COMPARATIVE MORPHOLOGY OF THE LUNG WITH SPECIAL REFERENCE TO THE ALVEOLAR LINING CELLS

II. LUNG OF THE REPTILIA

Yoshio OKADA, Shigetoshi ISHIKO, Shigeo DAIDO,
岡 田 慶 夫　　石 河 重 利　　大 道 重 夫
Jaeha KIM and Sadao IKEDA
金 在 河　　池 田 貞 雄

Surgical Division of the Tuberculosis Research Institute, Kyoto University
(Director: Prof. Chuzo NAGAISHI, M.D.)

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Introduction

Electron microscopic observations of the lungs of various vertebrates have been made by the present authors to clarify the origin of the lining cells of the alveolar wall of the lungs.

In a previous paper (Acta Tuberc. Japon. 11: 2, 63-72, 1962), we reported the alveolar walls of amphibian lungs were covered continuously with two kinds of cells; alveolar epithelial cells and alveolar wall cells, both of epithelial origin.

In the present paper, the electron microscopic findings of studies of reptilian lungs are reported and morphological changes of the two kinds of lining cells in the evolution of animals are discussed.

I. Materials and Methods

Materials used for this study were normal lung tissues of snakes (*Elaphe climacophora Boie* and *Elaphe quadrivirgata Boie*) and geckos (*Gekko japonicus Duméril et Bibron*).

The specimens were prepared by the same method as described in the previous paper for electron microscopic and light microscopic observations.

II. Results

A. The Lungs of Snakes

The lungs of snakes are elongated rod-shaped, whose fine structures are very similar to that of the frogs. Through the center of the lung there is a tubular lumen, that is called "Vorbronchus" by Marcus (1937), and it is thought to be comparable to the bronchus of the mammalian lung.

From the "Vorbronchus" many air spaces, or respiratory tracts, radiate forming small sacs. These sacs may be called "primitive alveoli" as in the case of the frogs' lung.

1. Hostological Findings

The central end of each septum of the primitive alveoli, which is shaped like a club and makes a part of the wall of the "Vorbronchus", is covered by a ciliated columnar epithelium as shown in Fig. 1. In the underlying wall of the "Vorbronchus" large blood vessels, lymphatics and smooth muscles are found.

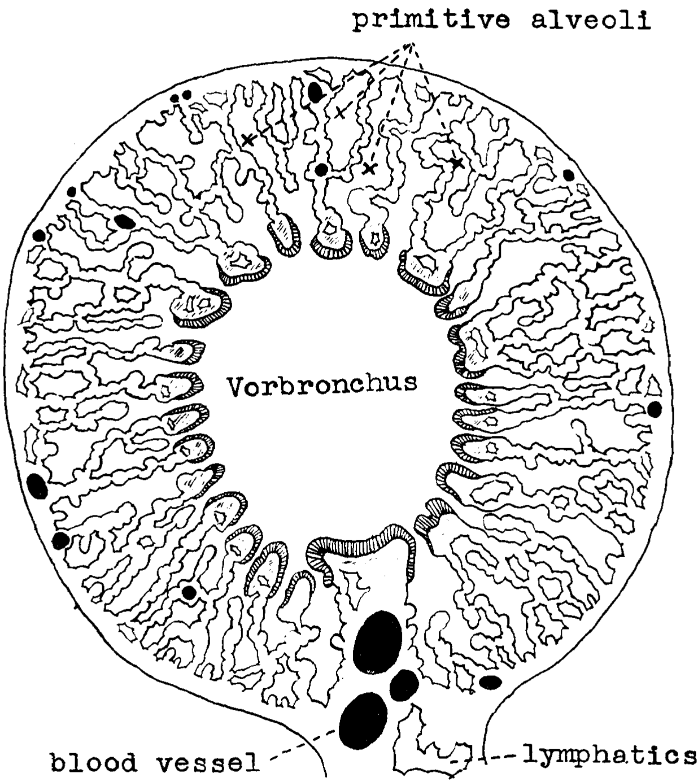

Fig. 1. The lung of the snake (schematic).

The septa of the air space of the snakes are branched more frequently and complicatedly than those of the frogs so that the primitive alveoli are more finely divided.

On the surface of the septa which face the primitive alveoli, thick capillary networks are observed as shown in Fig. 2.

