **Systemic** insecticides, molluscicides and nematicides **spread through the vascular system of plants and kill the pests feeding on the plants.**

Problems with pesticides

- **Toxicity** to non target species.
- They **persist** in the environments ie once they have got into the environment they do not degrade.
- **Bioaccumulation** is the build up of a chemical in an organism (usually from eating prey that contain the chemical).

If an area is polluted with a chemical eg. a pesticide then the concentration of the pesticide will increase as you move up the food chain as more of the chemical is being ingested.

This is called **biomagnification.**



Biological Control

An **alternative** to pesticides where the control agent is a **natural predator**, parasite or pathogen of the pest. When using this method care must be taken to ensure that the control organisms does not become an **invasive species**.

Integrated Pest Management

Where the pest is managed by a **combination** of biological, chemical and cultural control.

Key Area 4—Animal Welfare

Animal welfare refers to the wellbeing of an animal. This includes the ability of the animal to express its natural behavioural patterns.

Costs, benefits and ethics

Animal welfare refers to the wellbeing of an animal. This includes the ability of the animal to express its natural behavioural patterns.

Improving the welfare of domesticated animals involves an **expensive initial payment** from the farmer.

However, this has **long-term benefits** including:

- increased growth of animals
- increased success rate of breeding
- higher quality end products

For example;

Free range requires more land and is more **labour intensive** but can be sold at a **higher price** and animals have a **better quality of life**.

Intensive farming is less **ethical** than free range farming due to **poorer animal welfare** but is often more **cost effective**, generating higher profit as costs are **low**.

Behavioural Indicators of Poor Welfare

Displays of behaviour can indicate poor welfare and wellbeing of domesticated animals.

The behaviour indicators that they may display are;

- Stereotypy—repetitive movement eg. Pacing up and down a cage
- Misdirected behaviour—behaviour directed at self eg. Plucking out feathers, knowing on solid objects, hyperagression.
- Failure in sexual or parental behaviour—not able to produce offspring or not looking after young.
- Altered levels of activity eg. Sleeping all day.

Key Area 5—Symbiosis

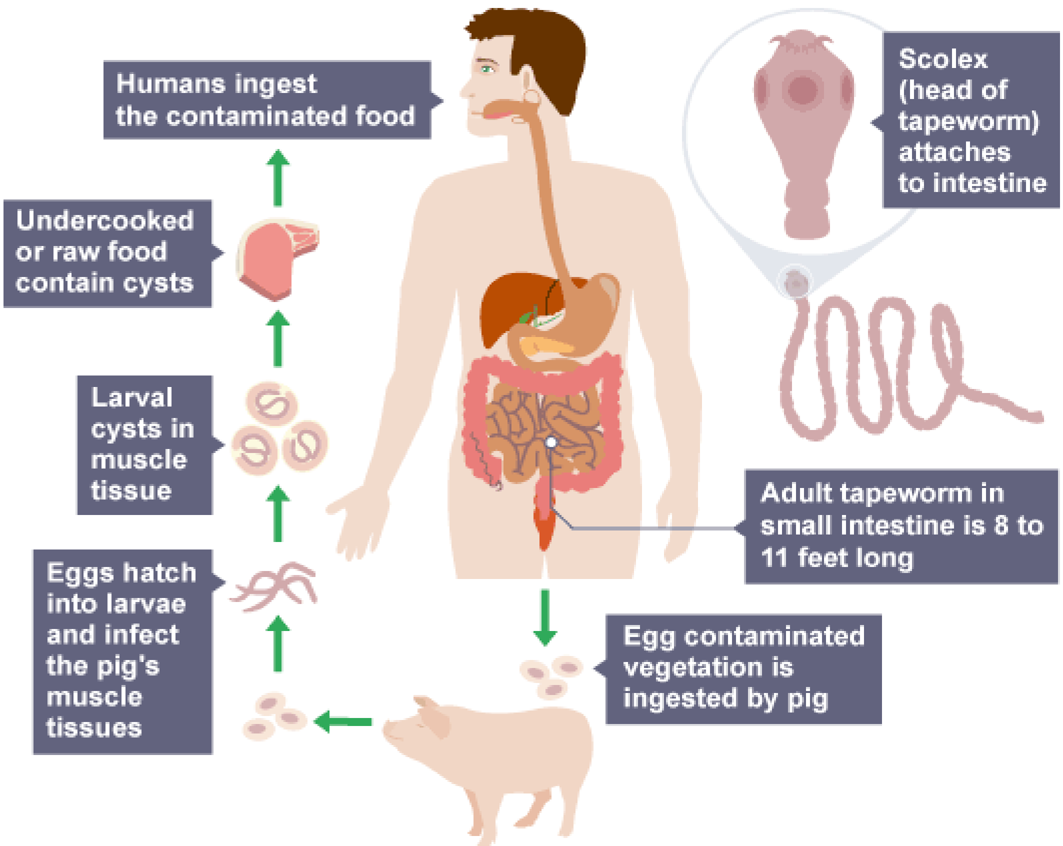
Symbiosis describes the co-evolved intimate relationships between members of two different species.

