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9.4 Reproduction in Plants

IB Biology - Revision Notes

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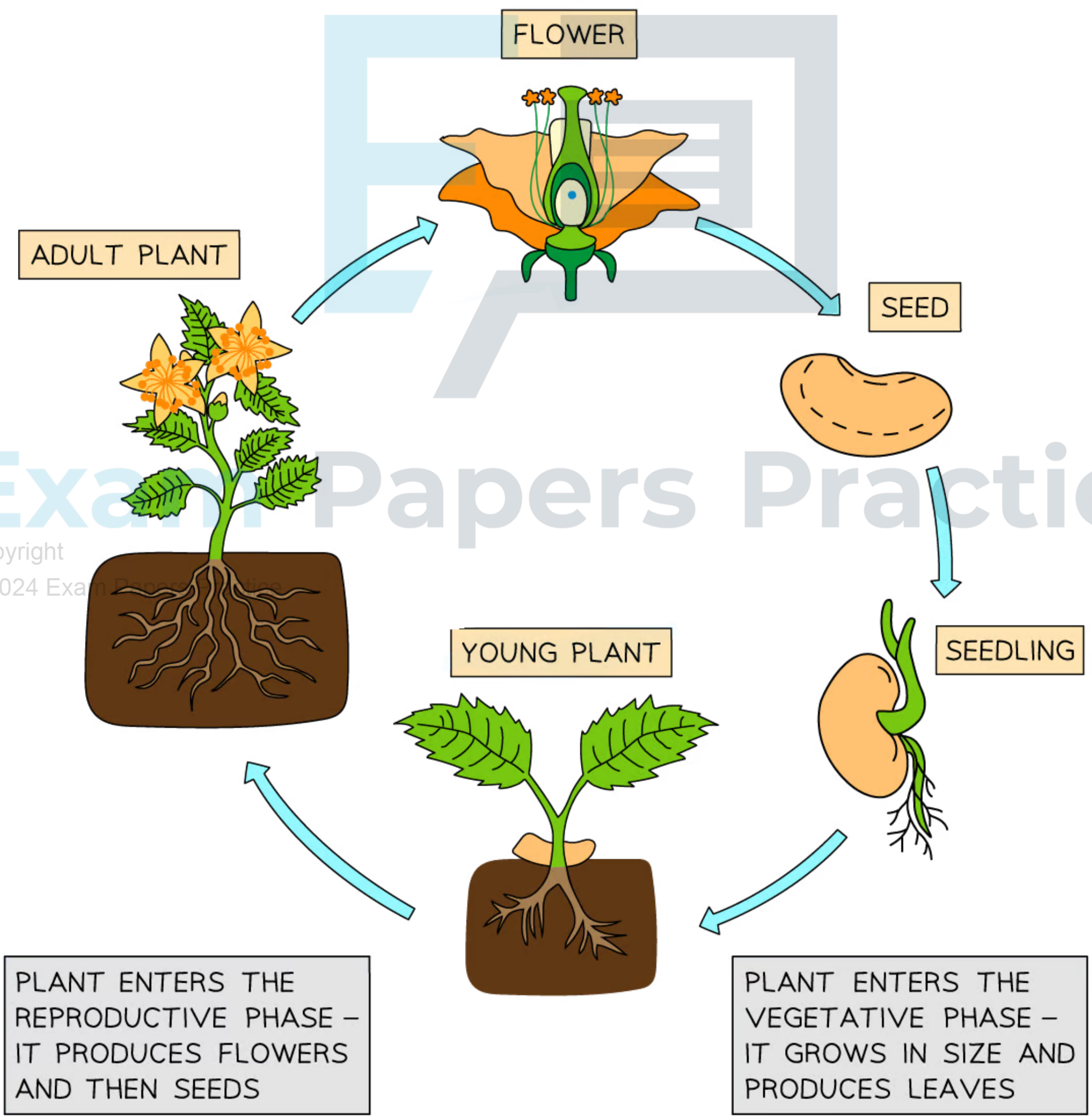
9.4.1 Flowering

Flowering & Gene Expression

- The life cycle of a flowering plant involves
  - The **vegetative phase**
    - The part of the life cycle during which **plant growth** takes places
    - A plant in the vegetative phase consists of **roots, stems and leaves**
    - A plant in this phase can often reproduce asexually
  - The **reproductive phase**
    - The part of the life cycle when **flowers** are produced by the **shoot apical** meristems
    - A plant in the reproductive phase can reproduce **sexually**



A flowering plant alternates between vegetative and reproductive phases

- Sexual reproduction involves **two parents** and the fusion of two gametes
- In order for a plant to move from the vegetative phase to the reproductive stage, meristems in the shoot needs to be stimulated to produce a **flower** rather than a **leaf**
- This stimulation can be brought about by changes in certain abiotic factors such as **temperature** or **night length** which **alter gene expression** in the shoot apical meristem

Flowering & Photoperiods

- It has been shown that the controlling factor in flowering is the **length of the night**
  - It was previously thought that day length was the controlling factor
- When the night reaches a certain **critical length**, genes that control flowering in the plant may be **switched on or off,** leading to the **activation or inhibition of flowering**
  - Genes that are switched on **are expressed**, leading to **production of the polypeptides** for which they code, while genes that are switched off **are not expressed**, so the polypeptides for which they code **are not produced**
- This critical length is important as it determines the quantities of different forms of a pigment called **phytochrome** in the leaf