Collagen fibers, elastic fibers, smooth muscles, blood vessels and lymphatics are also found in the interstices of the septa.

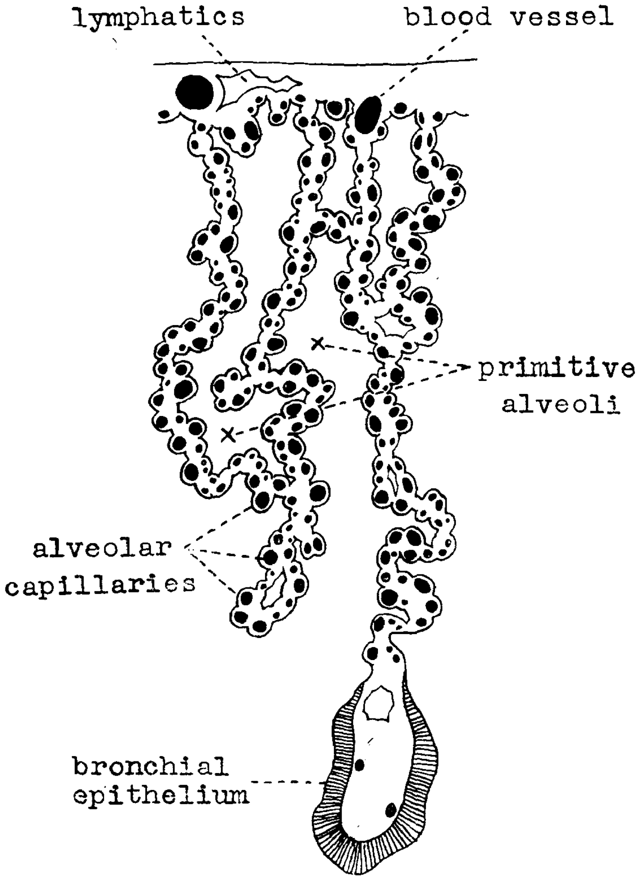

Fig. 2. Alveolar wall of the snake (schematic).

2. Electron Microscopic Findings

The surface of the primitive alveoli is, as in the mammalian and the amphibian lungs, completely covered with two kinds of epithelial cells, that is, alveolar epithelial cells and alveolar wall cells.

The alveolar epithelial cell is shown in Fig. 3. The cell bulges out into the alveolar space at the site of nucleus, and its cytoplasm extends far as a thin membrane, whose thinnest parts measured less than 0.1 micron thick as shown in Fig. 4. The nucleus is oval or round and is situated not only on the outer surfece of a bulging capillary but also in the niche between adjacent capillaries. In the cytoplasm some mitochondria and a few endoplasmic reticula are found. Golgi's complex is rarely observed. As to osmiophilic bodies and microvilli observed in the frog's lungs, they are not found at all in this cell.

A continuous basement membrane lies beneath this cell.

The alveolar wall cell is shown in Fig. 5. This cell is situated only in the niche between adjacent capillaries and devoid of the cytoplasmic extension. In the cytoplasm many mitochondria and endoplasmic reticula are found. Golgi's