There are 2 types;

1. Parasitism

In a parasitic relationship the parasite benefits in terms of energy or nutrients whereas the host is harmed by the loss of these resources.

- Parasites often have a **limited metabolism** and **cannot survive outwith the host**.
- Parasites can be transmitted by **direct contact**, **resistant stages** and **vectors**.
- Some parasites require a **secondary host** in order for them to **complete their lifecycle** eg. Tapeworm.



2. Mutualism

In mutualism **both partners benefit** in an interdependent relationship.

Rhizobium are a type of bacteria that live in the roots of legumes and fix nitrogen, which the plants need in order to make protein. In return for the nitrogen, the rhizobium get carbohydrates from the plants. Both the bacteria and plant benefit in this relationship.

Key area 6—Social Behaviour

(a) Many animals live in social groups and have behaviours that are adapted to group living such as **social hierarchy**, **cooperative hunting** and **social defence**. These behaviours have evolved through the process of natural selection.

Behavioural adaptation	Species as an example	Survival value
Social hierarchy	Grey wolf	Lowers aggression and saves energy Experienced leadership guaranteed Most favourable genes passed on
Cooperative hunting	African wild dogs	Larger prey can be killed Subordinate animals benefit Energy usage per individual reduced
Cooperative defence	Baboons	Early warning can be given Younger individuals defended Predators intimidated or confused

(b) **Altruism** and **Kin Selection** and its influence on survival.

An altruistic behaviour **harms** the donor but **benefits** the recipient.

For example vampire bats may regurgitate blood to feed other bats who have been unable to feed themselves.

This behaviour only benefits the recipient as the donor loses out on nutrients. However the donor may benefit from this behaviour in the future which will increase species survival.

Kin Selection

Behaviour that appears to be altruistic may be common between a **recipient** and a **donor** if they are related (kin).

Donor long tailed tits with no offspring might feed other parents offspring in terms of food shortage.

Long tailed tits live in loose colonies with related individuals and so the chances of the donor sharing genes with the recipient is high therefore contributing to genetic success.

Social Insects

Some insects live in social **colonies**, for example bees, wasps, ants and termites.

Only a **few** individuals carry out **reproduction** while other, **sterile** individuals called **workers** carry out most of the food collection. This is known as a division of labour and is an adaptation that increases the survival of the species.

The feeding of offspring of the fertile by the sterile is an example of kin selection since the breeding system ensures that the offspring are close relatives of all of the colony members.

Primate Behaviour

Primates have a **long period of parental care** to allow learning of complex social behaviour.

Complex social behaviours support the **social hierarchy**. This **reduces conflict** through ritualistic display and appeasement behaviour. Alliances form between individuals, which are often used to increase social status within the group. Some examples are shown in the table below.

