THE BLOOD SUPPLY OF DEVELOPING LONG BONES
WITH SPECIAL REFERENCE TO THE METAPHYES

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Humphry (1858) described a dual blood supply to any long bone, periosteal vessels supplying the compact bone and the nutrient artery supplying the marrow. Weinmann and Sicher (1947) pointed out that the nutrient artery also supplied the central part of the metaphysis, its more peripheral parts being supplied by metaphysical arteries derived from the periosteum. Trueta and Harrison (1953) believed that in the adult human femur the nutrient artery did not reach the metaphysical region, which was wholly supplied by metaphysical arteries.

Weinmann and Sicher described the vessels approaching the epiphysial cartilaginous plate, and invading the cartilage, as long hairpin-shaped loops, while Stump (1925) described the opening up of the dilated cartilage lacunae by the activity of syncytial masses of mesenchymal tissue. The peripheral parts of the syncytial masses were said to form osteoblasts applied to the trabeculae, while cavitation, with the formation of lumina, in the centre of the masses produced the extension of blood vessels in the progressively invading tissue.

The purpose of this investigation was to determine the extent of supply of the periosteal vessels and the nutrient arteries in developing long bones and to study the form of those vessels of the metaphyses approaching and invading the epiphysial cartilage plate.

Fig. 1
Metatarsal of an injected twenty-six day rabbit embryo showing nutrient artery giving branches terminating in dilations at the metaphysis of either end. The periosteal plexus of blood vessels can be seen on the surface of the bone. (× 35.)

METHODS

Long bones (e.g., tibia, femora, metatarsals) of rabbit embryos and young rabbits, injected with Monastral Fast Blue BNVS paste, were used, the whole bone, 100μ sections, or teased preparations being cleared and mounted. In addition, the phalanges of a human foetus injected with Indian ink were examined.

The injected material was correlated with histological sections of developing rabbit and human bones stained with haematoxylin and eosin, Heidenhain's iron haematoxylin, or Azan.

OBSERVATIONS

During the early stages of ossification of a long bone all the endochondral bone, including the metaphysis, is supplied by the nutrient artery, while some of the periosteal plexus of blood vessels is being included in the developing periosteal bone as its blood supply (Fig. 1).
As the bone grows, more periosteal bone is laid down, and is also supplied by included periosteal vessels, while the endochondral bone is progressively removed to form a medullary cavity containing marrow supplied by the nutrient artery. The more peripheral of those vessels approaching the epiphyssial cartilaginous plate are now derived from the periosteal plexus and are the metaphysial arteries, while the central part of the metaphysis is still supplied by the nutrient artery, which runs through the compact bone of the shaft parallel to its periosteal vessels of supply, to enter the medullary cavity (Figs. 2 to 5).

![Diagram](image)

**Fig. 2**
An early stage in the development of a long bone, with a later stage superimposed. Growth of the bone leads to deposition of periosteal bone, a, with its obliquely running periosteal vessels, on the surface of the endochondral bone, b, the peripheral parts of the metaphysis come to be supplied by metaphysial arteries derived from the periosteum. Epiphyssial cartilage plate, c.

The vessels approaching the epiphyssial plate, whether derived from the nutrient artery or the metaphysial arteries, have specialised terminations where they meet the plate, with its dilated lacunae. Groups of two or three fine vessels end in a saccular dilation intimately related to the epiphyssial plate (Figs. 6 to 8).

Histological sections show that endothelial-walled vessels approach the epiphyssial plate and terminate by funnel-shaped endings which open into the dilated cartilage lacunae which thus become filled with blood. Thus, the fine vessels approaching the epiphyssial plate in injected specimens are endothelial-walled, and have a peripheral mesenchymal sheath of cells developing into osteoblasts, while their saccular endings are the blood-filled lacunae, unlined by endothelium, opened up in the degenerating cartilage (Figs. 9 to 11).