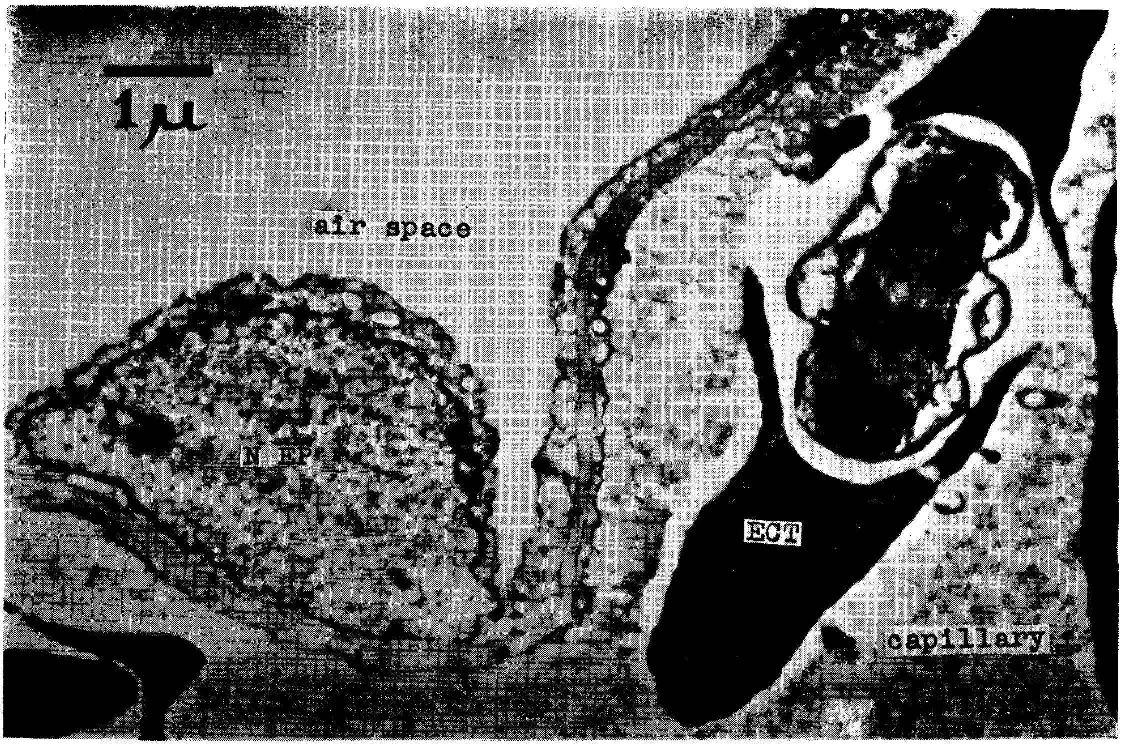

Fig. 3. Alveolar epithelial cell of the snake.
N EP : nucleus of the alveolar epithelial cell,
ECT : erythrocyte.

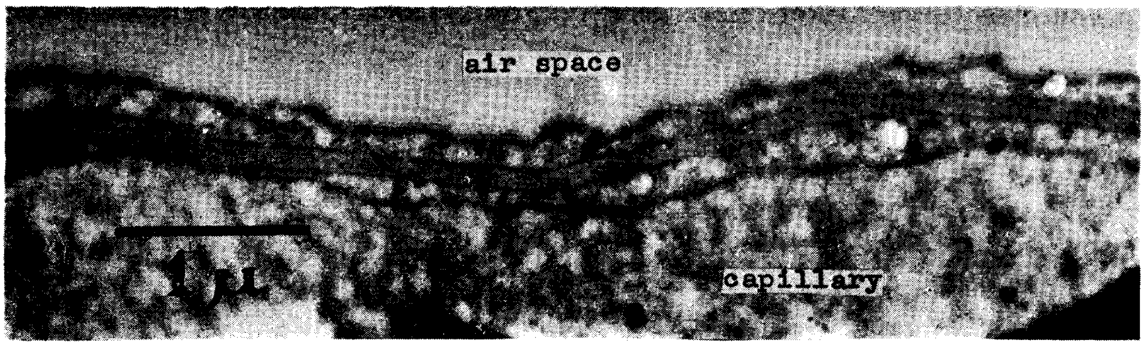

Fig. 4. "Blood-air-barrier" of the snake.

