Bio Factsheet

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Germination

Germination is the formation of a self-supporting seedling from an embryo within a seed.

- Many seeds require a period of **dormancy** before they can germinate. Particular concentrations of cytokinins, gibberellins and abscisic acid in the seed, maintain dormancy. These **growth substances** will be diluted when the seed absorbs water so that their inhibitory effect is removed.
- Seeds may also need to undergo a period of **vernalisation** or chilling. In seasonal climates this will prevent the seed from germinating until warm favourable conditions return. Chilling is thought to activate the production of gibberellins which stimulate synthesis of the enzyme α – amylase, for example, in cereal grains. This enzyme can then mobilise the starch reserves in the seeds thus enabling germination. The gibberellins act by 'switching' genes on (induction) or off (repression).

Germination requires the presence of the following physical conditions:

- Water which is absorbed by the dry seed through the micropyle and testa by a process called **imbibition**. This is a physical process by which colloidal substances, such as proteins, starches and cell wall materials in the seed, take in water and thus swell, increasing volume by up to 200%. The swelling forces are so great that they will rupture the testa (and pericarp, if present) surrounding the seed.
- Oxygen, which is needed for aerobic respiration.
- A suitable temperature to enable enzyme activity within the seed.

The two main centres of activity in the germinating seed are:

- the **food storage areas** (endosperm or fleshy cotyledons).The following hydrolytic reactions (digestive reactions) occur in the food storage areas:

  1. proteins $\xrightarrow{\text{protease enzymes}}$ amino acids
  2. starches $\xrightarrow{\text{alpha-amylase enzymes}}$ maltose
  3. maltose $\xrightarrow{\text{maltase enzyme}}$ glucose
  4. lipids (oils) $\xrightarrow{\text{lipase enzymes}}$ fatty acids and glycerol

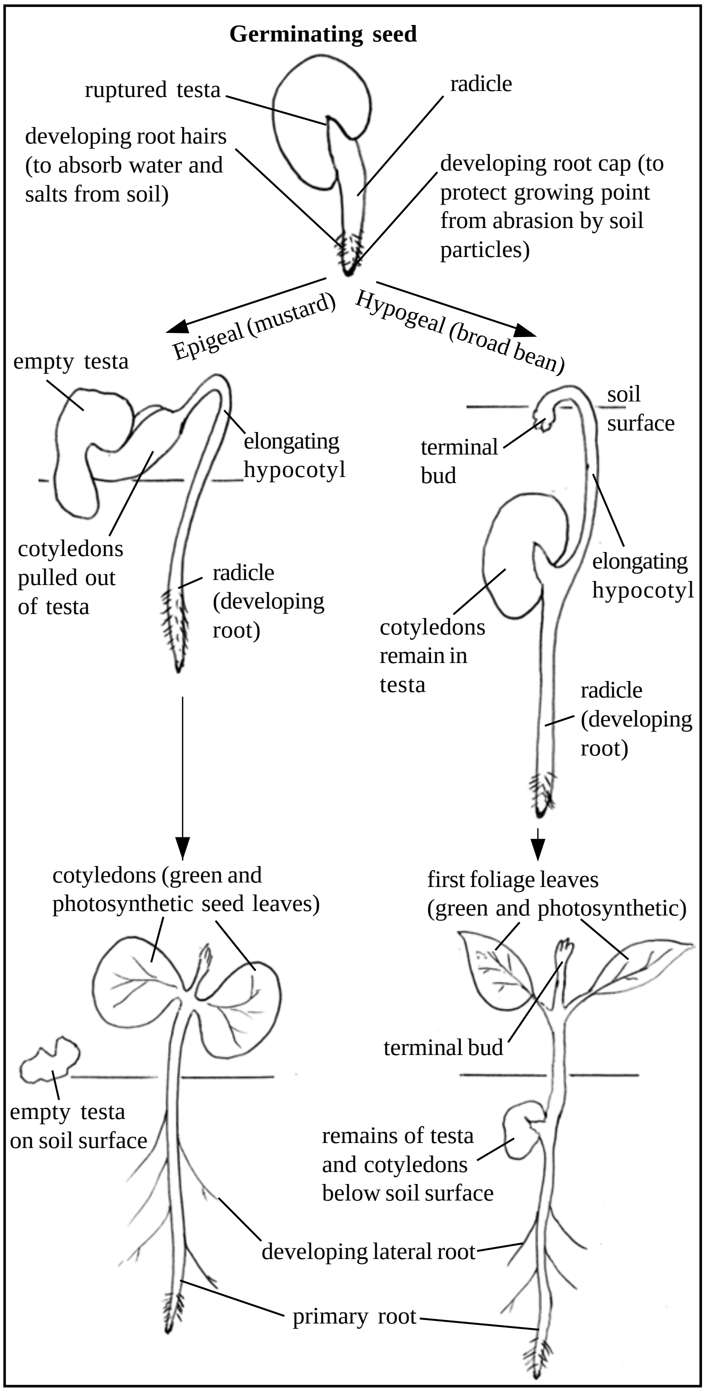
  These are all **catabolic** (breakdown) processes and the products are translocated in solution to the growing areas in the embryo.
- the **growth centres** of the embryo. Mitosis occurs in the apical meristems of the plumule and radicle. This process requires ATP energy obtained from the respiration (catabolism) of glucose, fatty acids and glycerol. **Anabolism** (synthesis) also occurs, for example, when new proteins (enzymes and structural components) are synthesized from amino acids and cellulose is synthesized from beta-glucose to make new cell walls.