Phytochrome

- The phytochrome pigment exists in two forms
  - **P_R** is the **inactive form** of phytochrome, it absorbs light from the **red** part of the spectrum (wavelength 660 nm)
  - **P_{FR}** is the **active form** of phytochrome, it absorbs light from the **far red** part of the spectrum (wavelength 730 nm)

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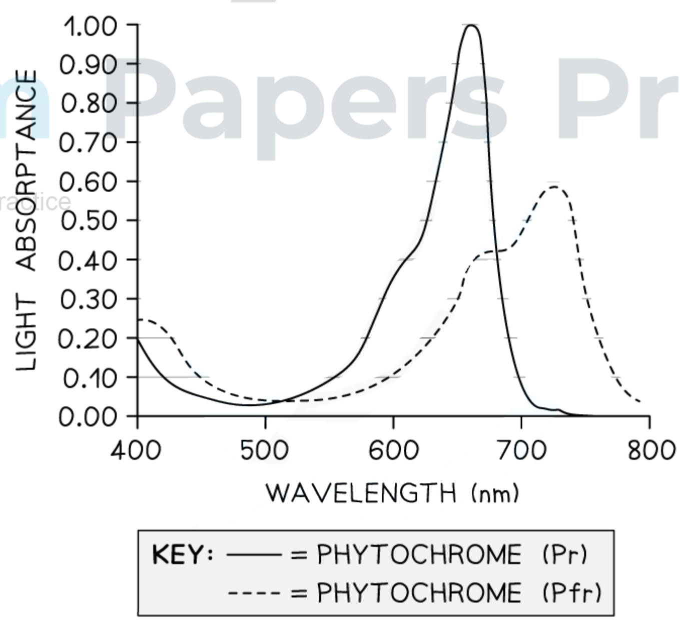
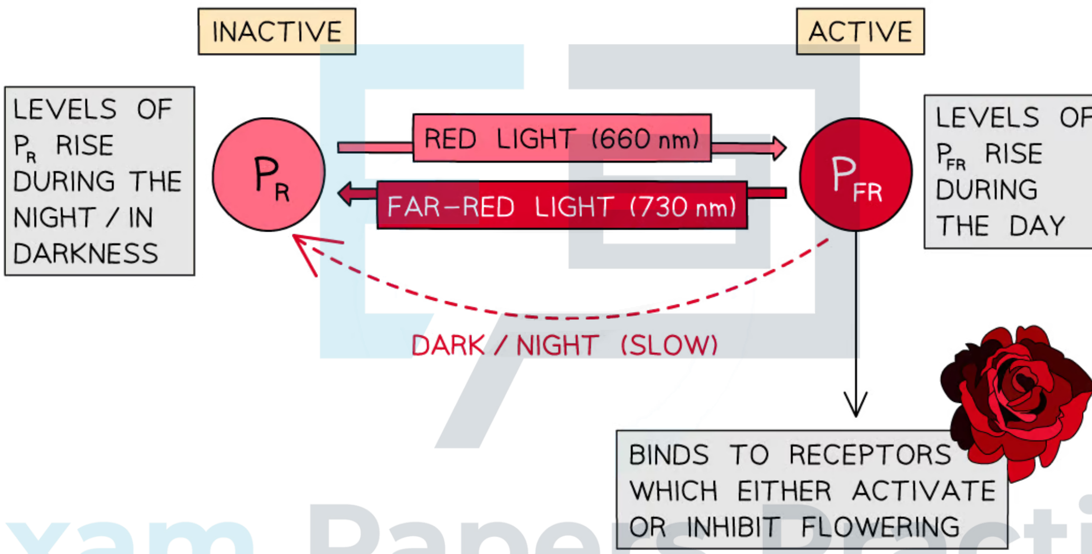


Two forms of phytochrome absorb light from different parts of the spectrum. Note that absorptance is the ratio of the total amount of light absorbed to the total amount falling on an object

- Absorption of different wavelengths of light causes a **reversible conversion between the P_R and P_{FR}** forms of phytochrome
  - When **P_R absorbs red light** (660 nm) **it is converted into P_{FR}**
  - When **P_{FR} absorbs far red light** (730 nm) **it is converted back into P_R**
  - In the **absence of red light** the unstable **P_{FR} gradually converts back into P_R**
- **During the day** levels of **P_{FR}** rise
  - Sunlight contains more wavelengths at 660 nm than 730 so the conversion from P_R to P_{FR} occurs more rapidly in the daytime than the conversion from P_{FR} to P_R
- **During the night** levels of **P_R** rise

- Red light wavelengths are not available in the darkness and P_{FR} converts slowly back to P_R



