Deer antler: an animal organ or a plant?

With specific comparison between antler and ginseng

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Introduction

MORE than 10 million years ago, deciduous antler were already an integral part of the male cranial anatomy of most deer species (true deer, which cast their antlers, had evolved by the Miocene Period) (Chapman, 1975). The history of deer velvet antler as a derived medicinal in China goes back more than two thousand years (Kong & But, 1985). Why then do the authors raise this seemingly irrational question, "Deer antler: an animal organ or a plant?" The reason for this, we argue, that antler cannot even now be properly and formally classified in the animal kingdom! As a compromise, biologists describe antler a "unique animal organ". Throughout our studies of antler biology, we have found some distinctive similarities in biological features between antler and some kinds of plants. We propose therefore that it may not be so far fetched to classify antler as a kind of plant, or something between animal and a plant, or an animal organ that resembles plants.

Literature search

With this concept in mind, we began to review the relevant literature. Our proposal that there is an observable correlation between antler and some kinds of plants is certainly not the first. As early as the year 1758, Buffon thought that antler growth and development were like those of tree branches. Barr (1807) deemed that antler was a kind of plant which was implanted on a deer's head (quoted from Noback and Modell, 1930). Modell and Noback (1931) reported that antler grew in a way somewhat similar to a branch of a tree. The soft tissue at the tip might be compared with the terminal meristem of a plant, since it contained young undifferentiated cells in active proliferation. In China, antler pedicles (permanent frontal protuberances from which antlers grow and cast) are called 'grass roots'. Antler growth may have been considered as a kind of analogous to grass. In France, antlers are called 'bois', which means wood or tree; and velvet is called 'ecorce', which means bark.

Antler growth cycle

Before making the comparison between antlers and plants, the antler growth cycle must be reviewed first (Plate 1). Deer antlers are bony organs which are cast and fully regenerate each year. Antlers do not directly grow from the head of the deer, but instead form from permanent bony projections, or pedicles. Deer are not born with pedicles, these develop from the frontal bone (Figure 1A and 1B) when deer approach puberty (5-7 month old in Red deer *Cervus elaphus).* When pedicles grow to their species-specific height (about 5-6cm high in Red deer), first antlers generate spontaneously from the apices of these pedicles. This generation can be easily identified by a change in skin from typical scalp-like to velvet-like (Figure 1C), which is called velvet. After initiation, first antlers enter a rapid growing period. First antlers normally express as a single main beam and do not branch, hence they are called spikes (Figure 1D). When the rutting season comes, spike antlers become fully calcified, nerve and blood supply are terminated, and velvet is shed to expose bare bone. First antlers are cast in the next spring and regeneration of second antlers immediately follows (Figure 1E). From then on, annual development of subsequent antlers enters a well-defined cycle: old antler casting and new antler regeneration in spring, rapid growth and maturation in summer (Figure 1F), calcification and velvet shedding in autumn (Figure 1G and 1H). This cycle is precisely controlled by seasonal photoperiod change (Goss, 1983).

General comparison

The most obvious property which makes antler resemble some kinds of plants is the annual cycle of death (Figure 2A) and regeneration (Figure 1E), which is controlled by photoperiod. This property was considered as unique in the animal kingdom (Goss, 1983). However, it is a common sight in the plant kingdom, as demonstrated by deciduous twigs (Figure 2B) and leaves. The stems and leaves of perennial herbs die in autumn and regenerate in the next year's spring. The second property of antler is that its growth rate is biologically astonishing during the rapid growing period. For example, daily antler growth rate of Moose *(Alces alces)* is 2.75cm/day (Goss, 1970); for Sika deer *(Cervus nippon)* growth rates of 1.12 cm/day (Gao and Li, 1988) are recorded. To date, no animal organ is known that can be compared to antlers for such a prolific tissue growth rate. By contrast in the plant kingdom, this growth rate is relatively unremarkable. For example, during the jointing stage bamboo, corn, or sorghum, may have growth rates reaching 3-10cm/day! Antlers also sprout branches (tines) under strict controls of growth, position and timing along with the fast main beam rate of growth. This is very similar to the pattern of a tree growth. Moreover, antler growth centres are located in the apices of the main bean and tines (Figure 2C), like the apical meristems of trees or some other plants (Figure 2D). In sharp contrast, the horns grown by cattle, sheep, antelope and rhinoceros grow from the base