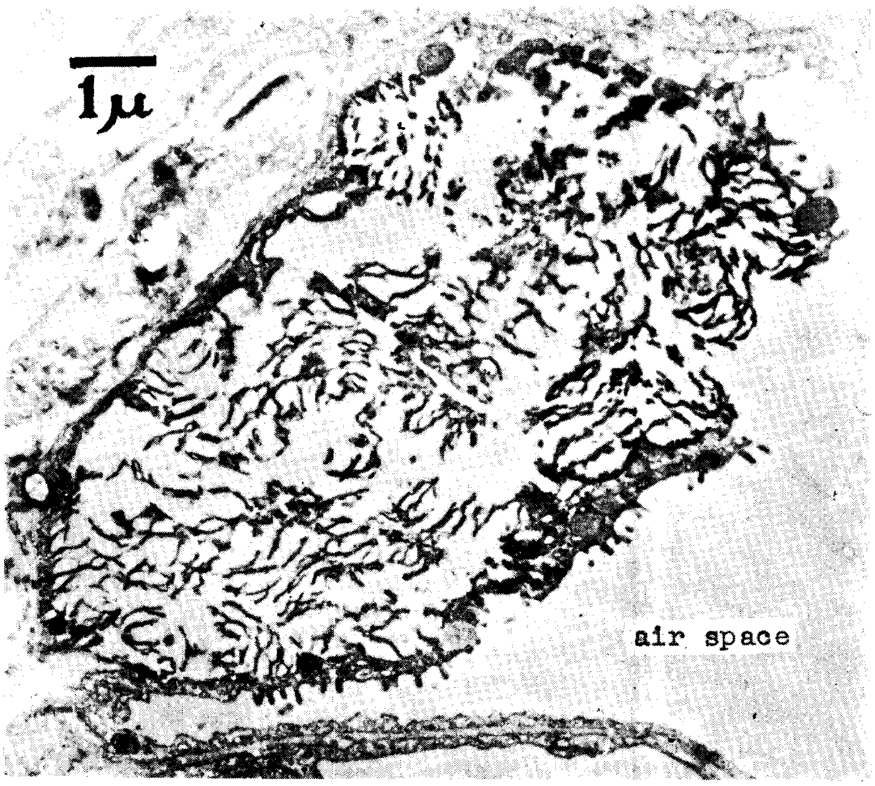

Fig. 5. Alveolar wall cell of the snake.

Fig. 6. Alveolar wall cell of the snake.
N : nucleus of the alveolar wall cell,
N ED : nucleus of the capillary endothelium.

complex is frequently observed. Besides these organelles, osmiophilic bodies are abundantly distributed, many of which are of type IIa (Ishiko, 1960) while the majority of the osmiophilic bodies of the frogs' lungs are of type I. Sometimes swollen osmiophilic bodies occupy a large portion of the cell so that the nucleus is compressed and deformed as shown in Fig. 6. Many microvilli are found on the free surface.

The endothelial cell of the alveolar capillary resembles the alveolar epithelial cell in shape. It bulges out into the capillary lumen at the site of nucleus and the cytoplasmic layer extends around to line the capillary wall as shown in Fig. 7.

