Seed Germination

FIGURE 31

An interior spruce seed splitting at the micropylar end, the junction of the upper and lower seed surfaces.

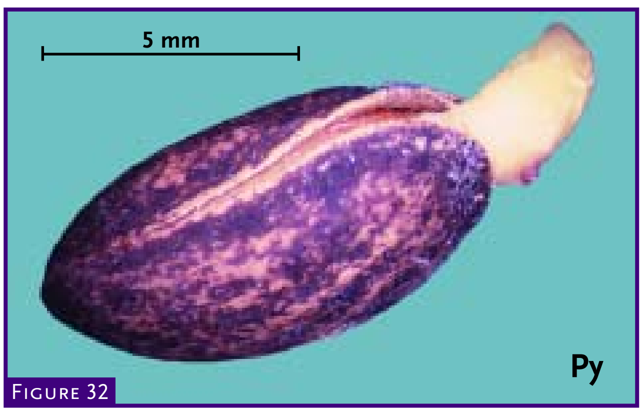

FIGURE 32

A germinating seed of ponderosa pine showing radicle emergence.

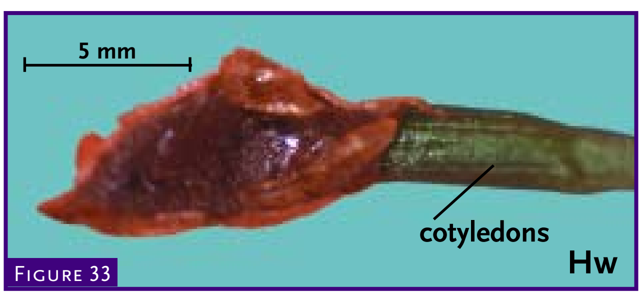

FIGURE 33

A germinating seed of western hemlock with cotyledons beginning to emerge.

Seed germination is recognized by the emergence of the radicle from the seed. The cotyledons may or may not emerge during germination. When the cotyledons emerge, germination is termed **epigeal** and this is characteristic of the conifers. When the cotyledons do not emerge, germination is termed **hypogeal** (e.g., oak). The germination process is actually initiated upon imbibition of the seed components. Imbibition is accompanied by an immediate release of gases and the initiation of respiration, enzyme activity, protein synthesis, and organelle activity within the embryo[8,10].

Germination is an energy requiring process and the megagametophyte supplies the energy and nutrients for embryo growth and emergence. Lipids, proteins, and reserve phosphorous compounds are used for the synthesis of carbohydrates, and various structural and soluble compounds in the germinant[10]. The breakdown of protein bodies precedes the breakdown of lipid bodies[38], releasing free amino acids exported immediately to the embryonic axis[23].

The initial sign of germination is radicle emergence, which results from both cell elongation and cell division at the root apical meristem[8]. Water is required for cell expansion and development and free water should be available during the rapid growth phase that occurs during germination. The pressure exerted by the radicle causes a splitting of the seed coat at the micropylar end along the junction that joins the two seed surfaces (FIGURE 31). The radicle will emerge through this opening causing further splitting of the seed coat (FIGURE 32). Radicle elongation will continue, followed by growth in the cotyledons and hypocotyl. This, in turn, will force the cotyledons to begin to emerge (FIGURE 33). A longitudinal section through a subalpine fir germinant illustrates the green coloration of photosynthetic parts and a prominent shoot apical meristem. The megagametophyte has become discoloured and softened by the translocation of its reserves to the growing embryo (FIGURE 34).