(Goss, 1983). Banks and Newbrey (1982b) proposed that the relationship of mesenchymal tissue cap to the differentiating tissue beneath it may be analogous to those relationships that characterise stem and root growth in angiosperms. The cap of mesenchyme is spatially and functionally similar to apical meristematic tissue. Histologically, although growing antlers consist of skin and cartilage (Banks and Newbrey, 1982a), they are very different from their somatic counterparts. Antler cartilage is highly vascularised unlike somatic cartilage which is essentially devoid of blood vessels. Antler velvet (Figure 2E), unlike somatic skin (Figure 2F), does not possess sweat glands and arrector pili muscle, but instead contains huge bi- or multi- lobed sebaceous glands and thickened epidermis.

Curiously the external appearance of some antler velvet (Figure 2G) resembles the grain pattern of wood (Figure 2H). Moreover, if the growing antler is amputated, a new antler bud will regenerate from the stump, which is rare in the animal kingdom, but common in the plant kingdom. For instance, when grass or chives are cut, the second crop will form again as a natural regeneration. In forestry, in order to promote seedling growth, the upper part of it is cut. Similarly, if the antler spike is experimentally removed above the coronet (the junction of pedicle and antlers), it will stimulate regeneration of bigger and branched antlers (Figure 3A). Sometimes, if the dead hard button does not drop off or cast in the spring, the regeneration of new antlers still takes place and 'bush-like' antlers result (Figure 3B).

Specific comparison

To reinforce the idea that antler is an animal organ or tissue that can be considered as mostly resembling plants, we'd like to make a specific comparison between antlers and plants. The plant, ginseng is selected not only as ginseng is also a highly regarded TCM, but also both ginseng and antler resemble each other very much in terms of general biology.

Firstly, a comparison of antlers (Figure 3C) to ginseng stems and leaves (Figure 3D) is valid. In spring, ginseng stems and leaves develop from ginseng roots, likewise incipient antlers grow from the apices of the pedicles. In summer, both ginseng stems and leaves and velvet antlers are at the fast growing period. In autumn, ginseng stems and leaves die; antlers become calcified and clean to become dead bones. Next spring, ginseng stems and leaves regenerate from the roots again, and new antlers reappear from the pedicles after the old dead antlers are cast (Figure 1E). Each year ginseng stems and leaves and antlers repeat their own cycle respectively. In addition, the branch numbers of both ginseng stems/leaves and antlers increase year by year.

Secondly, a pedicle (Figure 3C) may be compared to a ginseng root (Figure 3D). The Ginseng root can survive many years after it sprouts from the seed, likewise once a pedicle has formed it will survive on the deer head for the deer's whole life.

Thirdly, cells (antlerogenic cells) in the antlerogenic periosteum (Figure 3E) behave very similarly to ginseng seeds (Figure 3F). Previous studies have shown that the histogenesis of pedicles and antlers originates from the antlerogenic cells (Hartwig & Schrudde, 1974; Goss & Powell, 1985; and our unpublished results). Ginseng seeds which when planted in any kind of suitable soil give rise to a complete generation of ginseng roots, stems and leaves. When antlerogenic cells are implanted into any part of the deer body autologously, an ectopic pedicle and antler will form from them (Figure 3G) (Figure 3H, after Goss 1983). Antler antlerogenic cells in our view may be termed as "antlerogenic seeds".

The biological properties of antlers and ginseng are so similar to each other that one cannot help speculating that when the ancient Chinese decided to test if one product (ginseng or antler) possessed a medical effect, they may have been inspired by the biological similarity of the one to the other (ginseng or antler).

Discussion

Is there any particular point in demonstrating the plant-like properties of antlers? We believe the answer is precisely yes. Biologically, the origin and evolution of antlers is relatively unknown.