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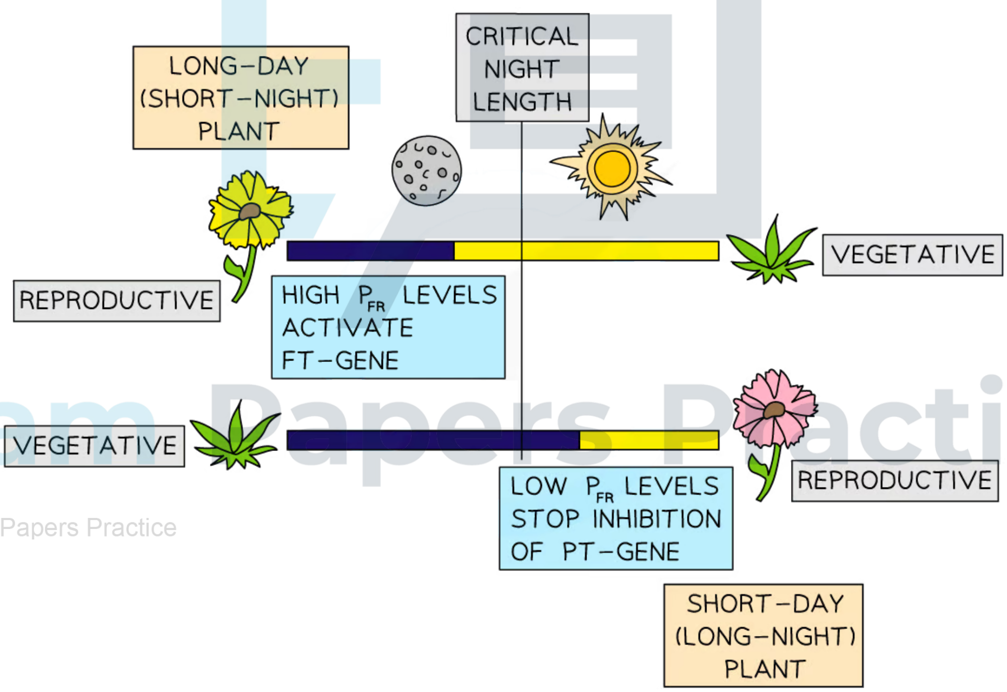
PR is converted to PFR in a reversible reaction which controls flowering

Long day plants

- Long day plants flower when the nights are **shorter than** the critical length **e.g in summer**
  - When nights are short, the **day length is longer**, hence the term 'long day plants'
- In **long day plants**, high levels of the **active form of phytochrome activate flowering**
- Flowering occurs due to the following process
  - Days are long so **P_R is converted to P_{FR} at a greater rate** than P_{FR} is converted to P_R
  - The **active form of phytochrome**, P_{FR}, is present at **high levels**
  - High levels of P_{FR} **activate flowering**
    - P_{FR} binds to **receptors** in the cytoplasm of the leaf cells, activating expression of the **flowering time (FT) gene**
    - The active gene is transcribed and translated in the shoot apex
    - The resulting protein binds to a transcription factor which leads to the expression of **multiple genes** associated with flowering and converts the meristem from **vegetative to reproductive**

Short day plants

- Short day plants flower when the nights are **longer than** the critical length **e.g. autumn**
  - When nights are long, the **day length is shorter**, hence the term 'short day plants'
- In **short day plants**, high levels of the **active form of phytochrome inhibit flowering**
  - Note that this is the **opposite effect** to that of high levels of P_{FR} in long day plants
- Flowering occurs due to the following process
  - P_{FR} **inhibits flowering** in short day plants when it is present at high enough levels
    - P_{FR} binds to **receptors** in the cytoplasm of the leaf cells and **inhibits transcription and translation** of the **flowering time (FT) gene**
  - Long nights lead to **low levels of P_{FR}** due to the slow conversion of P_R back into P_{FR} in the absence of red light
  - When P_{FR} levels are low, there is **no inhibition of flowering** as the **FT gene** can be transcribed and translated
  - The resulting protein binds to a **transcription factor** which leads to the expression of **multiple genes** associated with flowering and converts the meristem from **vegetative to reproductive**