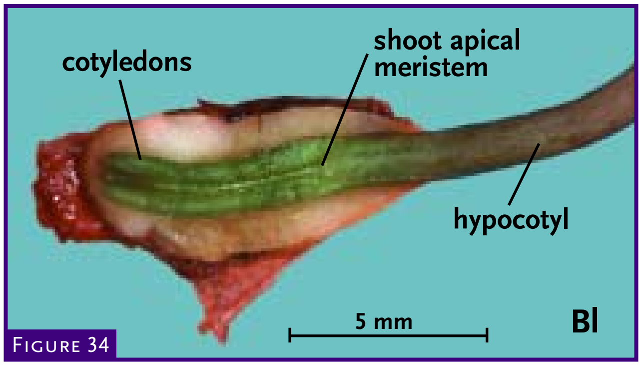

Figure 34

Longitudinal section of a germinating subalpine fir seed illustrating the deteriorating megagametophyte.

As growth of the cotyledons continues, the seed coat will be elevated and will eventually be shed (Figure 35). Prior to seed coat shedding seed morphology does not appear different from the exterior, but many anatomical changes have occurred within the seed (Figure 36). In the dissected seed of ponderosa pine the megagametophyte has almost completely been utilized and the main remaining feature is the megaspore cell wall. The nucellus is obvious and extends over about one quarter of the megagametophyte. On the interior of the seed coat one can see how the inner layer has torn away from the much thicker stony layer. The hypocotyl and radicle are not visible (Figure 36).

The fully expanded cotyledons maximize sunlight reception and photosynthesis to provide energy to the germinant for growth after the reserves of the megagametophyte are utilized. The hypocotyl is also photosynthetic[37]. Maturation of both cotyledons and hypocotyl tissues involves differentiation of **stomata** and parenchyma cells with abundant chloroplasts[37]. Stomata contain **guard cells** in the epidermis that act to regulate the exchange of gases and water vapour between the plant and the external atmosphere. The location, number and time of initiation of stomatal lines varies by species. Figure 37 presents four cotyledons of subalpine fir that have been dissected from a germinant. The white flecks are the stomata that are filled with wax and for this species they are arranged in lines on the upper surface. The apical meristem is apparent in the centre of the cotyledons and will produce all subsequent stem growth above the cotyledons (**epicotyl**) through cell division and expansion.

Figure 35

Germinants of Douglas-fir in the nursery prior to seed coat shedding.

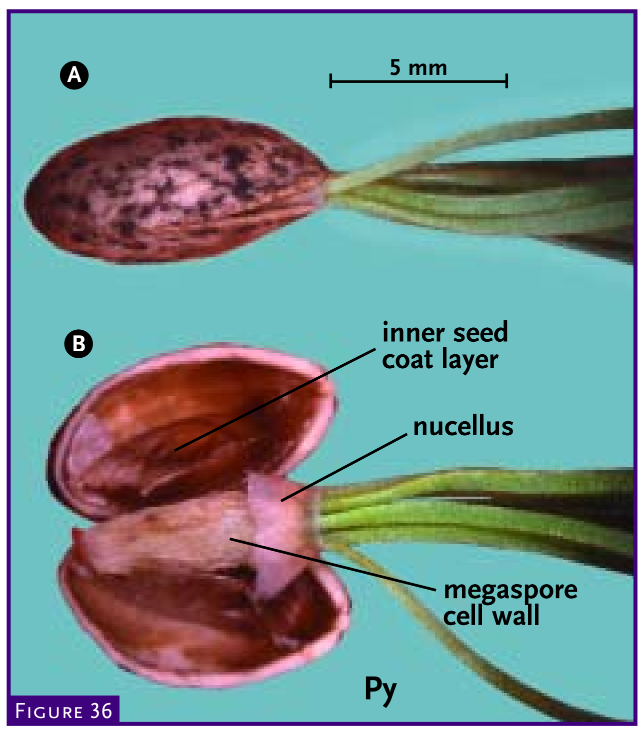

Figure 36

Cotyledon emergence of ponderosa seed (A) from the exterior and (B) from the interior displaying the structures remaining at this stage.