Chimpanzee social group behaviour	Description	Function
Grooming	Includes the preening of one animal's coat by another	Reduction of tension and strengthening of alliances to increase social status in the group; strengthening of bonds between individuals
Facial expressions	Include eye closing, teeth baring, mouth opening	Act as signals to indicate position in dominance hierarchy and avoid conflict
Body postures	Include lowering of body position and bowing actions	Act as signals to emphasise position in dominance hierarchy and avoid conflict
Sexual presentation	Includes the presentation of genitalia by females to males	Acts as a signal by females to appease dominant males and avoid aggression

Key Area 7— Components of Biodiversity

Components of biodiversity are **genetic diversity**, **species diversity** and **ecosystem diversity**, as detailed in the following table.

Diversity component	Definition
Genetic	The number and frequency of alleles in a population
Species	The number of species (species richness) and the relative abundance of each species in an ecosystem
Ecosystem	The number of distinct ecosystems within a defined area

Key Area 8—Threats to Biodiversity

(a) Exploitation and recovery of populations and their impact on their genetic diversity.

Humans exploit natural resources for food, raw materials and space. **Overexploitation** is when resources are used up quicker than they can be replaced. Exploitation of cod turned into **overexploitaion** when overfishing caused depletion of stock. Quotas have been introduced by governments in recent years and there are some signs that cod stocks might recover.

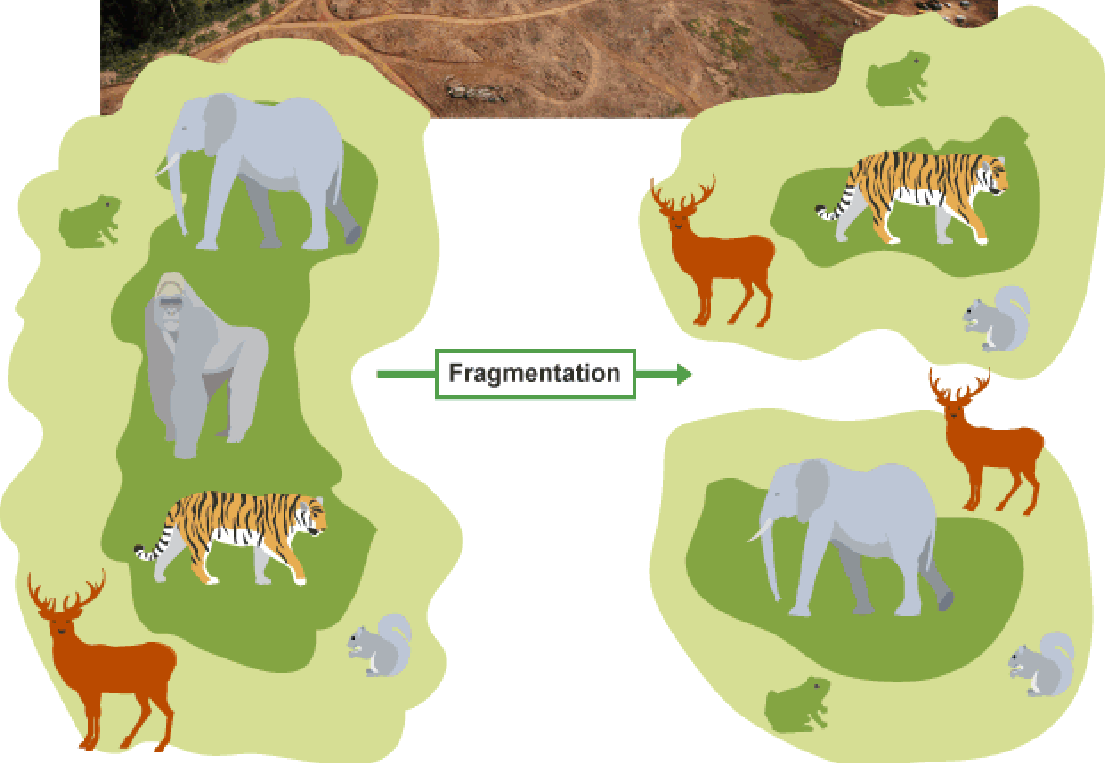
The Bottleneck Effect

Small populations may lose the **genetic variation** necessary to enable evolutionary responses to environmental change.

Northern elephant seals have reduced genetic variation mostly likely due to being hunted. Hunting reduced their population size to as few as 20 individuals at the end of the 19th Century.