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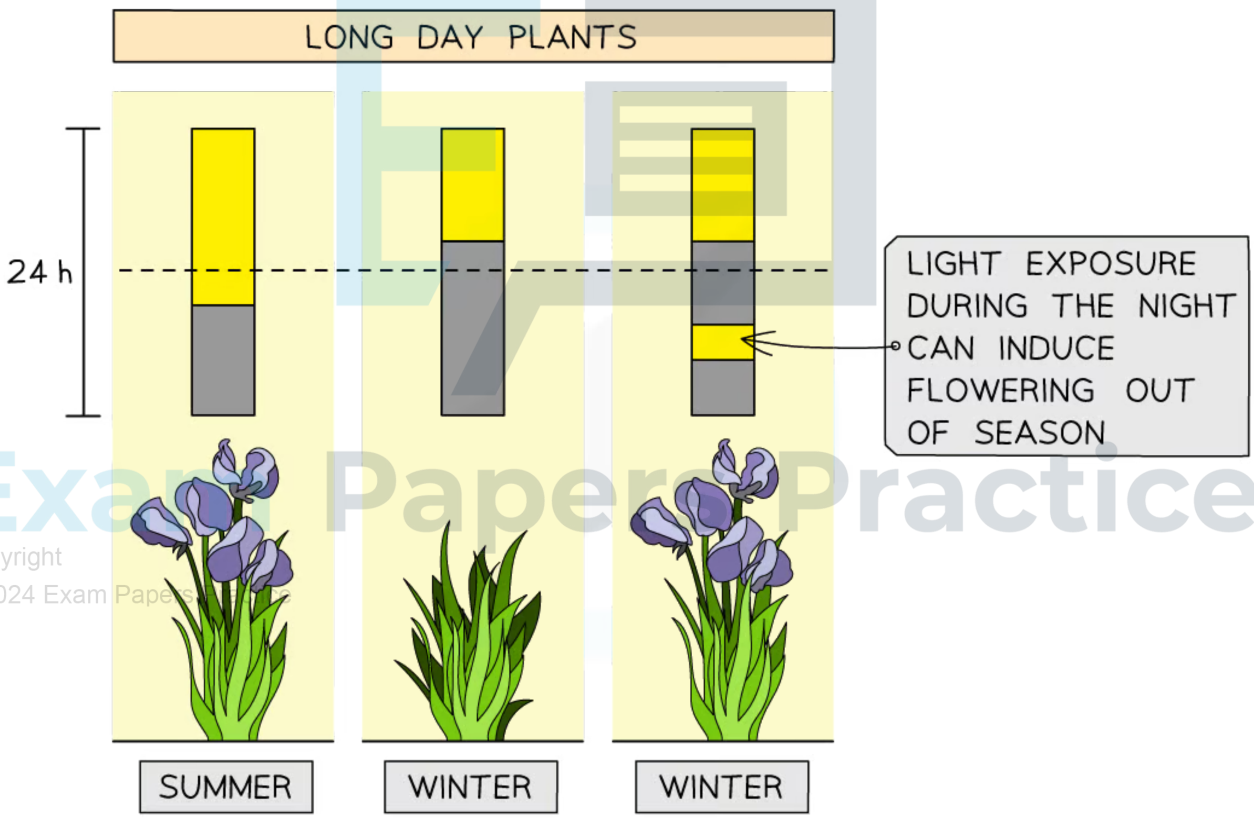
Long day plants flower when PFR levels are high and short day plants flower when PFR levels are low.

Exam Tip

Plants can be confusing as plant substances don't always have a consistent effect on plant growth! Here you need to remember that a high level of P_{FR} **activates flowering in long day plants**, and **inhibits flowering in short day plants**.

Inducing Flowering Out of Season

- Normal flowering times in plants require the critical dark period to be **uninterrupted**
- Sometimes it might be necessary to **induce flowering** at times when plants would normally be in their vegetative state
    - For example, growers of flowers which are sold as cut flowers can provide flowers **out of season** through manipulation of night length
- Flowering in **short day plants** can be induced during the longer day season, such as during the summer, by **providing a longer dark period** e.g. by covering plants up
- Flowering in **long day plants** can be induced during the winter months when days are short, by **providing periods of light** during the night time



Long-day plants can be induced to flower out of season through providing additional light

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9.4.2 Plant Reproduction

Mutualism Between Flowers & Pollinators

- **Sexual** reproduction in plants requires the **transfer of pollen** between flowers
- Methods of pollen transfer can include:
  - Wind
  - Animals
  - Water
- Most flowering plants use **mutualistic relationships** with animal **pollinators** in sexual reproduction
  - The pollinator visits the flower to obtain food, often in the form of **nectar,** from the plant
    - Pollinating animals can be insects, birds, or small mammals such as bats
  - **Pollen sticks** to the body of the animal and is subsequently **transferred to the flowers of the next plant** visited by the pollinator
  - It is a **mutualistic** relationship because **both organisms gain** a benefit during the process
    - Mutualism is a type of symbiotic relationship
    - Mutualism relies on repeated interactions, sometimes between one species and several others
      - An example is a bee that will visit, feed on the nectar from and pollinate many species of flower
    - Symbiosis relies on two species remaining in partnership exclusively to each other

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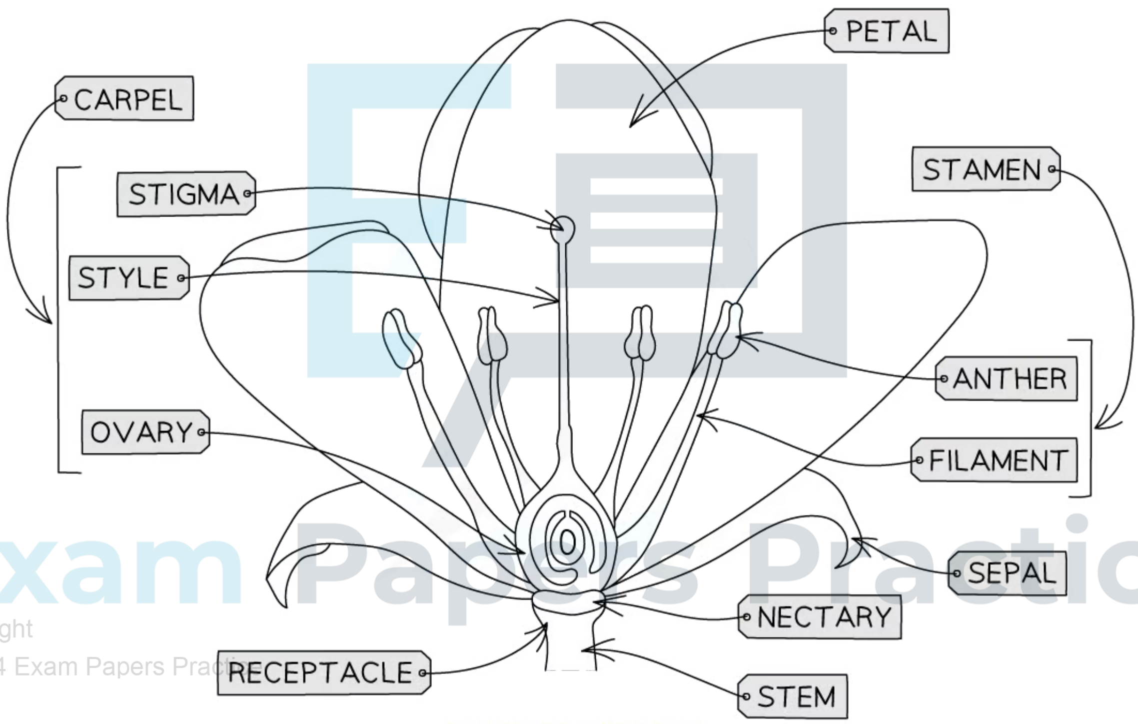
Pollination, Fertilisation & Seed Dispersal