After the seed has absorbed water and the testa has burst, the radicle is the first organ to emerge and grows down into the soil towards gravity (**positive geotropism**). It is closely followed by the plumule which grows up from the soil towards light (positive phototropism) and away from gravity (**negative geotropism**). The cotyledons behave in one of two ways:

- in some species, for example, broad bean, the cotyledons remain below the soil enclosed in the testa and shrivel as their food stores are used up to drive the germination process. This is called **hypogeal** germination.
- in other species, for example, mustard, sunflower and castor oil, the cotyledons are pulled by plumule growth above the soil surface, develop chlorophyll when exposed to sunlight, and become the first photosynthetic leaves. This is called **epigeal** germination.

Hypogeal and epigeal germination are illustrated in Fig 1.
The term **hypocotyl** is the part of the plumule below the cotyledons. The term **epicotyl** is the part of the plumule above the cotyledons.

Fig. 1. Hypogeal and epigeal germination



In hypogeal germination the terminal bud is protected from soil abrasion by the curving over of the epicotyl. In epigeal germination the terminal bud is protected by the surrounding cotyledons.

Non-endospermous seeds with fleshy cotyledons can germinate by epigeal germination, for example, castor oil seeds. The food reserves in the cotyledons are mainly used up by the time the cotyledons develop chlorophyll and become photosynthetic.

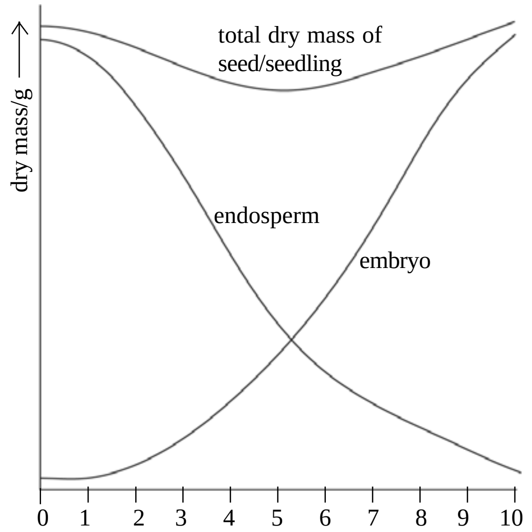
Viability

A seed that is capable of germinating to produce a healthy new plant is said to be '**viable**'. Commercial seed producers often state the expected percentage seed viability on the packets of seeds they sell. For example, if a packet containing 500 pea seeds was labelled as 98% viable, the purchaser could expect that 490 of the seeds would successfully germinate, providing:

- the correct physical conditions for germination were present,
- the seeds had been stored correctly,
- the seeds had received the correct conditions for dormancy and vernalisation.