(b) ***Habitat loss, habitat fragments and their impact on species richness.***

The clearing of habitats has led to **habitat fragmentation**. Degradation of the edges of the habitat fragments results in **increased competition** between species as the fragment becomes smaller. This may result in a **decrease in biodiversity**.



To remedy widespread habitat fragmentation, isolated fragments can be linked by **habitat corridors** to help increase species diversity as species can mate, find food and recolonize habitats.

(c) ***Introduced, naturalised and invasive species and their impact on native populations.***

Introduced (non native) species are those that humans have moved either intentionally or accidentally to new geographic regions.

Some then become established in this new area and then are term **naturalised species**.

Some of these naturalised species can spread rapidly and outcompete or prey on native species—these are termed **invasive species**.

<u>Japanese Knotweed</u>

The invasive root system and strong growth can damage concrete foundations, buildings, flood defences, roads, paving, retaining walls and architectural sites. It can also reduce the capacity of channels in flood defences to carry water.[

<u>Grey Squirrel</u>

The grey squirrel (Sciurus carolinensis) is native to North America and was first released into the UK in 1876 by the Victorians.

The introduction of the grey squirrel has decimated the native red squirrel population as they outcompete them for resources.

Invasive species may well be free of the **predators**, **parasites**, **pathogens** and **competitors** that limit their native habitat. Invasive species may **prey** on native species, **out-compete** them for resources or **hybridise** with them.

Unit 3 Sustainability & Interdependence

Key Area 3.2 Plant & Animal Breeding

1.

Holstein, Normande and Scandinavian Red are breeds of dairy cattle.

An investigation was carried out to compare average milk yield, the average fat content and the average protein contents of milk from pure bred Holstein, Holstein × Normande F_1 hybrid and Holstein × Scandinavian Red F_1 hybrid cattle.

The results are shown in the table.

Breed	*Average milk yield per cow* (kg per day)	*Average fat content of milk* (%)	*Average protein content of milk* (%)
Pure bred Holstein	44·80	4·15	3·25
F_1 Hybrid Holstein × Normande	48·64	4·25	3·10
F_1 Hybrid Holstein × Scandinavian Red	51·52	4·25	3·15

(*a*) Calculate the percentage increase in average milk yield per day from the Holstein × Scandinavian Red F_1 hybrid compared to pure bred Holstein.

Space for calculation

______________ % **1**

(*b*) In milk for butter production, the fat content is important.

Calculate the total fat production in a day which would be expected from a herd of 200 Holstein × Normande F_1 hybrids.

Space for calculation

____________ kg per day **1**

(*c*) Summarise the effects of crossbreeding on the three characteristics shown in the table.

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____

____ **1**

(*d*) The development of pure breeds such as Holsteins has led to accumulation of deleterious recessive alleles.

Give the term which describes this.

______________________________ **1**

(*e*) Some F_2 offspring from crosses of F_1 Holstein × Scandinavian Red hybrid cattle will have less desirable milk-producing characteristics compared to their parents.

(i) Give a reason for this.

