Morphology of the Acinus of the Human Lung

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Further morphologic studies of the human lung acinus were undertaken by means of microdissection of latex corrosion models. Two human lungs, one from an elderly man and another from a 26-year-old woman were used for the preparations. Four acini, two from each lung, were dissected in detail. A distinct difference was noted between the acini from the elderly man and those from the 26-year-old woman's lung. The terminal bronchiole always divides dichotomously, whereas the respiratory bronchioles divide by dichotomous, trichotomous and even quadrivial division. Unusual types of branchings are described. Approximately 40 percent of the alveoli of the acinus are located on respiratory bronchioles, including alveolar ducts, whereas 60 percent are on the alveolar sacs. A similar ratio exists between the volumes of the respiratory branches and the alveolar sacs. From the data obtained the acinar volumes, alveolar surface area and number of alveoli present in the lung were calculated.

Gratefully dedicated to Prof. Edward A. Boyden

This work is the second part of a study of the acinus of the normal human lung. The findings were again obtained by microdissection of latex corrosion models.

Latex models are durable, withstand repeated manipulations without changing their shape or form. Measurements can, therefore, be taken repeatedly as their dimensions remain stable. However, such models lack histologic characteristics, making it difficult to classify certain structures. Special reference is made to the inability to differentiate alveolar ducts from respiratory bronchioles of the higher orders. In a latex model an alveolar duct is recognized only by its position when it immediately precedes an alveolar sac. Therefore, alveolar ducts, which undergo further divisions before terminating in alveolar sacs, can not be identified as such in corrosion models, a view also expressed by von Hayek.

Thus, in order to avoid confusion, we have omitted the use of the term alveolar duct. Instead all branches have been labeled as respiratory bronchioles with their appropriate numerical sequence. It must be kept in mind throughout this discussion that only the first few branches are technically respiratory bronchioles.

In this presentation special attention has been paid to the measurements of the various respiratory components of an acinus, to enumeration of the alveoli on all the structures, as well as a description of unusual forms of respiratory bronchioles and alveolar sacs. Furthermore, by using the data obtained the total volume and total alveolar surface area of an acinus has been calculated.

METHODS

Corrosion models were prepared by a method previously described. Vultex Moulage, a latex preparation, was injected into the tracheobronchial tree under a pressure of 50 mm Hg, carefully sealing all leaks during the procedure. The injected lung was then digested by immersion into concentrated HCl, leaving behind the latex model.

Satisfactorily injected acini were dissected under a stereoscopic Leitz microscope. The diameter and length of terminal and respiratory bronchioles, alveolar sacs and alveoli were measured by means of a calibrated scale in the eyepiece of the microscope.

To determine the length of a respiratory bronchiole the distance between the carina of its origin and the carina of its own division was measured. It is granted, that on occasions these demarcations are so extensively covered with alveoli as to make exact measurement difficult.

The alveoli located on the surface facing the viewer were counted on each bronchiole and alveolar sac. Since it was impractical to turn the specimen over to count the reverse side, the total number of alveoli was estimated by multiplying by two the count of just one side.

Two normal lungs were injected for this study. One lung was that of a man over 70 years old, who died of an ailment not involving the respiratory system. A 26-year-old woman who succumbed to a cerebrovascular accident supplied the second lung.
MORPHOLOGY OF ACINUS OF HUMAN LUNG

Four acini were dissected, two from each lung. Additional dissections were made of numerous other acini to study individual acinar components.

The method of labeling the various components of the acinus has been changed from that used originally (Fig 1). Each respiratory bronchiole is denoted by the letter "R", followed by an arabic numeral indicating the number of divisions it has undergone. All branches arising from the left R.1 are further identified by a small "a", whereas those arising from the right R.1 by the letter "b". The subdivision of individual respiratory bronchioles is indicated by adding a second letter, viz: R1b divides into a, b and c branches (R1ba, R1bb, R1bc). Alveolar sacs arising from a respiratory bronchiole are enumerated consecutively with arabic numerals.

As the dissections and measurements progressed the acini were dismembered and successive portions mounted on slides. Suitable parts of acini were then photographed and drawn.

