Structure and Function: A Synopsis*

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It is a great pleasure to participate in the 1964 Stoneburner lectures and to present some recent views on the structure and function of the lung. In this report I will give a brief summary and show you three pictures to indicate some of the inter-relationships that exist. A more detailed review covering similar material, with numerous color illustrations, can be found in *Anesthesiology* 24: 831–854, 1963.

We all know that the venous blood returning from the organs of the body is pumped by the right ventricle through the pulmonary artery into the lung. It flows along the branching arterial system to the respiratory surfaces (alveolar-capillary level) where it is aerated. The arterialized blood drains via the pulmonary veins and left atrium into the left ventricle, which pumps it into the systemic circulation.

During inspiration, the air we breathe flows down the trachea, into the multibranching bronchi and bronchioles, and then into the respiratory spaces (alveoli and alveolar ducts) where oxygen molecules diffuse into the red blood cells in the pulmonary capillaries, and CO_2 molecules diffuse out. During expiration, alveolar gas flows back up the airways to the atmosphere.

One of the remarkable aspects of pulmonary structure is the very close relationship between the blood vessels and the airways. Figure 1 is a picture of the hilum of a lung lobe in an experimental animal, showing the main lobar bronchus and adjoining it, the pulmonary artery and the pulmonary vein. These lungs were prepared by rapid freezing in the open thorax in an anesthetized animal. The colors you see are not stains but are the actual colors of the living lung. The photograph was made while the lung was still frozen. Notice the dark venous color in the pulmonary arterial blood in contrast to the bright red color in the pulmonary veins, and the snow-white lining of the airways in contrast to the orange color of the respiratory spaces (alveolar walls) in the background. The main lobar bronchus branches twice in the picture, and you can see that each branch is accompanied by a pulmonary artery branch. The pulmonary veins, on the other hand, do not branch as evenly as the arteries, nor do they follow the airways as closely.

The most important aspect of lung function is the efficiency of getting air and blood into close contact and in proper proportion. We refer to this as the balance of ventilation to perfusion. It is the single most important feature of lung function in health and in disease. Imbalances may be due to destruction or narrowing of airways, to narrowing or occlusion of vessels, or to destruction of the alveolar-capillary walls within the respiratory portion of the lung. Anatomically, we see how closely the pulmonary artery (perfusion) follows the airway branchings (ventilation). At each successive level of the lung there is an intimate relation between the blood supply and the air supply right down to the respiratory portion of the lung, the part which I refer to as the terminal respiratory unit. When the blood and air are within this unit, the diffusion of oxygen and CO_2 gas molecules becomes the major process.

Figures 2 and 3 show two aspects of the alveolar wall in human and in cat lung. In contrast to figure 1, these specimens were fixed while frozen, then embedded, sectioned, and stained. The human samples were obtained at thoracic surgery. These figures show the business portion of the lung (the alveolar-capillary wall). Here oxygen and CO_2 molecules are exchanged between the alveolar gas and the red blood cells in the pulmonary capillaries. Note how large the alveolar air space is relative to the thickness of the alveolar wall (fig. 2). Gas molecules move a great deal faster through air than through tissue (water). See how the blood cells are spread out in a single layer and how much of the alveolar surface area they occupy (fig. 3).

By the insights afforded us when we consider both organ structure and function, we will be able to advance our understanding of normal and abnormal conditions so that we may intelligently correct the latter.

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* Presented at the 1964 Stoneburner Symposium.