Introduction to Flower Structure

- The development of flowers occurs in the **reproductive stage** of the plant life cycle
- Flowers contain all the necessary organs and tissues required for **sexual reproduction** by **pollination**
- Key structures of the flower include
  - The **anther** - where the male gamete, pollen, is found
  - The **stigma** - part of the female reproductive organ which receives the pollen
  - The **ovary** - where the female gametes are located



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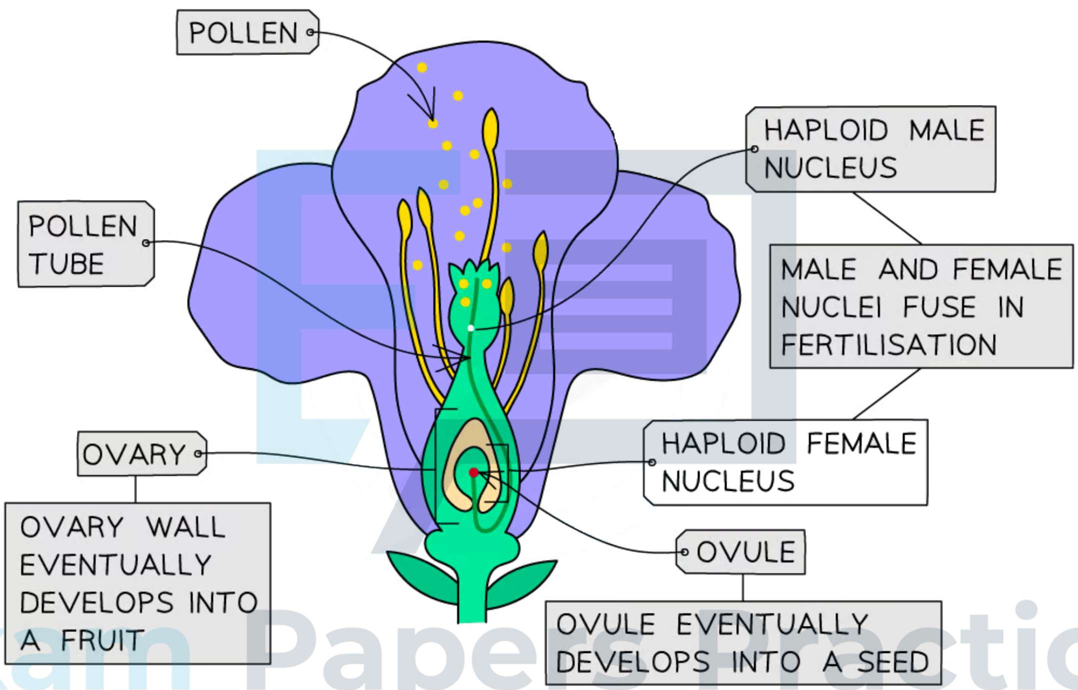
Animal pollinated flowers have structures that attract pollinators and aid the process of pollination

Pollination and Fertilisation

- **Pollination** is the process of transferring pollen from the **anther** of one flower to the **stigma** of another
  - **Self pollination** can occur in some species when pollen is transferred between different flowers on the same plant, or even from anther to stigma within the same flower

- After pollination has occurred, a **pollen tube** grows from the **pollen grain** down the **style** to the **ovary** of the plant
- The **male nuclei** travel down the pollen tube to the female ovule
  - Two male nuclei travel down the pollen tube to the ovule; one will fuse with an ovule nucleus to form the zygote while the other will go on the form the plant embryo's food store
- **Fertilisation** occurs when the **haploid** male and female nuclei fuse and a **diploid zygote** is formed
  - After fertilisation, the **ovule** becomes a **seed** and the **ovary** develops into the **fruit**



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After pollination the haploid male and female nuclei can fuse in fertilisation to make a diploid zygote

Seed Dispersal

- **Seed dispersal** is then required in order to distribute the seeds away from the parent plant and **reduce competition** between the offspring and the parent plant
  - Methods of seed dispersal include
    - **Wind or water**
      - Parachute or wing shaped lightweight seeds will travel on the wind or float in water
    - **Animals**
      - Fleshy fruit is eaten by animals and seeds distributed through egestion
      - Sticky or hooked seeds catch on to the fur or feathers of passing animals
    - **Explosions**

- Some pods explode propelling the seeds away from the parent plant

> **Exam Tip**
>
> Be careful not to mix up pollination and seed dispersal; pollination is the **transfer of pollen from anther to stigma**, while seed dispersal is the **distribution of mature seeds**. Both processes can involve wind, water, or animals.