Observations

A distinct difference was noted between acini from the elderly male lung and those from the 26-year-old woman's lung, even though both were subjected to the same injection procedure. The acini of the former failed to inject as uniformly, resulting in smaller and less distinct alveoli. Frequently alveoli of a respiratory bronchiole represented only indistinct elevations. In contrast, the acini from the younger lung exhibited prominent alveolar sacs and alveoli.

The Acinus

A lung acinus, as defined by Loeschke, consists of a terminal bronchiole with all its branches. In shape the acinus can be likened to that of a deciduous tree, in which the trunk is represented by the terminal bronchiole (Fig 1). After dissection as in Figure 1, an acinus measures approximately 8.5 mm in width and 7.5 mm in height.

As shown in Figure 1 the terminal bronchiole always divides dichotomously into respiratory bronchioles of the first order (R1a and R1b). Each of these gives rise to R2 branches (Fig 1 and 2) by dichotomous, trichotomous or even quadrivial division. Usually this variable pattern of division continues as far as R5 or R6; however, in our dissections four R6 and even one R7 were encountered (Fig 3). The last respiratory bronchiole terminates into one to five or more alveolar sacs (inset, Fig 3). It should be remembered, however, that the more peripheral branches are presumably alveolar ducts, which cannot be identified in a corrosion model.

Acini differ in the total number of respiratory bronchioles, alveolar sacs and alveoli (Tables 1 and 2). In addition acini also differ in shape, a variant which appears to be dictated by the location or its environment. Thus a subpleural acinus or one adjoining septal tissue may have its peripheral

Figure 1. Incomplete dissection of one acinus. R1a and R1b—respiratory bronchioles of the first order. R1aa, R1ab, and R1ac—respiratory bronchioles of the second order, arising from R1a.

R2ba, R2bb, and R2bc—respiratory bronchioles of the second order arising from R1b. Other branches are labeled in the same manner. R2aa had its branches severed to permit visualization of other parts. S—alveolar sacs. Q—location of branch broken off during dissection. DEF—defect in terminal bronchiole.
branches spread out along the plane of the pleura or septum (Fig 3). Other acini, located in an angle between two bronchioles or blood vessels are forced to assume a triangular form. The adaptation to its environment may even demand differences in size and shape of the two halves of an acinus, each half being the offspring of a R.1.

To fulfill these variations a multiplicity of patterns of divisions, beyond the dichotomous division of the terminal bronchiole are necessary. The variety of patterns becomes more profuse in a peripheral direction.

Branches of neighboring acini may interdigitate freely, much like the branches of closely placed trees.

**Terminal Bronchiole**

Von Hayek defines the terminal bronchiole as the last portion of the bronchial tree which still has a continuous lining of cuboidal epithelial cells. It is devoid of cartilage and, supposedly, of alveoli. However, numerous dissections of latex models have shown that some terminal bronchioles have a few rudimentary and, on occasions, well-formed alveoli, a finding also confirmed by Hieronymi. Six out of 15 terminal bronchioles in our series had alveoli. If present, they are usually located on the distal one-third. In some acini the point of bifurcation of the terminal bronchiole is well covered with alveoli.

In our studies it was found that this bronchiole always divides dichotomously into R.1 (Fig 1). There are instances where one or both R.1 may divide almost immediately, giving the impression that the terminal bronchiole divided into three or more branches. However, close inspection will prove that this is not the case.

The length of a terminal bronchiole may vary considerably, ranging from 0.200 mm to 1.250 mm in 15 terminal bronchioles dissected. The average length was calculated to be 0.705 mm. The width is less variable, ranging from 0.325 mm to 0.875 mm with an average of 0.488 mm.

The angle of division is about 90°, so that the two R.1 together with the terminal bronchiole give the shape of a "T". However, it must be remembered, in order to examine the terminal bronchiole with its two R.1 the acinus has to be cleaved and held open. It is following this procedure that the terminal bronchiole and R.1 assume the form of a "T". A variation where the angle between the two R.1 is an acute angle is occasionally seen.

