	Monocot seeds	Dicot seeds
3.	Usually endospermic.	Usually non-endospermic (except castor seed).
4.	Germination usually hypogeal, except in onion.	Germination usually epigeal, except in some dicots such as pea, gram.
5.	Primary root soon disappears and is replaced by adventitious roots arising from the base of the stem.	Primary root develops from the radicle and persists through the life of the plant.

6.3.2 Germination

To the seed analyst, **germination** is 'the emergence and development from the seed embryo of those essential structures which, for the kind of seed provided, indicate the ability to produce a normal plant under favourable conditions' (Grabe 1970:1126). Not all germinating seeds produce normal seedlings; the percentage of germination is expressed on the basis of normal seedlings only. Seeds present two modes of germination based on the behaviour of the cotyledons or storage organs.

1. Epigeal germination. (*epi* 'above' and *geos* 'earth'). The cotyledons come out above the soil surface and generally turn green and act as first foliage leaves (Fig. 6.2-top). This type of germination is characteristic of groundnut, bean, cotton, sunflower, and castor seeds.

2. Hypogeal germination. (*hypo* 'beneath' and *geos* 'earth'). The cotyledon(s) do not come above the soil surface (Fig 6.2-bottom). This type of germination is found in gram, chickpea, pea, maize, wheat, and barley.

Conditions necessary for germination. The essential conditions for germination are (1) water, (2) air, (3) temperature, and (4) light.

WATER. Water is a basic requirement for germination. The absorption of water softens the seed coat, causes the embryo to swell, initiates enzymatic action, and bursts open the softened seed coat. Water makes the seed coat permeable to gaseous exchange and renders the insoluble food substances soluble by the action of enzymes. Water carries the soluble substances (solutions) to the growing points of the embryo.

AIR. Air is composed of about 20% oxygen, 0.03% carbon dioxide, and about 80% nitrogen. Access of oxygen to seeds is essential, because respiration (involving the absorption of oxygen and release of CO_2) is always very active in germinating seeds. Seeds sown near the soil surface get plenty of oxygen, in contrast to deep-sown ones. In waterlogged soils there is a lack of oxygen and seeds fail to germinate.