____

____ **1**

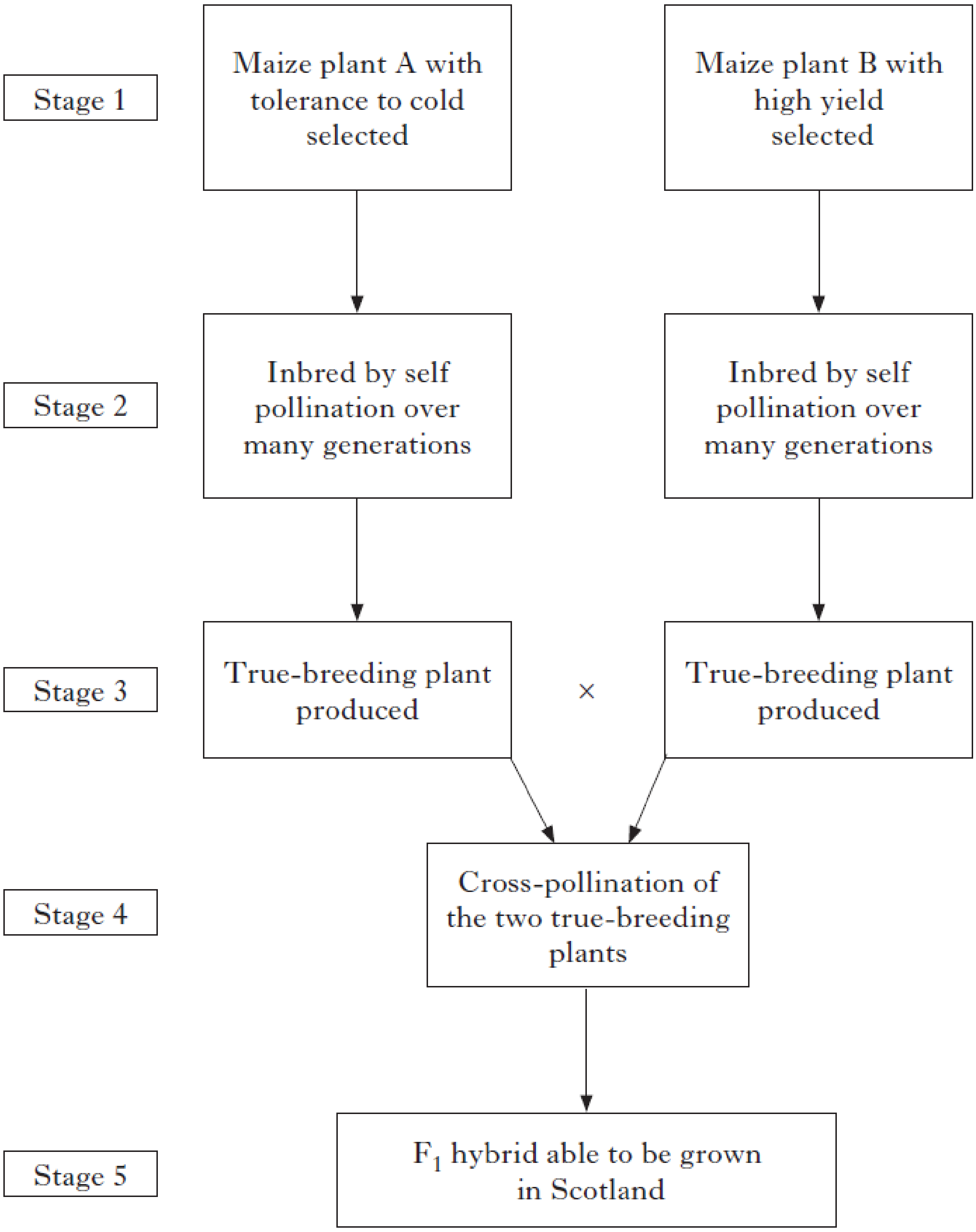
2. Which line in the table below correctly describes the type of variation and inheritance pattern normally involved in growth rate in pigs?

	Type of variation	*Inheritance pattern*
A	continuous	polygenic
B	discrete	polygenic
C	continuous	single gene
D	discrete	single gene

3.

Maize is a naturally self-pollinating crop plant native to the warmer areas of the USA.

An outline of the stages in the breeding of a hybrid plant with high yield which can be grown in the colder environment of Scotland is shown below.



(a) State **two** characteristics of the F_1 hybrid at Stage 5 that would be beneficial to the breeder.

1 ______________________________

2 ______________________________ **1**

(b) The F_1 hybrids can be grown in Scotland and can be crossed with each other to produce an F_2 generation.

(i) Describe why some F_2 plants produced from this cross may not grow successfully in Scotland.

____

______________________________ **1**

(ii) Give an advantage to breeders of producing an F_2 generation in this case.