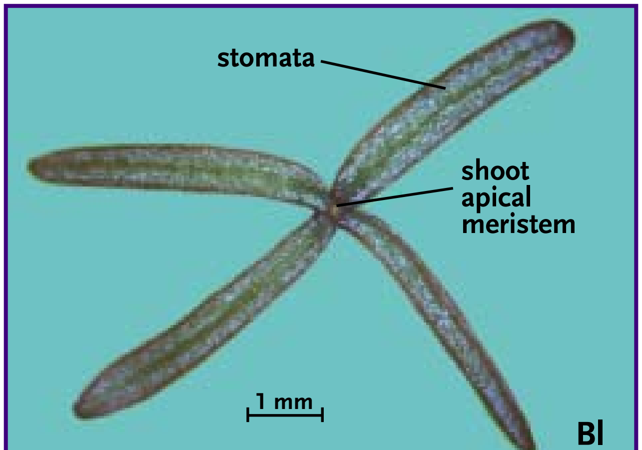

Figure 37

Four cotyledons with stomatal lines surrounding the shoot apical meristem in subalpine fir.

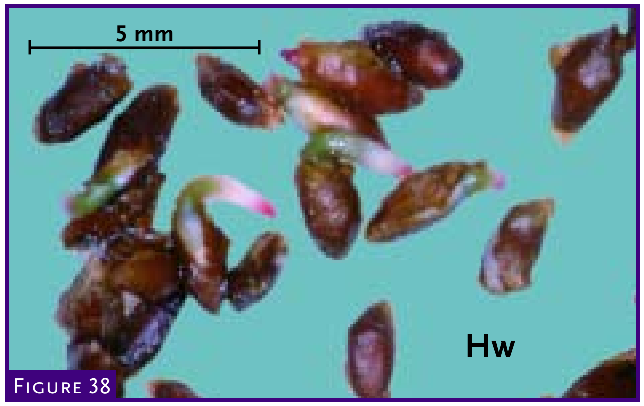

Figure 38

Germinating seed of western hemlock displaying the characteristic red-tipped radicles.

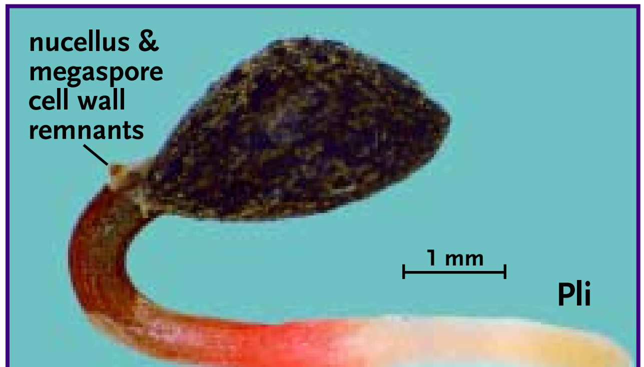

Figure 39

A germinating seed of lodgepole pine.

Figure 40

A germinating seed of interior spruce.

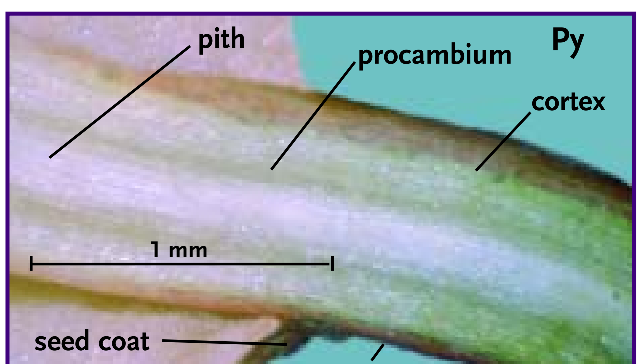

Figure 41

A magnified view of the tissues present in the hypocotyl during germination of a ponderosa pine seed.