Practice Questions

1. The graph below shows the relative changes in dry mass of embryo and endosperm during the germination of broad bean seeds.



(a) Explain the changes which occur, during the 10 day germination period, in the dry mass of
(i) the endosperm, **4**
(ii) the embryo, and **4**
(iii) the seed (total dry mass). **4**

(b) Specify the catabolic and anabolic processes involved in germination. **4**

Total 16

2. (a) Suggest three reasons why it is important for a dry seed to absorb water to allow germination. **4**

(b) What is 'vernalisation' and why is it important for seeds to be 'vernalised'? **3**

(c) Since the 1980s astronauts have been trying to germinate seeds in space. What difficulties might this cause? **3**

Total 9

3. The results of an experiment on germination in peas showed that in the first three days of germination there was a 43% decrease in total dry mass. 40% of the initial total mass of the peas was found to be due to water content. The initial total mass of the peas was 450 g.

(a) (i) Calculate the initial total dry mass of the peas. Show your working. **2**
(ii) Calculate the mass of dry matter remaining after the first three days of germination. Show your working. **2**

(b) (i) Why does the dry mass fall during germination? **2**
(ii) When would an increase in dry mass occur? Explain your answer. **2**

Total 8

Answers

1. (a) (i) enzymes mobilise food reserves by hydrolysis/digestion;
starch to maltose using amylases/maltose to glucose using maltase;
proteins to amino acids using proteases/lipids(oils) to fatty acids and glycerol using lipases;
products of digestion translocated to growing points of embryo and so dry mass of endosperm decreases; **4**
(ii) dry mass of embryo increases due to accumulation of food translocated from endosperm;
(dry mass also increases) due to synthesis of proteins from amino acids;
forming new cells/cell components/enzymes;
(dry mass also increases) towards end of period due to photosynthetic products formed after development of chlorophyll in first leaves/cotyledons; **4**
(iii) drop in total dry mass over first 5/6 days due to aerobic respiration;
uses up glucose of endosperm and embryo for energy/ATP synthesis;
photosynthetic sugar synthesis starts around day 7 in first green leaves/cotyledons;
when rate of photosynthesis exceeds rate of respiration there will be a net gain in dry mass; **4**

(b) <u>catabolic:</u>
hydrolysis/digestion of food substances in the endosperm/fleshy cotyledons;
respiration in the embryo/endosperm;
<u>anabolic:</u>
synthesis of proteins in embryo;
synthesis of chlorophyll in first leaves/cotyledons; **4**

2. (a) to cause swelling so that the testa bursts;
to dilute inhibitory growth substances/abscisic acid/cytokinins/gibberellins;
water is required to dissolve enzymes before they can act;
water is required for hydrolysis reactions when food reserves are digested;
soluble food reserves are translocated in solution/water; **max 4**

(b) the subjection of seeds/flower buds to a period of cold before they can germinate/flower;
activates gibberellins which stimulate seed to synthesise amylase/starch digesting enzymes;
(in seasonal climates) prevents seeds germinating until favourable temperature conditions return; **3**

(c) ref to zero gravity in space;
thus no geotropic responses so radicles and plumules will tend to grow in all directions;
difficult to keep soil/growth medium/ water in one place so hard to provide a specific surface for seeds to germinate on;
no air/oxygen in space so must be grown in air-tight containers;
allow any other reasonable suggestions; **max 3**

3. (a) (i) $\frac{450 \times 60}{100}$; = 270g; **2**

(ii) $\frac{270 \times 43}{100}$ = 116.1g; 270 - 116.1 = 153.9g; **2**

(b) (i) aerobic (and anaerobic) respiration;
uses up glucose, fatty acids/glycerol (from starch and oils); **2**
(ii) when the cotyledons/first foliage leaves appear and develop chlorophyll;
enabling photosynthesis to make sugars/other named products; **2**

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