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______________________________ **1**

4. Many varieties of garden plants grown by breeders are F_1 hybrids which often show increased vigour and yield.

Further generations are not usually produced from these F_1 plants because the F_2 generation would be

A heterozygous

B homozygous

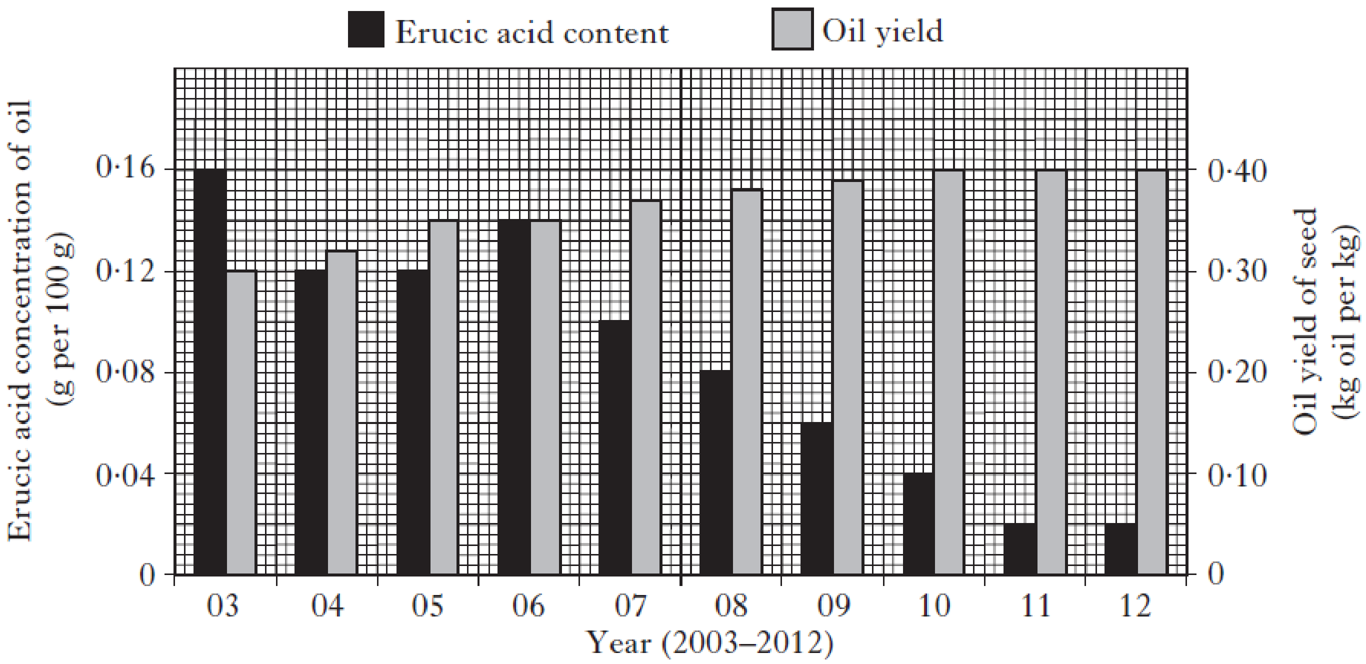
C genetically variable

D genetically uniform.

5.

Oil from wild varieties of oilseed rape plants contains a high concentration of erucic acid which makes the oil unsuitable for human consumption.
Selective breeding programmes have produced modern varieties of oilseed rape plants with oil of low erucic acid concentration which is suitable for human consumption.
In 2003 a new selective breeding programme was started which aimed to further reduce the erucic acid concentration of the oil and to increase oil content of seeds.

The **bar chart** below shows the results of the new selective breeding programme over a 10 year period.



(*a*) (i) Use values from the **bar chart** to describe the changes in erucic acid concentration of the oil from 2005 until 2012.

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____

____

____ **2**

(ii) Calculate the simplest whole number ratio of the erucic acid concentration of the 2003 harvest compared with that of the 2011 harvest.

Space for calculation

________ in 2003 : ________ in 2011 **1**

(iii) Calculate the average increase per year in oil yield from 2003 to 2011.

Space for calculation

________ kg oil per kg seed per year **1**

(iv) Calculate the mass of seed from 2012 which would be needed to produce one kilogram of oil.

Space for calculation

____________ kg **1**

(*b*) The bacterium *Bacillus thuringiensis* produces Bt-toxin, a substance harmful to leaf-eating insects. Some oilseed rape plants were genetically engineered so that they contained the gene for Bt-toxin.