The same vascular pattern is seen at the advancing margin of ossification in the epiphyssis—that is, on all sides of the secondary centre of ossification except at the surface related to the diaphysis.

No vessels were seen traversing the epiphyssial cartilaginous plate, from diaphysis to epiphysis, at any stage.

**DISCUSSION**

The compact periosteal bone of the shaft of a developing long bone is supplied by vessels running an oblique and parallel course through the compact bone and derived from the periosteal plexus of blood vessels, while the endochondral bone, until its removal, is supplied...
Figure 3—Injected tibia of a thirty-seven day old rabbit showing nutrient artery entering bone parallel to the obliquely running periosteal vessels supplying the compact periosteal bone of the shaft. (×30.) Figure 4—Upper extremity of injected tibia of a thirty-seven day old rabbit. The blood supply of the peripheral part of the metaphysis from periosteal vessels can be seen. (×3.)

Same bone as Figure 4, showing a metaphysial artery, a, entering from the periosteum. (×35.)
by the nutrient artery. In the later stages the nutrient artery supplies the bone marrow of the medullary cavity. The metaphysis is at first supplied by the nutrient artery only, but as the bone grows metaphysical arteries derived from the periosteum take over the blood supply of the peripheral parts of the metaphysis to an ever-increasing extent. Thus, Trueta and Harrison (1953) found no evidence that the nutrient artery supplied any blood to the metaphyseal region in the adult femur (Fig. 2).

![Figure 6](image)

**FIG. 6**
Teased preparation of injected metaphysis of a twenty-six day rabbit embryo tibia showing the saccular dilations on the vessels eroding the epiphysial cartilage plate. (×110.)

![Figure 7](image)  ![Figure 8](image)

**FIG. 7**  **FIG. 8**
Figure 7—Showing the line of saccular dilations on the vessels where they are related to the epiphysial cartilage plate. Injected tibia of twenty-six day rabbit embryo. (×35.)

Figure 8—Another 100µ section of same bone as in Figure 7. (×100.)

Blood cells fill the dilated cartilage lacunae at the line of advancing ossification and the blood itself is apparently in direct contact with the cartilage and may play a part in eroding the columns of dilated cartilage cells. In the wake of this process a layer of osteoblasts lined by a layer of endothelial cells extends up the inner walls of the cartilaginous tubules so formed, thus progressively forming endothelial-walled vessels in the new-formed bone. The saccular dilations of injected specimens at the line of cartilage invasion are blood-filled lacunae and no endothelial layer is observed lining their cartilaginous walls.

The periphery of each secondary centre of ossification advances in similar fashion and at the end of growth the vascular loops, as described by Trueta and Harrison, beneath the
FIG. 9
Section of metaphysis of tibia of a twenty-six day rabbit embryo showing blood-filled lacunae, a, corresponding to the saccular dilations shown in Figures 6, 7 and 8. Stained with Heidenhain's iron haematoxylin, 8μ section. (x 80.)

FIG. 10—Section of metaphysis of a twenty-five day rabbit embryo tibia. Blood cells are seen lying free in the lacunae without the intervention of an endothelial wall. e, endothelial cell. 8μ section. Heidenhain's iron haematoxylin. (x 330.) Figure 11—The same bone as in Figure 10, again showing the unlined blood-filled lacunae at the termination of a vessel which opens in funnel-like fashion into the lacuna. e, endothelial cell. (x 500.)

SUMMARY
1. Periosteal bone is supplied by periosteal vessels and endochondral bone by the nutrient artery.
2. In the earliest stages of development the metaphysis is supplied by vessels derived only from the nutrient artery. Later, metaphyseal arteries derived from the periosteum take over the supply of its peripheral part, the extent of their area of supply progressively increasing.

3. In injected specimens the blood vessels approaching the epiphysial cartilaginous plate end in saccular dilations. Histological sections show these dilations to be blood-filled cartilage lacunae, with no endothelial lining and into which open the blood vessels approaching the epiphysial plate.
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REFERENCES