**Respiratory Bronchioles**

This term applies to a bronchiole distal to the terminal bronchiole, except where it immediately precedes an alveolar sac, when it is called an alveolar duct.

In corrosion models the outstanding feature of respiratory bronchioles is the presence of alveoli in their walls (Fig 1 and 2). The manner of division of respiratory bronchioles is rather variable, as described above. After each branching the newly formed respiratory bronchiole is given a numerical order one higher than its parent. Occasionally we have encountered respiratory bronchioles which gave off alveolar sacs directly without the usual intervening alveolar duct (Fig 5—R.aa, alv. sac 1).

In order to be consistent we have considered even such branching as a division of a respiratory bronchiole, thus giving it a higher numeral after the branching. Using this method of labeling we have encountered in the dissection of the third and fourth

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**Figure 2.** Microdissection of part of an acinus showing the successive divisions from terminal bronchiole to alveolar sacs. Respiratory bronchioles are approximately as long as they are wide. Note the square ends of alveolar sacs of R.aa and R.ab, as if they had been pressed against a surface.

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K. K. PUMP
Table 1—Calculated Averages for Respiratory Bronchioles and Alveolar Sacs

<table>
<thead>
<tr>
<th>Name of Struct.</th>
<th>No. of Them</th>
<th>Av. Length</th>
<th>Av. Width</th>
<th>Av. No. of Alv.</th>
<th>Av. No. of Branches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acinus 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terminal Br.</td>
<td>1</td>
<td>1.60</td>
<td>0.75</td>
<td>—</td>
<td>2</td>
</tr>
<tr>
<td>Resp. Br. I</td>
<td>2</td>
<td>0.725</td>
<td>0.875</td>
<td>34</td>
<td>2.5</td>
</tr>
<tr>
<td>Resp. Br. II</td>
<td>5</td>
<td>0.750</td>
<td>0.795</td>
<td>16.4</td>
<td>2.5</td>
</tr>
<tr>
<td>Resp. Br. III</td>
<td>10</td>
<td>0.361</td>
<td>0.533</td>
<td>15.6</td>
<td>2.2</td>
</tr>
<tr>
<td>Resp. Br. IV</td>
<td>11</td>
<td>0.329</td>
<td>0.309</td>
<td></td>
<td>2.8</td>
</tr>
<tr>
<td>Alveolar Sacs</td>
<td>40</td>
<td>0.517</td>
<td>0.320</td>
<td></td>
<td>24.4</td>
</tr>
<tr>
<td>Total No. of Resp. Br.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>28</td>
</tr>
<tr>
<td>Acinus 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terminal Br.</td>
<td>1</td>
<td>0.500</td>
<td>0.350</td>
<td>Not calculated</td>
<td>2</td>
</tr>
<tr>
<td>Resp. Br. I</td>
<td>2</td>
<td>0.512</td>
<td>0.337</td>
<td></td>
<td>2.2</td>
</tr>
<tr>
<td>Resp. Br. II</td>
<td>5</td>
<td>0.365</td>
<td>0.316</td>
<td></td>
<td>2.2</td>
</tr>
<tr>
<td>Resp. Br. III</td>
<td>12</td>
<td>0.231</td>
<td>0.239</td>
<td></td>
<td>2.3</td>
</tr>
<tr>
<td>Resp. Br. IV</td>
<td>11</td>
<td>0.350</td>
<td>0.202</td>
<td></td>
<td>2.2</td>
</tr>
<tr>
<td>Resp. Br. V</td>
<td>4</td>
<td>0.118</td>
<td>0.131</td>
<td></td>
<td>1.7</td>
</tr>
<tr>
<td>Alveolar Sacs</td>
<td>36</td>
<td>0.465</td>
<td>0.253</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total No. of Resp. Br.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>34</td>
</tr>
<tr>
<td>Acinus 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terminal Br.</td>
<td>1</td>
<td>0.400</td>