Protecting Pollinators

NOS: Paradigm Shift; more than 85% of the world's 250,000 species of flowering plant depend on pollinators for reproduction. This knowledge has led to protecting entire ecosystems rather than individual species

- Paradigm shifts occurs when **frameworks underlying scientific thinking** change due to e.g.
  - Discovery of **new knowledge**
  - **Developing understanding**
- Updating processes as a result of changed knowledge and understanding can allow progression towards more **successful approaches** in science
- A shift in the approach to conservation is an example of this:
  - Early efforts in conservation were primarily focused on **protecting individual species** or **populations** which were under threat
  - However, whilst it is still essential to promote the maintenance of animal populations over time, it has become apparent that the **relationships between species and the ecosystems in which they live** are just as fundamental, if not more so
  - With this in mind, it is important to **conserve habitats** and the **ecological processes** relied on by the communities within those habitats
- The **role of pollinators** is a key example of a **relationship between species and ecosystem** where changes in the process of pollination could have huge impacts on the wider ecosystem
  - **Pollinators directly support the survival of plant species** with which they interact, and also **indirectly impact the other species** within the associated community
    - Loss of either pollinator or plant species could cause an ecosystem to break down, leading to huge biodiversity losses
  - Pollinators play a huge role in the **production of crops** and therefore are relied upon by the farmers growing those crops for an income, but also by the consumers of the crops who require affordable and good quality food sources

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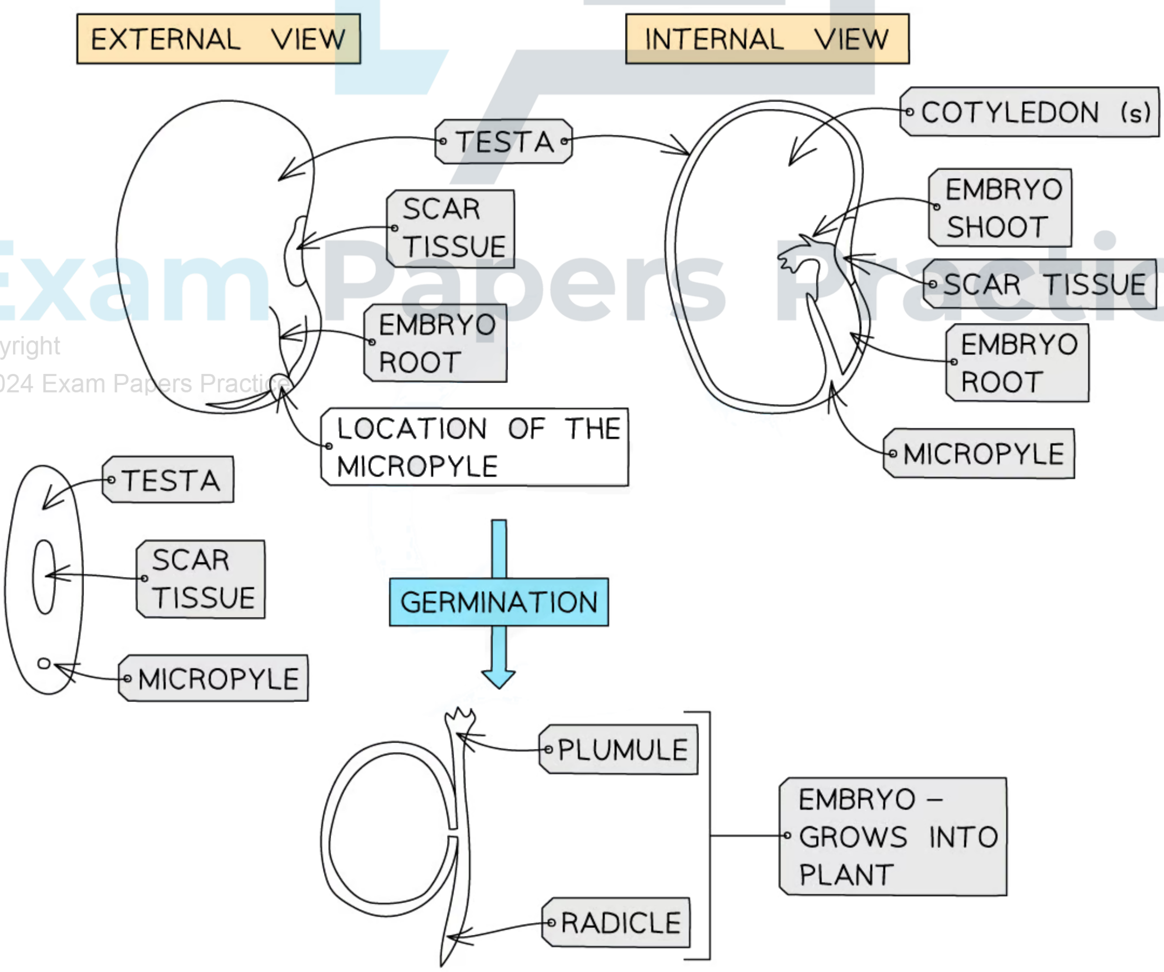
9.4.3 Skills: Drawing Plant Structures