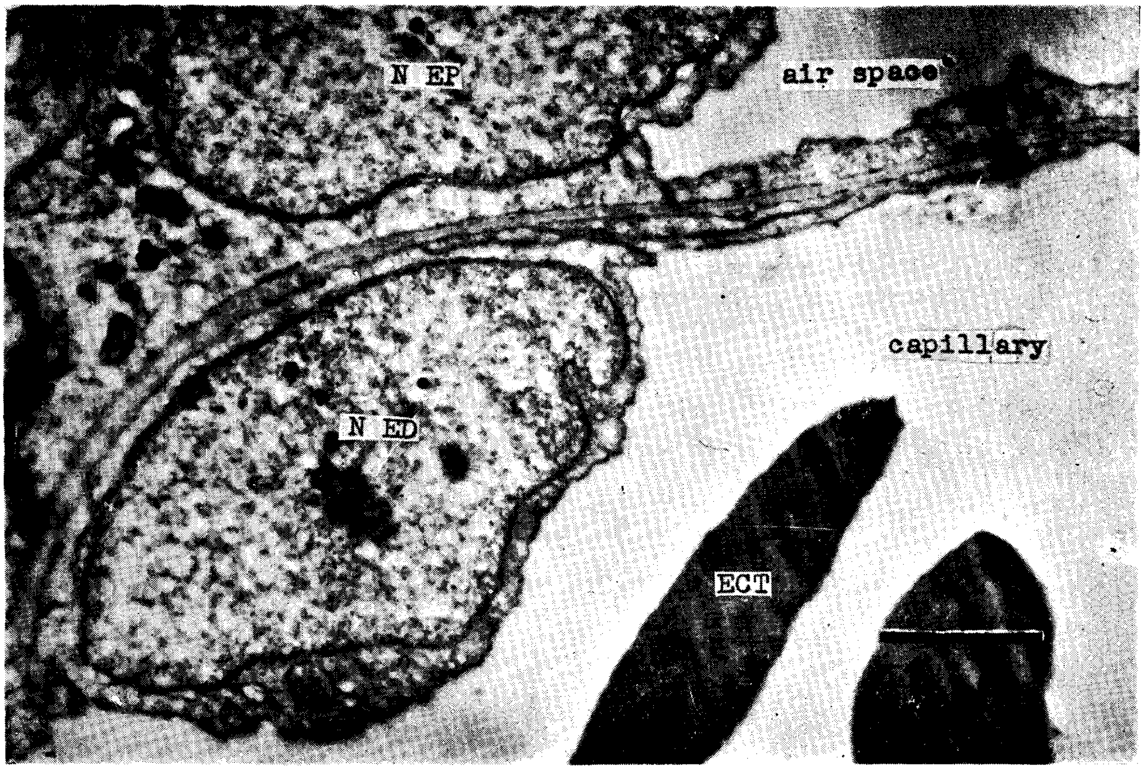

Fig. 7. Capillary endothelial cell of the snake.
N ED : nucleus of the capillary endothelial cell,
N EP : nucleus of the alveolar epithelial cell,
ECT : erythrocyte.

The thickness of the thinnest part of the cytoplasmic membrane is less than 0.1 micron. Some mitochondria are found but endoplasmic reticula are rarely seen in this cell.

The basement membrane is homogeneous as is that of the epithelial cell.

The entire blood-air-barrier, which consists of the epithelial cells, the endothelial cells and the basement membranes of both cells, is about 0.3 microns thick at the thinnest part.

B. The Lungs of Geckos

1. Histological Findings

The structure of the Geckos' lungs is similar to that of the snakes' lungs.

2. Electron Microscopic Findings

The primitive alveoli of the geckos' lung are continuously covered with two kinds of epithelial cells, that is, alveolar epithelial cells and alveolar wall cells.

The alveolar epithelial cell is shown in Fig. 8. The thinnest parts of the cytoplasmic extension are less than 0.1 micron of thickness.

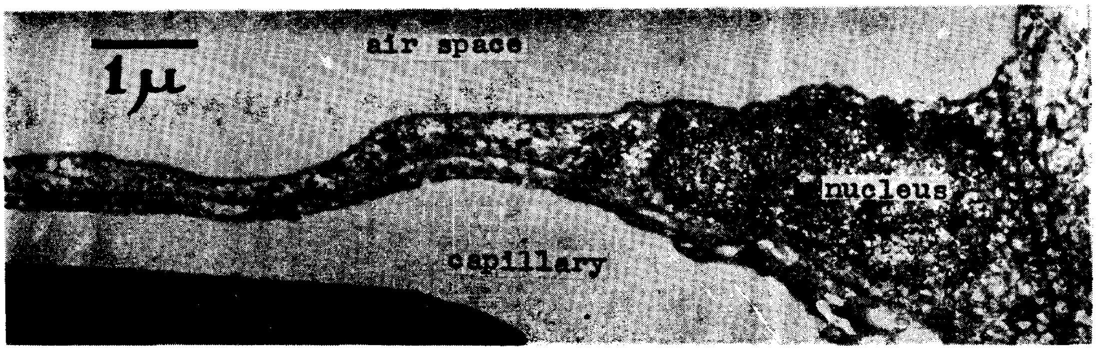

Fig. 8. Alveolar epithelial cell of the gecko.