<td>0.875</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>Resp. Br. I</td>
<td>2</td>
<td>0.812</td>
<td>0.725</td>
<td>56</td>
<td>3</td>
</tr>
<tr>
<td>Resp. Br. II</td>
<td>6</td>
<td>0.875</td>
<td>0.875</td>
<td>32.8</td>
<td>3</td>
</tr>
<tr>
<td>Resp. Br. III</td>
<td>12</td>
<td>0.713</td>
<td>0.701</td>
<td>27.8</td>
<td>1.9</td>
</tr>
<tr>
<td>Resp. Br. IV</td>
<td>13</td>
<td>0.490</td>
<td>0.746</td>
<td>16.6</td>
<td>2.5</td>
</tr>
<tr>
<td>Resp. Br. V</td>
<td>11</td>
<td>0.514</td>
<td>0.666</td>
<td>21.2</td>
<td>3.1</td>
</tr>
<tr>
<td>Resp. Br. VI</td>
<td>1</td>
<td>0.250</td>
<td>0.500</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Resp. Br. VII</td>
<td>11</td>
<td>0.500</td>
<td>0.500</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Resp. Br. VIII</td>
<td>1</td>
<td>0.625</td>
<td>0.500</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td>Alveolar Sacs</td>
<td>72</td>
<td>0.789</td>
<td>0.640</td>
<td>25.6</td>
<td></td>
</tr>
<tr>
<td>Total No. of Resp. Br.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>47</td>
</tr>
<tr>
<td>Acinus 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terminal Br.</td>
<td>1</td>
<td>0.750</td>
<td>0.250</td>
<td>—</td>
<td>2</td>
</tr>
<tr>
<td>Resp. Br. I</td>
<td>2</td>
<td>too short</td>
<td>0.400</td>
<td></td>
<td>3.5</td>
</tr>
<tr>
<td>Resp. Br. II</td>
<td>7</td>
<td>0.589</td>
<td>0.578</td>
<td>25.4</td>
<td>2.2</td>
</tr>
<tr>
<td>Resp. Br. III</td>
<td>10</td>
<td>0.675</td>
<td>0.468</td>
<td>27.2</td>
<td>2.3</td>
</tr>
<tr>
<td>Resp. Br. IV</td>
<td>20</td>
<td>0.434</td>
<td>0.448</td>
<td>19</td>
<td>2.2</td>
</tr>
<tr>
<td>Resp. Br. V</td>
<td>16</td>
<td>0.325</td>
<td>0.356</td>
<td>17.2</td>
<td>2.9</td>
</tr>
<tr>
<td>Resp. Br. VI</td>
<td>12</td>
<td>0.350</td>
<td>0.425</td>
<td>20</td>
<td>2.6</td>
</tr>
<tr>
<td>Resp. Br. VII</td>
<td>14</td>
<td>0.340</td>
<td>0.456</td>
<td>20</td>
<td>2.7</td>
</tr>
<tr>
<td>Resp. Br. VIII</td>
<td>3</td>
<td>0.266</td>
<td>0.500</td>
<td>18.6</td>
<td>3.6</td>
</tr>
<tr>
<td>Resp. Br. IX</td>
<td>1</td>
<td>0.175</td>
<td>0.300</td>
<td>—</td>
<td>2.0</td>
</tr>
<tr>
<td>Alveolar Sacs</td>
<td>118</td>
<td>0.488</td>
<td>0.429</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Total No. of Resp. Br.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>85</td>
</tr>
</tbody>
</table>

acini (both from the younger lung) four Rₐ and one R₉ (Table 1). The last respiratory bronchiol (alveolar duct) as a rule gives rise to two to six alveolar sacs. Here, too, exceptions were seen, where the respiratory bronchiol terminated in a blunt stump or tapered off into a point, making it difficult to categorize such a structure (Fig 5—Rₐaa, 2). Also seen are respiratory bronchioles which are bent at a right angle without giving off any branches at the point of angulation (Fig 6—R₉ba).

While counting alveoli on respiratory bronchioles the impression was gained that the number of alveoli per respiratory bronchiol decreased peripherally. Also, it appeared that the alveoli increase in size in a peripheral direction. The combination of diminishing length of respiratory bronchioles and increase in the size of alveoli in a peripheral direction probably account for the decrease in the number of alveoli on respiratory bronchioles as one proceeds from the center to the periphery of the acinus.