Drawing the Internal Structure of Seeds

- A **seed** consists of several parts which can be shown in a labelled diagram
  - **Testa**
    - The seed coat
  - **Cotyledon** or **cotyledons**
    - The leaf or leaves of the embryo which sometimes contain the food source for the growing embryo
    - Some plants have one cotyledon and are known as monocotyledonous, and some have two and are dicotyledonous
    - In some plants the food source is separate from the cotyledons and is called the **endosperm**
  - **Embryo** plant
    - Consisting of the embryo **root** and embryo **shoot**
  - **Micropyle**
    - A hole through the testa found near the **scar tissue** where the seed was attached to the parent plant



The internal and external structure of a bean seed

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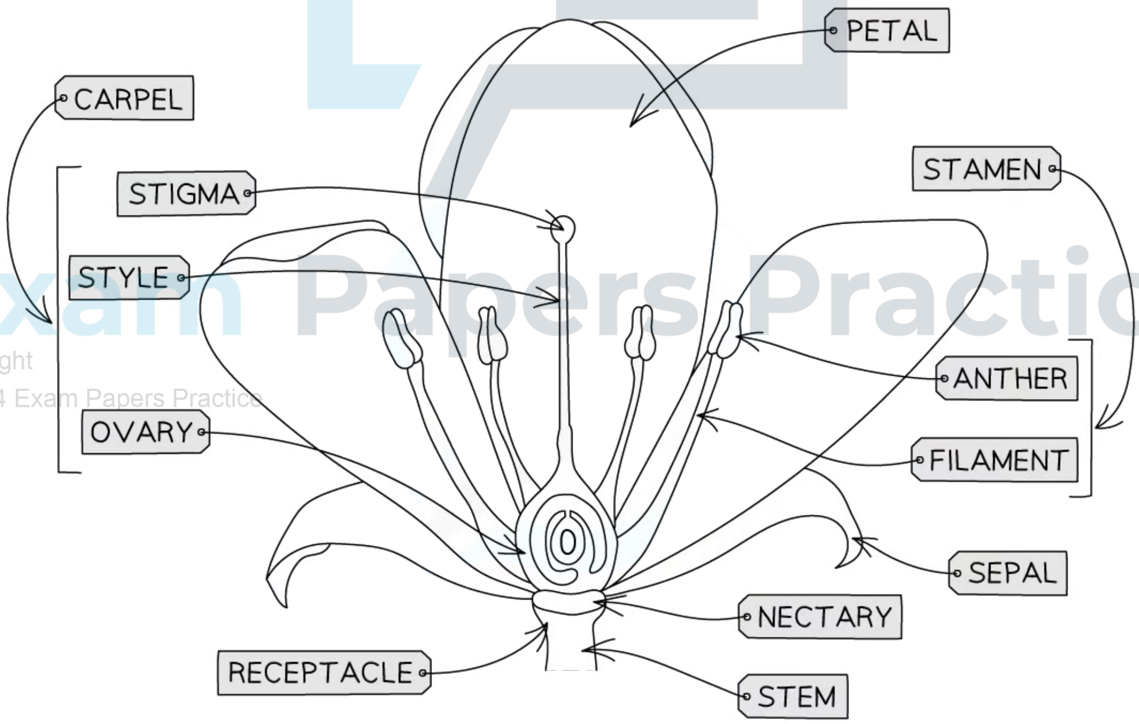
Drawing Animal-Pollinated Flowers

- **Animal pollinated flowers** have several features in common which should be included in a labelled diagram
  - **Nectary**
    - Nectar secreting glands to attract pollinators
  - **Petals**
    - Brightly coloured to attract pollinators
  - **Sepals**
    - Protect the unopened flower
  - **Stamen,** which consists of
    - The **anthers** which produce and release **pollen**
    - The **filaments** which hold the anthers in position
  - **Carpel**, which is made up of
    - The **stigma** which receives the pollen
    - The **style** which connects the stigma to the ovary
    - **Ovary** which contains the **ovules**
      - Ovules contain the female sex cells



Animal pollinated flowers have structures that attract pollinators and aid the process of pollination

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9.4.4 Skills: Investigating Factors Affecting Germination

Experiments Investigating Factors Affecting Germination

- Seeds remain **dormant** long enough to allow seed dispersal or until conditions are favourable
- During dormancy the seed is unable to germinate and the **metabolic rate is nearly zero**
- Germination results in growth of the **embryo shoot,** or plumule, and **embryo root**, or radicle
- Three factors are required for **successful germination**
  - **Water** allows the seed to **swell up**, causing the **seed coat**, or testa, to **burst;** this allows the growing embryo plant to exit the seed
    - Water also allows the enzymes in the embryo to function, increasing metabolic rate so that growth can occur
  - **Oxygen** is required for **respiration** so that **energy** can be released for germination
  - **Warmth;** germination improves as temperature rises (up to a point) as the reactions which take place are controlled by **enzymes** which cannot function effectively when temperatures are **too low**
  - Note that as carbon dioxide is not necessary for germination but also does not inhibit it, it makes no difference whether it is present or not