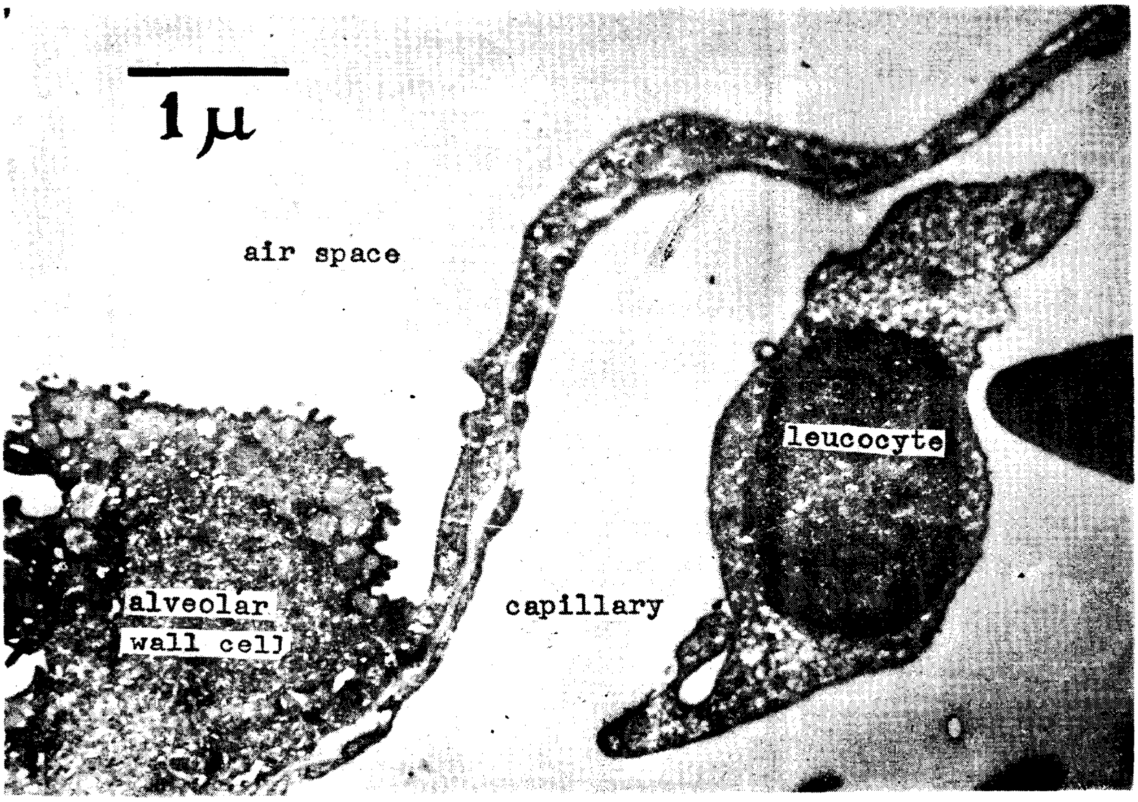

Fig. 9. "Blood-air-barrier" of the gecko.

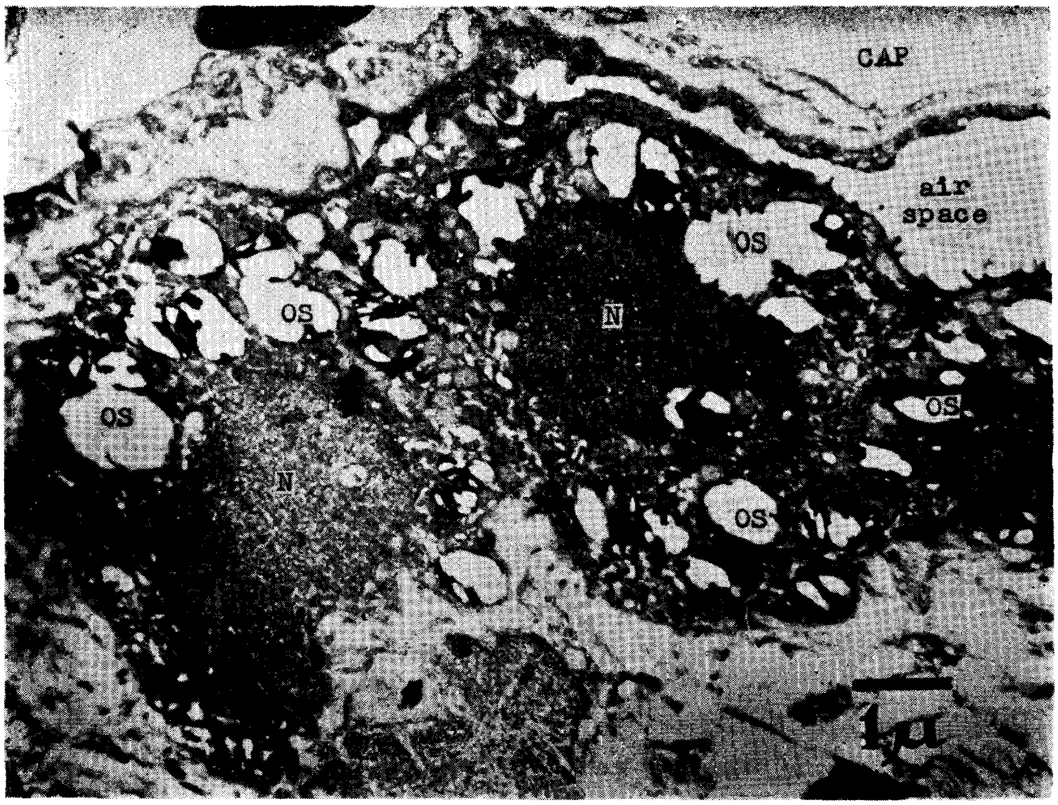

Fig. 10. Alveolar wall cells of the gecko.
N : nucleus of the alveolar wall cell,
CAP : capillary lumen, OS : osmiophilic body.