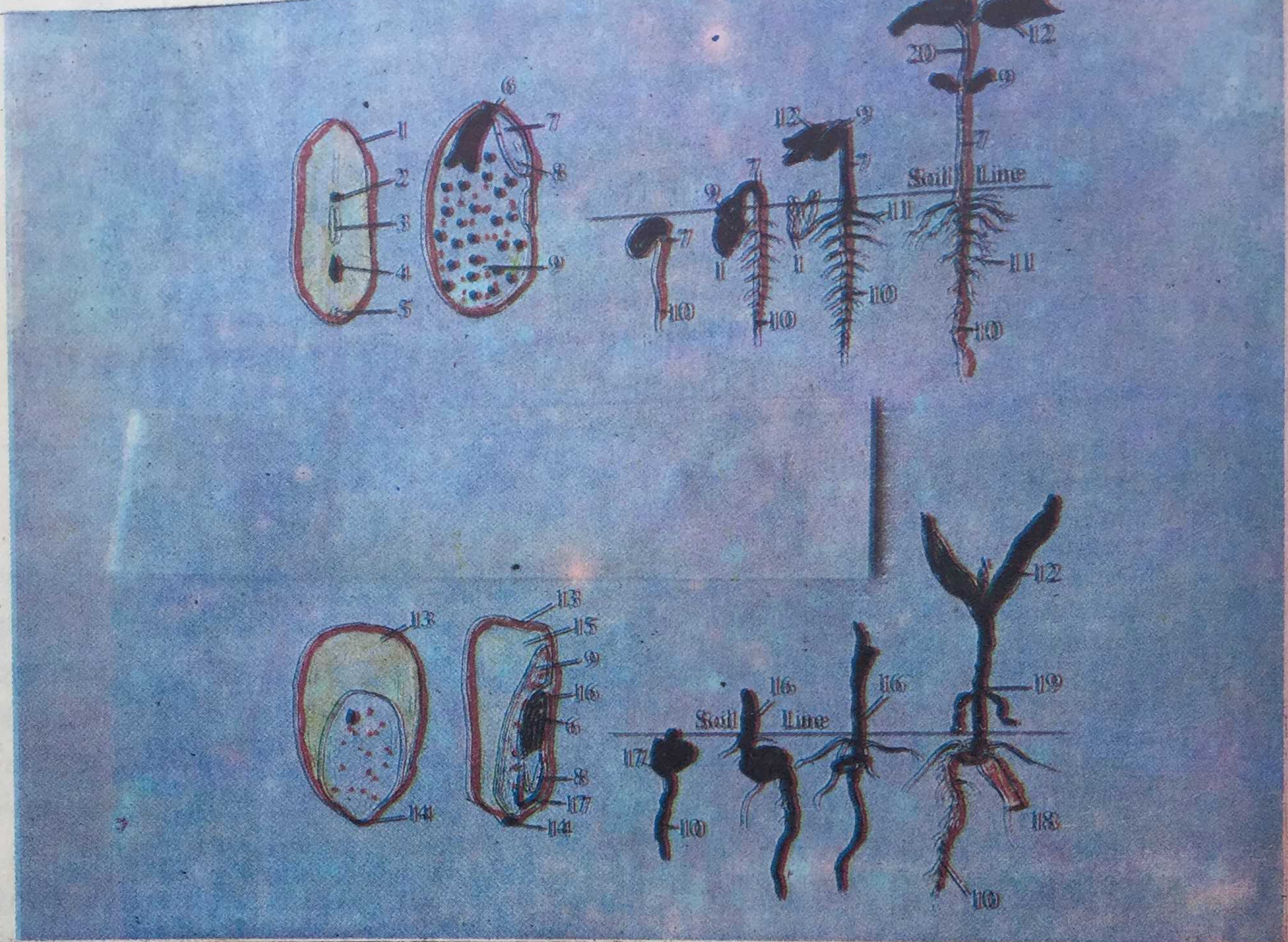

Figure 6.2 Epigeal (top) and hypogeal (bottom) germination. Reprinted with the permission of Macmillan College Publishing Company from *Principles of Seed Science and Technology*, 2/e by L. L. Copeland and M. B. McDonald. Copyright 1985 by Macmillan College Publishing Company, Inc.

Figure 6.2

TEMPERATURE. Each kind of seed has a minimum temperature below which germination does not occur, an optimum temperature at which germination takes place most rapidly, and a maximum above which germination totally stops. The optimum germination temperature for most seeds is between 15 and 30°C. For most species, the maximum temperature is between 30 and 40°C, and the minimum temperature is near the freezing point.

LIGHT. A small quantity of light is also required for the seeds of certain species to germinate. These species include tobacco, lettuce, pine, and several others.

Processes of germination. The major processes which most viable seeds undergo during germination are:

1. Water imbibition
2. Enzyme activation
3. Initiation of embryo growth
4. Rupture of seed coat

1. WATER IMBIBITION. Uptake of water by seeds is called **imbibition**. Imbibition depends upon three factors: composition of the seed, permeability of the seed coat, and availability of water. In addition to these factors, physical properties of soils like retention and conductivity of water are also important. Moisture exchange takes place between seeds and soil particles, and when sufficient moisture is available in the immediate vicinity of the seed, imbibition will continue.

2. ENZYME ACTIVATION. The process of water imbibition by the seed 'turns on' and accelerates metabolic processes. These processes lead to the activation of the embryonic axis and accelerate the essential process of respiration. Respiration provides energy by oxidizing glucose through complicated processes involving the breakdown of complex reserve materials such as starch and other complex carbohydrates, fats, oils, and proteins into simple translocatable forms which makes them available for germination. This process is called mobilization of reserves.

3. INITIATION OF EMBRYO GROWTH. The acceleration of respiration during imbibition and mobilization of organic reserves provide energy for germination, the initiation of embryo growth. Growth occurs as a result of cell elongation, expansion, and division. For most seeds, cell division and elongation occur in the embryonic radicle or root.

4. RUPTURE OF SEED COAT. With some seeds, cell elongation is sufficient to rupture the seed coat and cause the radicle to emerge. In other seeds, both cell elongation and division are involved in the emergence of the radicle. Beginning in the radicle part of the embryonic axis, active growth then spreads to the plumule, which will develop into the stem, leaves, and branches of the plant.

5. SEEDLING ESTABLISHMENT. The developing radicle or root responds positively to soil gravity and grows downward, whereas the plumule responds negatively to gravity and grows upward. During emergence, reserves are continuously drawn from the storage tissues, and this process goes on until the reserves are exhausted and decay of the cotyledons/endosperm takes place. When the supply of nutrients from the exhausted cotyledons is discontinued and the roots are anchored, the seedling begins to take up water and manufacture most of its own food. It thus becomes independent of the exhausted storage tissues, which completes the process of germination.

Media for germination tests.

SOIL AND ARTIFICIAL COMPOST are the principal media for germination and plant growth. It is, however, very difficult to standardize these media for germination tests as the amounts of nutrients and essential substances present vary. Sometimes undesirable substances may exert toxic effects on the seeds and seedlings, which then fail to express their full vigour. Water should be added carefully until the consistency of the soil is such that the soil ball formed by squeezing it in the palm of the hand is easily broken when pressed between two fingers.

PAPER (BLOTTER) should be of good quality and free of toxic substances. It is often advisable to soak the paper in water for two to four hours to moisten it evenly and to remove any water-soluble toxic substances which may be present. Blotter paper may be used in the following ways.

- TP *(top of paper/blotter)*: Seeds are germinated on top of one or more layers of a germination paper (blotter) in either a petri dish or a plastic box.
- BP *(between papers/blotter)*: The seeds are germinated between two or more layers of germination papers.
- PP *(pleated papers/blotters)*: A germination paper or blotter strip is pleated longitudinally into 10–50 pleats, which may be stapled at both ends. Seeds are placed in the pleat and sufficient water is added to moisten the blotter paper well.
- T *(toweling)*: Paper toweling is used either as folded towels or as rolled towels in horizontal or vertical position.