Can any information be obtained from the origin and evolution of some kinds of plants? Moreover, because of the existence of the unique organ, antler, is there any possibility that the demarcation line between the animal and the plant kingdoms had become confused in evolution? In addition, through such comparisons, new biological properties of antlers or certain species of plants might be found along with a consequent increase in our knowledge on plant/animal evolution. Economically, after new biological properties are discovered or knowledge gained, huge economic benefits may arise. For example, in the comparison between antlers and ginseng, ginseng stems/leaves are compared to antlers. Velvet antlers have high medicinal value in TCM, why not ginseng stems/leaves? So far only ginseng roots are used for medicinal purposes, whereas ginseng stems/leaves are discarded after they die in the autumn. If ginseng stems/leaves are harvested during their growing period, like velvet antler harvesting, then processed appropriately, a new ginseng product with high medical value might be developed.

The authors are recently aware that some Chinese ginseng experts have analysed ginseng stems/leaves and found them not only to be rich in the effective compounds of the ginseng roots, ginsengoside, but also to possess potent tonic effects. If this is true, the exploitable prospects and economic benefits of ginseng stems/leaves must surely surpass those of ginseng roots, especially since ginseng roots are normally harvested when they are about six years old, and they can be harvested only once. By contrast, ginseng stems/leaves can be harvested annually and renewably.

In conclusion, we are confidence to predict that as time goes by, more plant features of antlers will be revealed. The newly revealed plant features will make biologists face even greater challenge to find a proper position for antler classification in the animal kingdom!

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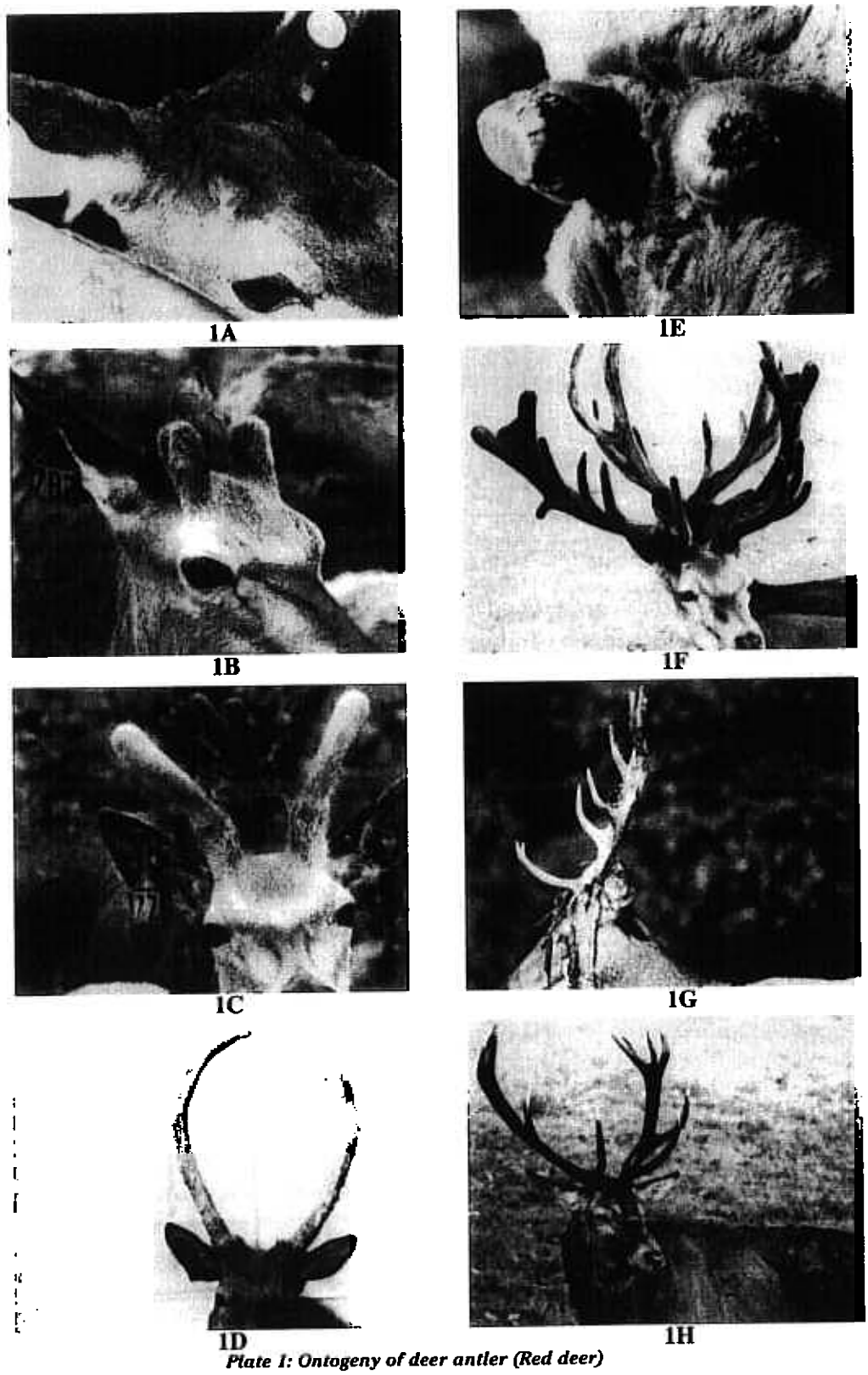