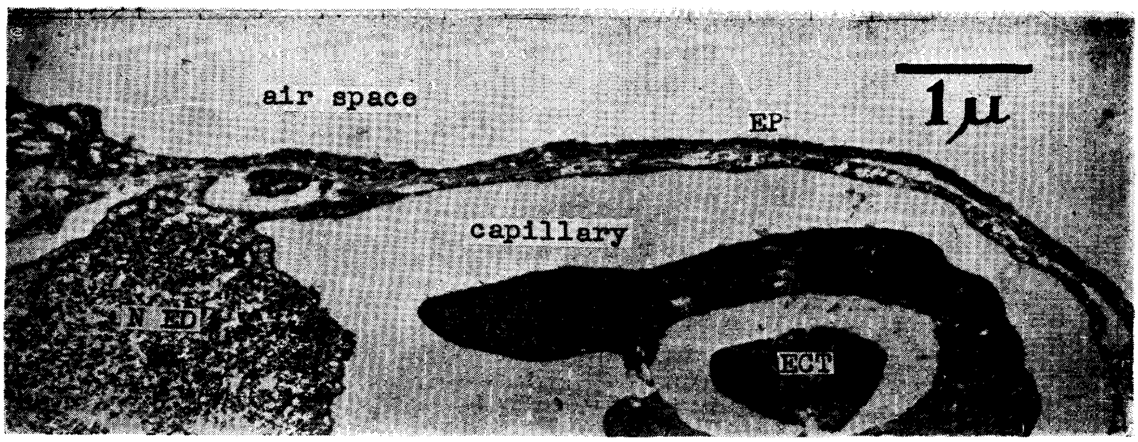

Fig. 11. Capillary endothelial cell of the gecko.
EP : alveolar epithelial cell,
N ED : nucleus of the capillary endothelial cell,
ECT : erythrocyte.

The cytoplasm of the alveolar wall cell has a higher electron density than that of the alveolar epithelial cell as shown in Fig. 9. This alveolar wall cell contains many mitochondria and osmiophilic bodies, the majority of which are of type I as shown in Fig. 10.

The capillary endothelium of the alveolar septum has the shape of a seal ring as in the snakes' lungs.

The blood-air-barrier measures about 0.1 micron thick in the thinnest parts as shown in Fig. 11.

III. Discussion

In both the reptilian and the amphibian lungs, there is the "Vorbronchus" at the center of the lung, and many air tracts radiate from it to form primitive alveoli at the periphery.

The primitive alveoli of the reptilian lungs are finer and more complicatedly divided than those of the amphibian lungs. It seems, therefore, likely that gas exchange may be performed more efficiently in the reptilian lungs than in the amphibian lungs.

In the amphibian lungs, the two kinds of the alveolar lining cells are not completely differentiated from each other. However, in the reptilian lungs, as in the mammalian lungs, they are differentiated enough to show their characteristic structures respectively. The alveolar epithelial cell has a cytoplasmic extension which covers the large portion of the alveolar wall, but does not have microvilli or osmiophilic bodies. The alveolar wall cell, conversely, has microvilli and osmiophilic bodies but not the cytoplasmic extension.

The thickness of the blood-air-pathway of the reptilian lungs is almost the same as that of the mammalian lungs, so, discounting variations of the blood-air contact time (the velocity of the blood flow), O_2 diffusion in the alveolar region, might be also almost the same in the two kinds of animals.

Considering the facts mentioned above, it may be said that the reptilian lungs stand between the mammalian and the amphibian lungs from the comparative morphological point of view.

Summary

1) Like amphibian lungs, the reptilian lungs consist of the "Vorbronchus" and primitive alveoli.

2) The primitive alveoli of the reptilian lungs are continuously covered with two kinds of epithelial cells, that is, alveolar epithelial cells and alveolar wall cells.

3) The alveolar epithelial cell has a cytoplasmic extension covering the alveolar wall but does not have microvilli or osmiophilic bodies.

4) The alveolar wall cell has microvilli and osmiophilic bodies but not a cytoplasmic extension.