SAND. Standard testing sand is pure silica and possesses certain characteristics desirable in a germination medium: (a) chemical inertness; (b) uniformity of texture; (c) maintenance of texture on handling and heat sterilization; (d) structure suitable for growth and germination of seeds; and (e) not crust-forming on drying.

6.3.3 Dormancy

Seed **dormancy** is the state of inhibited germination of seeds with viable embryos in conditions conducive to plant growth. A dormant seed is one which fails to germinate under conditions favourable for germination of non-dormant seeds of the same kind. Factors responsible for dormancy include:

1. Seed coat characteristics
   a. Impermeability to water
   b. Impermeability to oxygen
2. Embryo characteristics
   a. Dormant embryo
   b. Immature or rudimentary embryo
3. Light
4. Inhibitors

An *impermeable seed coat* does not allow water to be absorbed by the seed, and also restricts gas exchange. Thus the non-dormant embryo is unable to receive essential water and gases. This type of dormancy is found unable to receive essential water and gases. This type of dormancy is found in Leguminosae, Malvaceae, Compositae, and Gramineae. *Embryo dormancy* is a complicated condition in which the entire embryo or part of it is dormant. This type of dormancy is poorly understood and is found in trees, shrubs, and vegetable species.

Light is an important factor for the germination of some seeds, particularly when they are freshly harvested. Some Gramineae species and *Nicotiana* spp., etc. are particularly susceptible to the effects of the light factor. The germination process of some seeds is inhibited by the presence of some chemical substances. It is possible that these inhibitors are involved in all types of dormancy. Specific inhibitors have been isolated from *Avena*, *Oryza*, and *Beta* seeds.

Methods of breaking seed dormancy. The dormancy or rest period of seeds can be shortened by providing the natural factor which helps the seed to germinate. Various methods have been evolved to break seed dormancy, some of which are described below.

SCARIFICATION. Any treatment, physical or chemical, that makes the seed coat permeable, is known as **scarification**. This operation aims at rupturing, scratching, or puncturing the seed coat in one or the other of the following ways.

a. *Impaction.* Hitting the seed with force against a hard surface will cause fractures in the seed coat.

b. *Abrasion.* The seeds are abraded against a rough surface, causing minute scratches in the seed coat.

c. *Acid scarification.* Seeds are soaked in concentrated sulphuric acid for 10 minutes to 1 hour (depending on the kind). The permeability of the seed coat is increased by the action of the acid.

d. *Extreme cold.* Temperatures of the order of −50°C will cause fractures in the seed coats of dormant grass seed species such as *Triticum* and *Hordeum*.

e. *Heat.* Temperatures in the range of 60–80°C for 1–1½ hours are effective for some hard seeds like alfalfa.

f. *Hot water.* Seeds are soaked in water at 80°C for 1–5 minutes (depending upon kind of seed) before putting them out for germination. This is an effective method of breaking hard seededness in legumes.

STRATIFICATION. Stratification is the practice of exposing imbibed seeds to cool temperature conditions for a few days prior to germination in order to break their dormancy. Imbibed seeds with dormant embryos are subjected to low temperature stratification (2–5°C for 15–20 days). This method is effective for cherry and mustard, as well as many grass and woody species.

LIGHT. Some seeds, e.g. lettuce, some Gramineae species, and *Nicotiana* spp., do not germinate in the dark and need continuous or periodic exposure to light.

GROWTH REGULATORS AND CHEMICALS. Seed dormancy may be broken with the application of low levels of growth regulators and chemicals. Gibberellic acid (GA_3) and kinetins, potassium nitrate (KNO_3), thiourea, ethylene, chlorohydrin, hydrogen peroxide, and sodium hypochlorite in low concentrations have proved very useful.

6.4 Seed production

New varieties seldom occur as a result of chance; they are usually produced by knowledgeable and skillful plant breeders, but the amount of seed produced is usually small, sometimes a handful of seed (Carter 1965). Seed obtained from selected individual plants of a particular variety needs to be purified and multiplied in such a way as to maintain its genetic purity. This handful of seed, called **nucleus seed**, provides the basis for breeding and production programmes. The varietal purity of prebasic, basic, and certified seed classes largely depends upon the quality of the nucleus/breeder seed.

Since breeder seed is the source for the initial and recurring increase of seed of a newly developed or introduced variety, it has to pass through several stages of multiplication to reach the level of certified seed. Certification begins with breeder seed and ends several generations later with **certified class** seed in a continuous cycle. Thus seed production is *limited* to a restricted number of generations from the original seed stock (breeder seed).

6.4.1 Breeder-seed production in self-pollinated crops

In order to maintain the genetic purity of a promising line, off-type seeds are removed by negative selection during mass increase. It is very easy to select good plants, check their progenies, and bulk the seed of those progenies which are pure and true to type. The seed thus obtained is called breeder seed. The method of producing it is explained below using wheat as an example.

Selection and multiplication.

1. **SELECTION OF EARS**

a. In a plot laid out for seed multiplication of a promising line, some 300–5000 ears are selected based upon the unique characters of the varieties.