The typical reddish radicle tips found in western hemlock are displayed at various stages of germination in Figure 38. The green tissue evident in the larger germinants is due to the development of chloroplasts in the hypocotyl. In lodgepole pine seed anthocyanins are present in the hypocotyl, but the radicle tip is white (Figure 39). Note the remnants of the nucellus and megaspore cell wall above the point of radicle emergence. The radicle of interior spruce initially does not appear pigmented, but as the germinant advances the hypocotyl will turn green (Figure 40). The intensity and colour of the hypocotyl varies by species, but can be affected by pH[16]. Abnormal hypocotyl colouring may be a clue to check the pH of your growing media.

Figure 41 details a ponderosa pine germinant. The central pith remains unpigmented while the development of chloroplasts within the cortex produce the green colour in the hypocotyl. The cortex tissue that is still contained within the seed does not contain differentiated chloroplasts. The darker area between the pith and cortex is the procambium. This area will be differentiating rapidly to keep up with the increasing demands for water and photosynthate transport. The outer epidermal layer has accumulated pigments where it resides outside the seed.

FIGURE 42

Germination of pelleted seed of western redcedar.

FIGURE 42 shows how pelleted western redcedar radicles must penetrate both the seed coat and then the pellet before they can become established. This will slow germination, but most nurseries consider pelletting a necessity for seeding western redcedar because of the light weight, winged, and irregularly shaped seed. The species is not imbibed or stratified before pelletting. In FIGURE 43, two germinants of western redcedar are shown, one with a pellet present and one with it already shed or dissolved. Notice the amount of epicotyl growth above the cotyledons.

Abnormal germinants generally constitute a small percentage (less than 1%) of a seedlot. Abnormal germinants are defined in the ISTA International Rules for Seed Testing[24] and are not included in the germination percent recorded. The most common abnormal type is the reversed embryo or 'breached' germinant as displayed in FIGURE 44. In this situation the cotyledons emerge first before the radicle. It is unlikely that this germinant would survive due to the difficulty in establishing a root system. A description of germination variables is included in Appendix 4.

FIGURE 43

Germinants of western redcedar in the nursery prior to pellet breakdown.

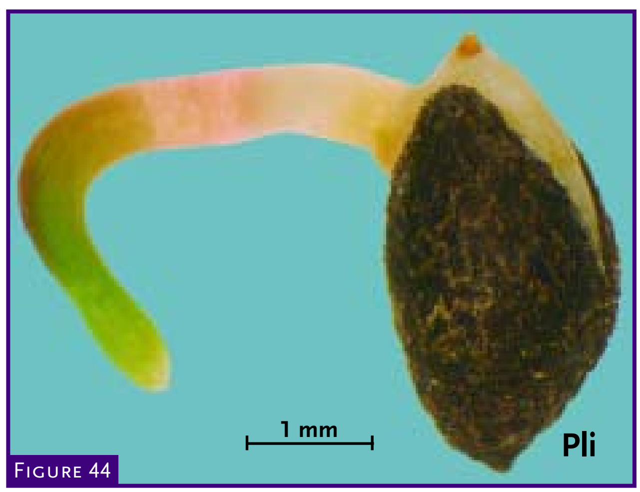

FIGURE 44

A reversed or 'breached' embryo emerging with the cotyledons before the radical from a lodgepole pine seed.