Plate 1: Ontogeny of deer antler (Red deer)

A-D:Pedicle formation and first antler generation

A. *Right side frontal lateral crest from a 5-month-old stag (in winter). Pedicles develop from the crests on reaching a threshold pubertal weight (late winter spring).*
B. *Pedicles of a 9-month-old stag (in early summer). Notice that the skin which envelops the pedicles is typical scalp skin.*
C. *First antlers (spike) from a 10-month-old stag (in summer). The junction of the pedicles and antlers can be easily discerned by differences in skin appearance and hair form.*
D. *Late stage spike velvet antlers (fully grown) from a 14-month-old stag (in early autumn). Notice that velvet dried on the antlers, blood and nerve supply to the velvet skin has been withdrawn. Antlers will strip this covering for the final emergence of the bony antler.*

E-H: Second and subsequent antler regeneration

E. *Annual antler regeneration in a 3-year-old stag (in spring). Notice that left side antler hard button remnant hard antler remaining following surgical velvet antler removal the previous season has shed and the wound has healed, with new velvet antler regeneration. The right side button is yet to cast. Normally both would cast within 24 hours.*
F. *Fully grown velvet antlers (summer) at ~120 days growth.*
G. *Velvet stripping from fully grown antlers from adult stags (in early autumn).*
H. *Exposed hardened, cleaned and polished antlers carried by adult stags (in late autumn and winter).*