A field trial was set up to compare seed yields in genetically engineered plants with the Bt-toxin gene and control plants without the Bt-toxin gene. Equal numbers of the two types of plant were grown under identical conditions in the presence of leaf-eating insects and their seed yields per hectare compared.

The results of the trial are shown in the **table** below.

Plants	*Seed yield* (kg per hectare)
Genetically engineered (with the Bt-toxin gene)	144
Control (without the Bt-toxin gene)	80

(i) Calculate the percentage increase in the seed yield per hectare from plants with the Bt-toxin gene compared with the control plants.

Space for calculation

__________ % **1**

(ii) Explain why the genetically engineered plants produce a higher yield of seed per hectare compared with the control plants.

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____ **2**

(iii) The selectively bred plants which produced the 2012 harvest were affected by leaf-eating insects.

Using information from the **table** and the **bar chart**, predict the increase in **oil yield** per hectare which could have been achieved, if these plants had been:

- genetically engineered to contain the Bt-toxin gene
- grown under identical conditions to those in the field trial.

Space for calculation

Increase in oil yield: __________ kg oil per hectare **1**

6.

The average yield, fat and protein content of the milk from each of three breeds of dairy cattle were determined.

The results are shown in the table below.

Breed	*Average milk yield per cow* (kg per day)	*Average fat content of milk* (%)	*Average protein content of milk* (%)
Pure bred Holstein	44·80	4·15	3·25
F_1 hybrid Holstein × Normande	48·64	4·25	3·10
F_1 hybrid Holstein × Scandinavian Red	51·52	4·25	3·15

(a) Calculate the percentage increase in average milk yield per cow from the F1 hybrid Holstein × Scandinavian Red compared to pure bred Holstein cattle. 1

Space for calculation

__________ %

(b) The fat content of milk is important for butter production.

Calculate the total fat content in the milk produced in a day from a herd of 200 F1 hybrid Holstein × Normande cattle. 1

Space for calculation

__________ kg per day

(c) Select **one** from: average milk yield per cow; average fat content of milk; or average protein content of milk.

For your choice, draw a conclusion about the effects of crossbreeding. 1

Choice ______________________________

Conclusion ______________________________

____

(d) The development of pure breeds such as Holsteins has led to an accumulation of deleterious recessive alleles.

State the term that describes this. 1

____

(e) Some F2 offspring from crosses of F1 hybrid Holstein × Scandinavian Red cattle will have less desirable milk-producing characteristics than their parents.

(i) Give **one** reason for this. 1

____

____

7. Inbreeding depression is a result of

A an increase in heterozygotes

B a genetically variable population

C crossbreeding for improved characteristics

D an accumulation of recessive deleterious alleles.

8.

Gluten is a protein found in crops that can cause human health problems. Scientists are breeding barley cultivars to produce ultra low gluten levels.

A commercially produced barley (Sloop) and a low gluten cultivar (LG) were crossed to produce two different cultivars with ultra low gluten levels (ULG 1 and ULG 2).

The gluten content of each cultivar is shown in the table.

Barley cultivar	*Gluten content* (mg/g)
Sloop	57·0
LG	5·1
ULG 1	1·7
ULG 2	0·004

(a) Calculate how many times greater the gluten content of Sloop is compared to that of ULG 2. 1

Space for calculation

____________ times greater

(b) Barley grains contain the enzyme amylase which breaks down starch in the grain to sugar used in brewing beer.

Average grain mass, starch content and amylase activity for three barley cultivars are shown in the table.

Barley cultivar	*Average mass of a single grain* (mg)	*Starch content of grains* (%)	*Amylase activity* (units/mg)
Sloop	53·6	70	0·6
ULG1	33·5	65	1·0
ULG2	39·2	64	1·4

(i) As well as total mass of all the grains, state the information required in order to calculate the average mass of a single grain. 1

____

(ii) Select a cultivar from the table that would be best to use in beer production and justify your selection. 1

Cultivar ______________________________

Justification ______________________________

____