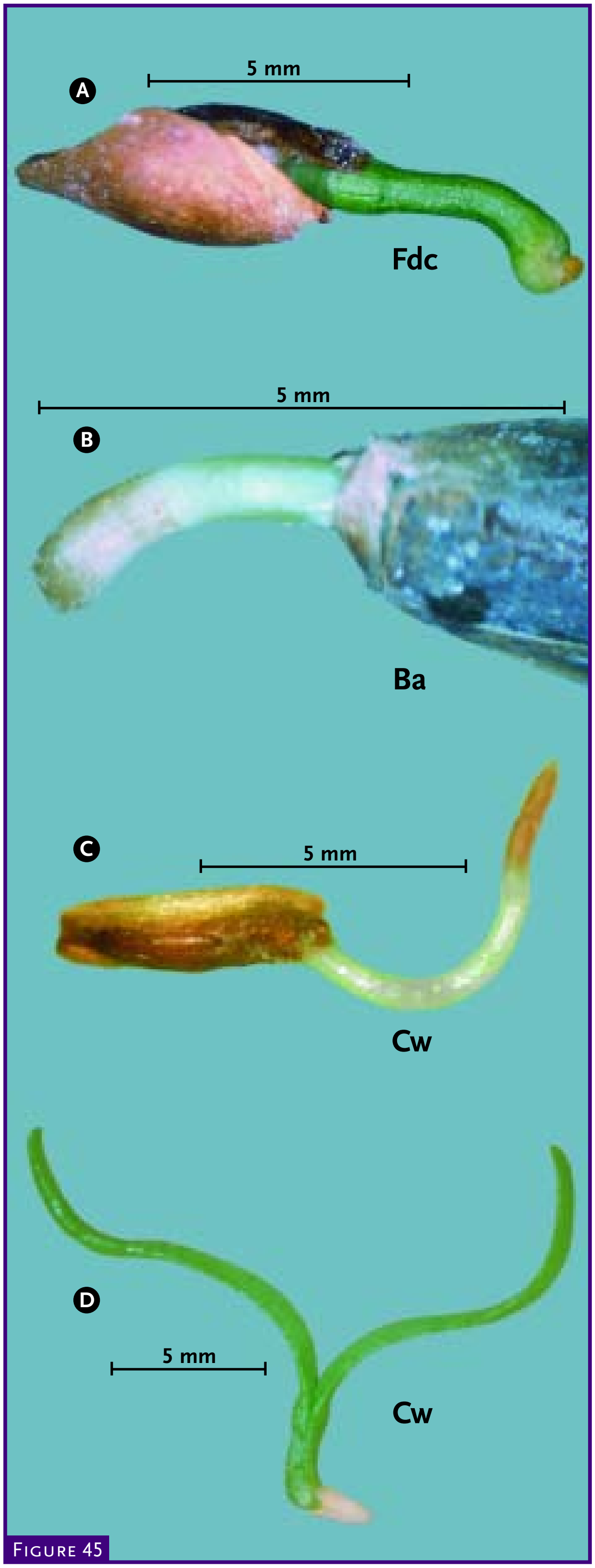

FIGURE 45

Examples of stunted radicles in (A) Douglas-fir, (B) Amabilis fir, and (C), (D) western redcedar.

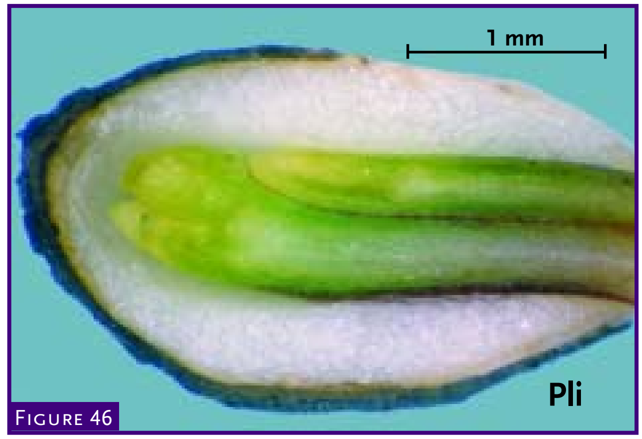

FIGURE 46

Advanced development of two embryos in an interior lodgepole pine seed.

Another common abnormality is the stunting or retarding of tissues, generally the hypocotyl or radicle. This may take several forms and FIGURE 45 displays the variety of stunted radicles found in several species. The possible reasons for stunting are physical impacts destroying the root apical meristem, a deleterious mutation, or pathogen infection.

A rare situation is the development to maturity of two or more embryos in a seed (FIGURE 46). This can occur through the process of polyembryony, which is common in conifers. Usually one embryo becomes dominant and the other degenerates at an early stage. Various types of polyembryony occur and a detailed anatomical analysis of polyembryony can be found in Berlyn[8].