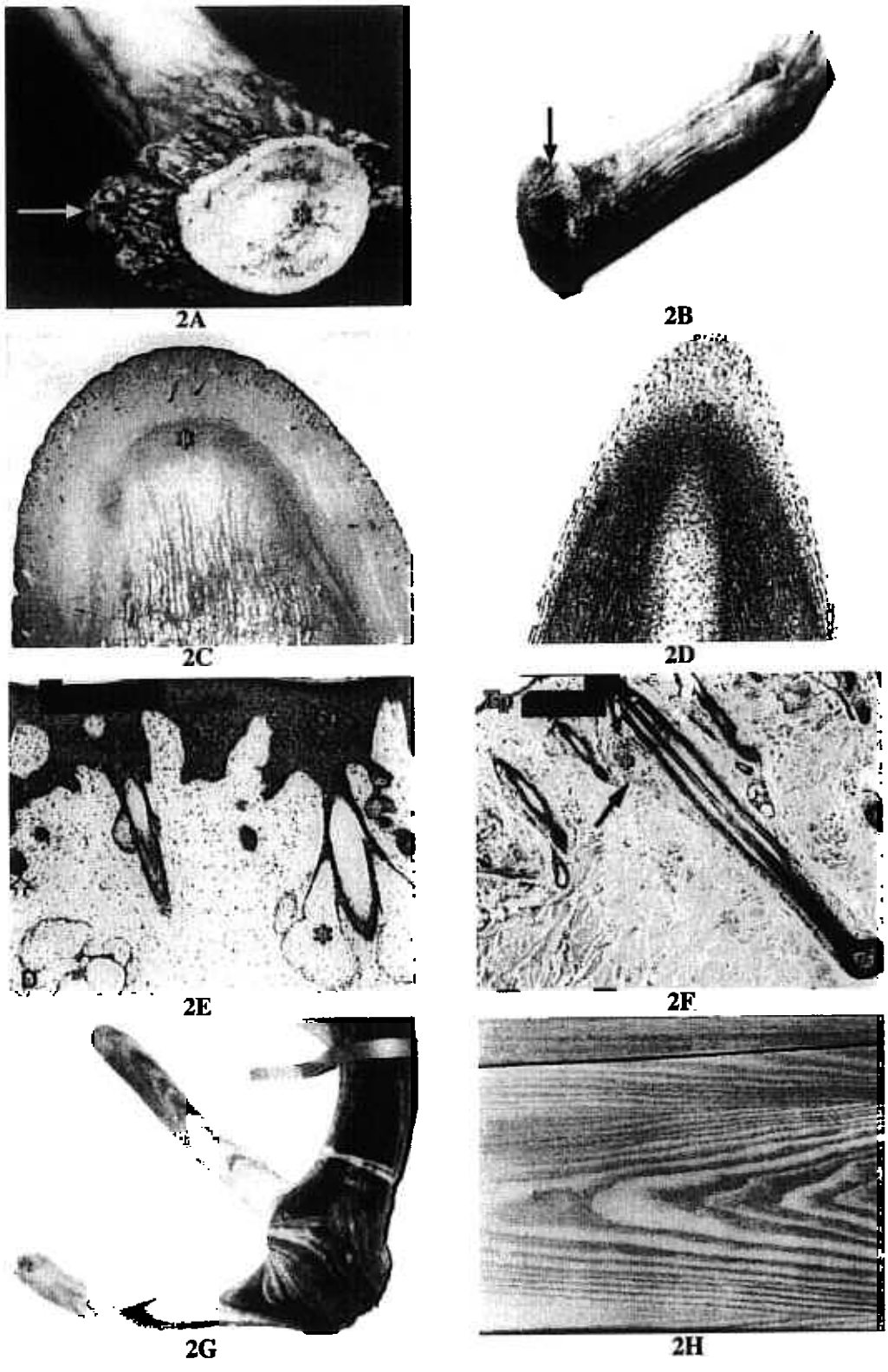

Plate 2: General comparison between antlers and plants

A and B: Casting surfaces and coronets.
(Key, asterist = casting surface; black arrow = coronet)

A *A cast red deer antler*
B *A cast oak tree twig*
C & D *Growth tips. (Key: asterist = growing centre)*
C *Tip of a growing spike antler (red deer)*
D *Tip of a growing bean root*

E and F: Histological structure of skin red deer types.
(Key: Ep = epidermis; asterist = sebaceous gland; white arrow = a de novo forming hair follicle; black arrow = arrector pili muscle; star = sweat gland)

E *Antler velvet skin, note the definitive thick epidermis and large sebaceous glands. Arrector pili muscle and sweat gland are not found.*
F *Deer scalp skin, note characteristic very thin epidermis and small sebaceous glands, arrector pili muscle and sweat glands.*
G & H *Grain pattern of antler velvet and wood.*
G *Harvested velvet antler (basal section, red deer), note hair and skin patterns.*