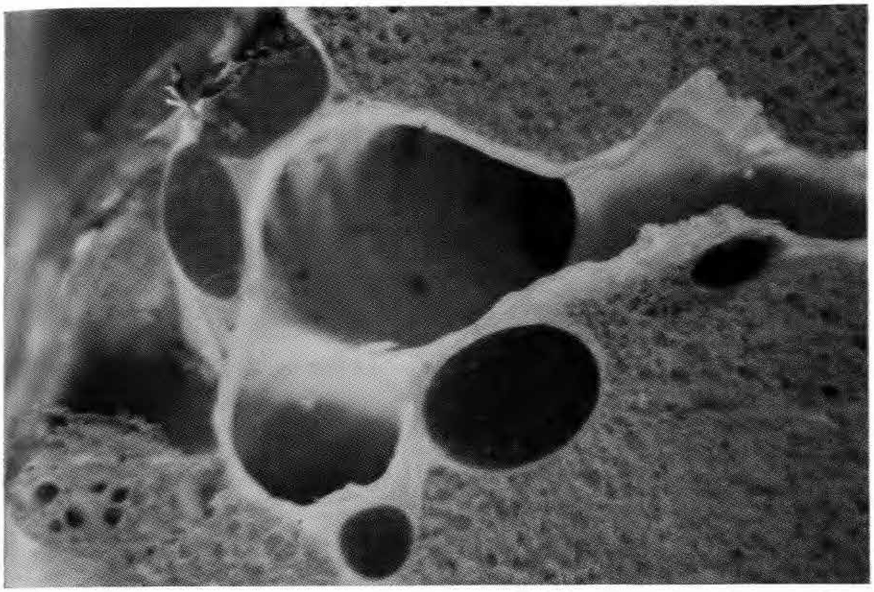

Fig. 1—Cat, × 2.4. Left lower lobe, main bronchus, and vessels at the hilum. This is a frozen, uninjected, unstained specimen. It demonstrates clearly the purplish color of partially desaturated (venous) blood in the pulmonary artery and the bright red color of well-oxygenated (arterial) blood in the pulmonary veins. The plane of section is just after the lobar bronchus enters the lung. The main bronchus is the large white opening. A small lateral branch to the apical segment of the lobe has been given off, and a large anterior branch is forming. The main bronchus continues nearly straight. Within the bronchus there is a faint circular ridging due to the cartilage in the walls. The pulmonary artery (*PA*) has divided, and a branch accompanies each airway. *PA* is one-third to one-half the diameter of the adjacent airway at all levels down to the terminal bronchiole. The pulmonary vein is larger than the artery. It is in the process of dividing. At the hilum the airway, pulmonary artery, and pulmonary vein are close together because of space limitations. This provides maximal mobility of the lung root. Note that even the largest airways and vessels are surrounded by alveolar tissue (*orange background color*).

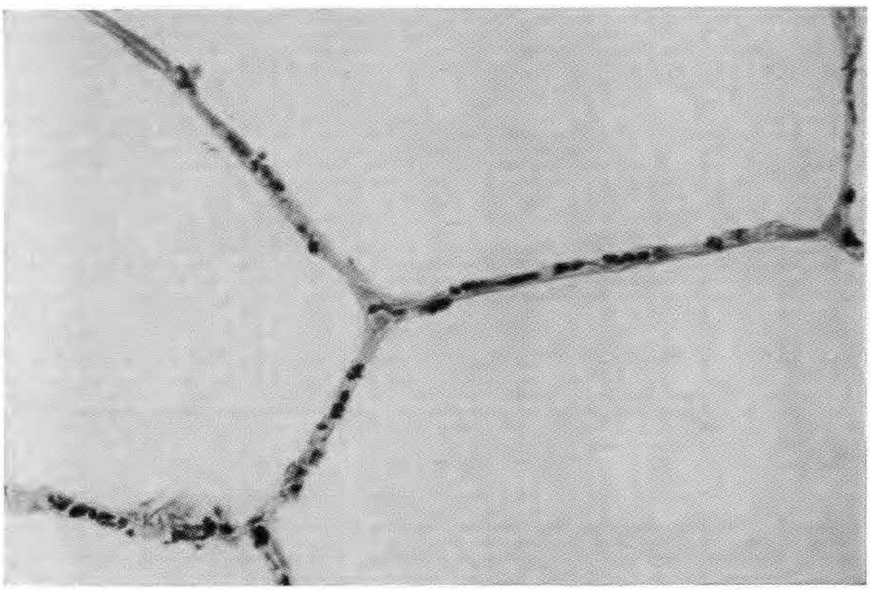

Fig. 2—Human, × 100. Fixed, 10-μ section, stained. Shows red blood cells in alveolar capillaries confined to plane of wall, not bulging into airspaces as so often stated. About 50% of the alveolar septal volume is capillary lumen. Endothelium, interstitial connective tissue, and alveolar epithelium make up the remainder. Septae range from 5 to 10 μ in thickness in well-inflated lung. Human lungs were obtained at thoracic surgery. The anesthetist inflated the lung fully, then allowed it to deflate to a known airway pressure. The surgeon then clamped the edge of a lobe. At the time of clamping, pulmonary blood flow was intact. The specimens were frozen within 30 seconds of removal from the chest.

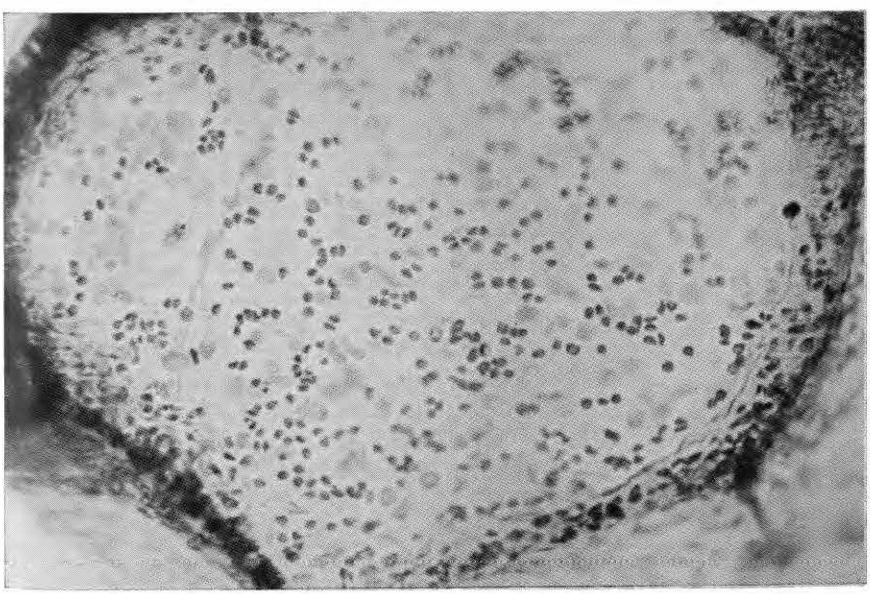

Fig. 3—Cat, × 200. Fixed, thick section, stained. Single alveolar wall in plane of focus. Individual red blood cells in alveolar capillaries are clearly seen. Normally the capillary net is not filled to capacity.