Gibberellin

- **Gibberellin** is a hormone required to trigger **mitosis** and **cell growth** in the plant embryo
- Production of gibberellin is **stimulated by a metabolic pathway** controlled by a series of **enzymes**
  - The genes that code for the relevant enzymes need to be expressed before this metabolic pathway can become active
- Gibberellin can also stimulate production of **amylase** which breaks down stored starch into **maltose**
  - Other enzymes break down the maltose further into soluble forms of sugar which can be **transported around the embryo plant**
    - Starch is **insoluble** so cannot be transported without first being broken down
  - Sugars from the broken down starch stores are required for **respiration** and **growth** of the cells in the embryo plant

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Crops and germination

- Germination rates for growers are an important factor in maximising **crop yield**
  - In agriculture, crops are often selected for their **short dormancy** period to decease germination time
- Growers must consider
  - **Age** of the seed; old seeds may be non-viable

- **Depth of sowing** seeds in the soil; too deep and the plumule may run out of energy before reaching the soil surface and too shallow may lead to the seed being eaten
- **Water availability**; both dry and waterlogged conditions could negatively affect germination
- **Storage conditions;** seeds may be damaged if stored incorrectly
- **Damage by pests;** some pests may eat or damage the seed itself while others may consume the growing plumule or radicle
- **Temperature;** many seeds need to be warm enough before germination occurs, but too much heat may cause damage, while some seeds need a period of extreme cold before germination can occur

Investigating the conditions for germination

- With germination being so crucial for effective crop farming it can be useful to investigate the factors that might affect its success
- We can use the following method to investigate the conditions required for successful germination

Apparatus

- Test tubes
- Test tube holder
- Cress seeds
- Cotton wool
- Fridge

Method

- Set up 4 test tubes, each containing 10 cress seeds on cotton wool
- Label the test tubes A, B, C, and D
  - For test tube A, leave the cotton wool **dry**
  - For test tube B, add enough water to the cotton wool so that it becomes **moist**
  - For test tube C, add enough water to **cover the cotton wool** and seeds, then carefully add a **layer of oil** on top of the water
  - For test tube D, add enough water to the cotton wool so that it becomes **moist**
- Leave tubes **A, B and C** at **room temperature** or incubated at a specific temperature e.g. 20 °C
- Place tube **D** in a **fridge** at approximately 4 °C
- Leave all tubes for a **set period of time** e.g. 3 - 5 days
  - Ensure the cotton wool in tubes B and D **remains moist** throughout this time by adding more drops of water if required
- Compare the results and see which tube has the **greatest number of germinated seeds**

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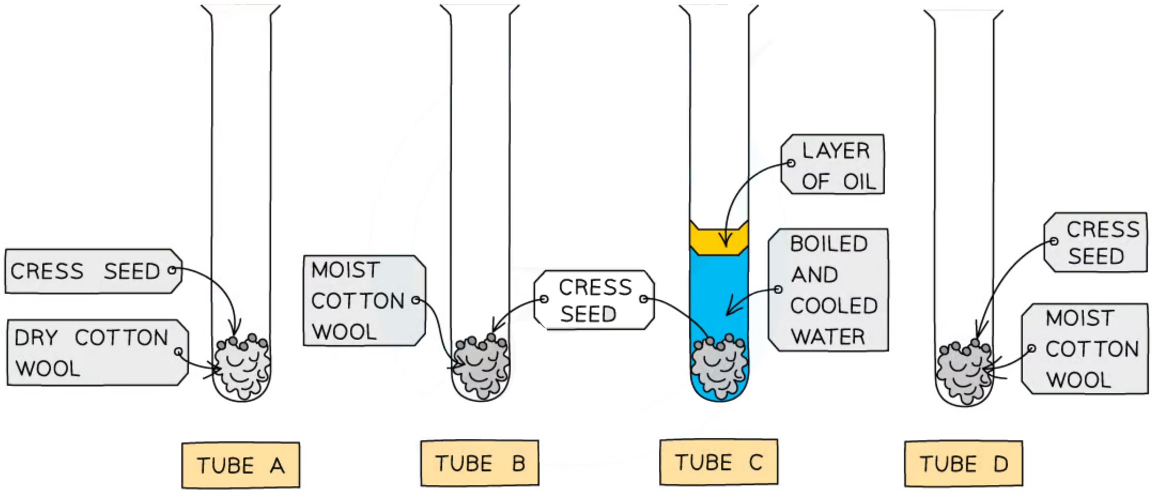

The ideal conditions for germination can be investigated by studying seeds under different conditions

Results and Analysis

- The test tubes are set up so that each of the factors required for germination (water, oxygen, and warmth) can be tested by **selectively removing each in turn**
  - In test tube A water is removed
  - Test tube B is the control tube where all factors are present
  - In test tube C oxygen is removed as it cannot pass through the oil and water layers on top of the seeds
  - In test tube D warmth is removed
- As germination **cannot occur** if the **conditions** are **not right** i.e. if even one of the three factors required is absent, it would be expected that **only the seeds in the control tube will germinate**

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Conditions Required for Germination: Example Results Table

TEST TUBE	FACTOR BEING TESTED	SEEDS GERMINATED
A	WATER / MOISTURE	NO
B	CONTROL (ALL FACTORS PRESENT)	YES
C	OXYGEN	NO
D	WARM TEMPERATURE	NO