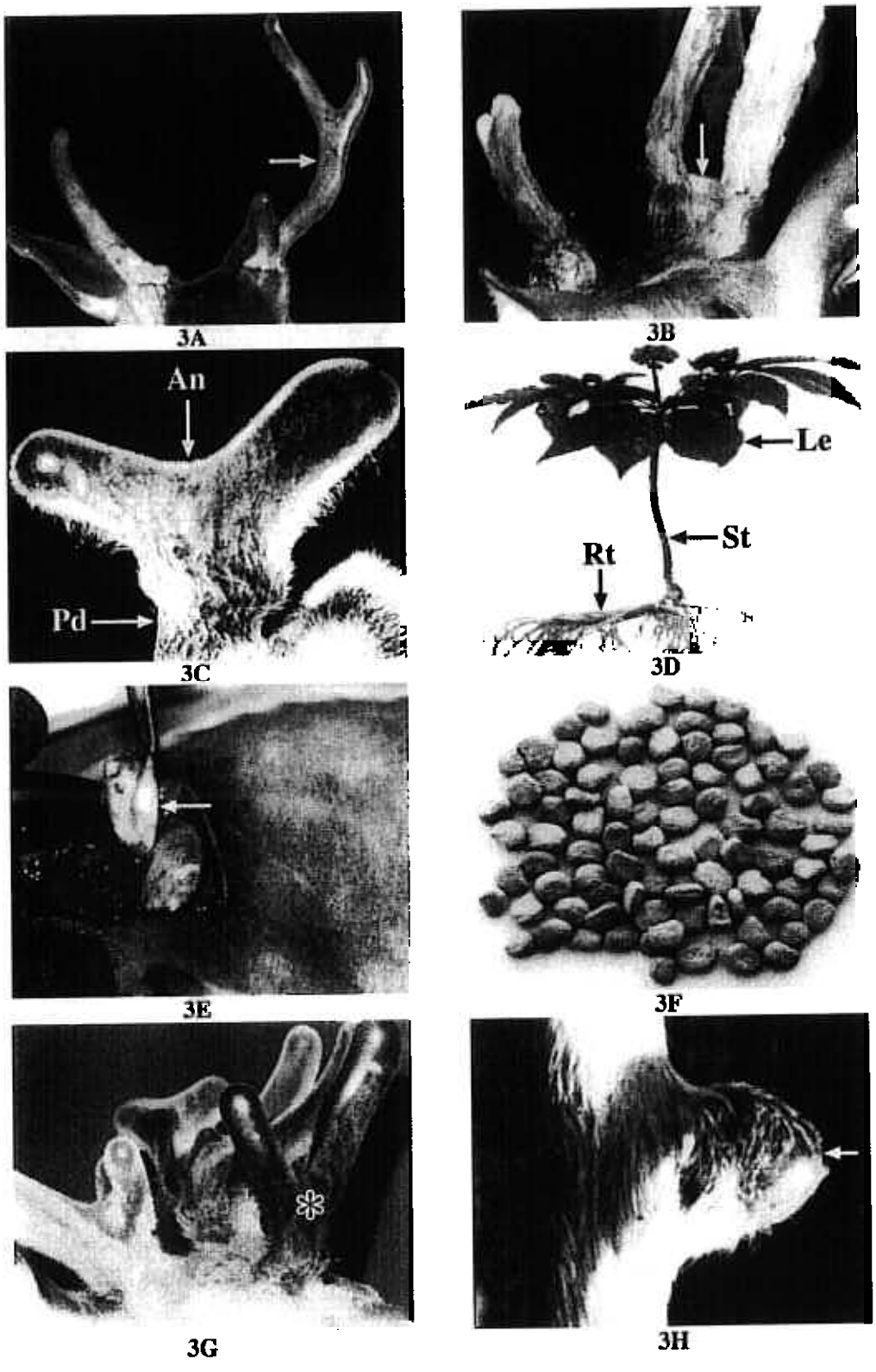

Plate 3: Antler and plant comparative features antlers and plants

1) Regeneration of antler features

A. First antlers from a young red deer stag. Notice that left side branched antler is the regenerated one after removing the original spike antler during its growth phase.

B. Growing antlers from a 3-year-old Red deer stag. Notice that the hard button did not drop off in spring, "bush-like" antlers regenerated from the pedicle and around the hard button.

2) Specific comparisons between whole antler and a ginseng plant;

C. Red deer antler and pedicle. (An = antler; Pd = pedicle)

D. Ginseng. (Le = leaf, St = stem; Rt = root)

3) Comparison of antlerogenic periosteum and ginseng seeds

E. Antlerogenic periosteum (arrow = in Red deer)

F. Ginseng seeds

G. An ectopic branched antler (asterist) formed from antlerogenic periosteum from a 3-year-old Red deer, transplanted to the frontal bone.

H. An ectopic antler (arrow) formed from the transplanted antlerogenic periosteum on a foreleg of a deer (after Goss, 1983).