The number of respiratory bronchioles for a par-
particular order increased with each division up to the fourth order (except in acinus 2 where it was the third order—Table 1), but after this their number decreased again.

Recurrent respiratory bronchioles described by von Hayek were also encountered in our dissections. This type of respiratory bronchiole branches off its parent bronchiole in such a manner as to come to lie parallel to the terminal bronchiole.

The number of respiratory bronchioles in the four acini dissected varied from 28 to 85 (Table 1). Alveoli were counted on all respiratory bronchioles and alveolar sacs in three of the four acini. In one acinus the alveoli were difficult to count for

<table>
<thead>
<tr>
<th>Acinus 1</th>
<th>Total No. of Alveoli on Respiratory Bronchioles</th>
<th>Total No. of Alveoli on Alveolar Sacs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal Br.</td>
<td>68</td>
<td>976</td>
</tr>
<tr>
<td>R. II</td>
<td>135</td>
<td></td>
</tr>
<tr>
<td>R. III</td>
<td>164</td>
<td></td>
</tr>
<tr>
<td>R. IV</td>
<td>172</td>
<td></td>
</tr>
<tr>
<td>Alveolar Sacs</td>
<td>559 = 36.5%</td>
<td>976 = 63.5%</td>
</tr>
<tr>
<td>Grand Total</td>
<td>1535 = 100%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acinus 2</th>
<th>Total No. of Alveoli on Respiratory Bronchioles</th>
<th>Total No. of Alveoli on Alveolar Sacs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal Br.</td>
<td>18</td>
<td>2059</td>
</tr>
<tr>
<td>R. B. I</td>
<td>115</td>
<td></td>
</tr>
<tr>
<td>R. B. II</td>
<td>197</td>
<td></td>
</tr>
<tr>
<td>R. B. III</td>
<td>334</td>
<td></td>
</tr>
<tr>
<td>R. B. IV</td>
<td>245</td>
<td></td>
</tr>
<tr>
<td>R. B. V</td>
<td>233</td>
<td></td>
</tr>
<tr>
<td>R. B. VI</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>R. B. VII</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>R. B. VIII</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Alveolar Sacs</td>
<td>1176 = 36.3%</td>
<td>2059 = 63.7%</td>
</tr>
<tr>
<td>Grand Total</td>
<td>3229 = 100%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acinus 3</th>
<th>Total No. of Alveoli on Respiratory Bronchioles</th>
<th>Total No. of Alveoli on Alveolar Sacs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal Br.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R. B. I</td>
<td>176</td>
<td>2360</td>
</tr>
<tr>
<td>R. B. II</td>
<td>172</td>
<td></td>
</tr>
<tr>
<td>R. B. III</td>
<td>272</td>
<td></td>
</tr>
<tr>
<td>R. B. IV</td>
<td>380</td>
<td></td>
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<td>R. B. V</td>
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<tr>
<td>R. B. VI</td>
<td>240</td>
<td></td>
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<tr>
<td>R. B. VII</td>
<td>280</td>
<td></td>
</tr>
<tr>
<td>R. B. VIII</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Alveolar Sacs</td>
<td>1681 = 41.6%</td>
<td>2360 = 55.4%</td>
</tr>
<tr>
<td>Grand Total</td>
<td>4041 = 100%</td>
<td></td>
</tr>
</tbody>
</table>

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There were 1,535 alveoli in the acinus taken from the lung of the elderly man, whereas in the two acini from the lung of the 26-year-old woman they numbered 3,229 and 4,041.

The shape of alveolar sacs was quite variable, but most were oblong with the distal half being wider than the proximal. In many instances the distal end was square, as if it had been pressed against a surface (Fig 2 and 6).

In some cases where several alveolar sacs originated from one respiratory bronchiole, the zone where the branching occurred was so profusely covered with alveoli that the exact origin of the alveolar sacs was difficult to delineate (Fig 8). A sufficient number of such cases have, however, been dissected to establish the fact that there is no atrium as described by Miller.

On rare occasions one alveolar sac may bud off another (Fig 6—arrow).

The shape of alveoli may also vary considerably (Fig 5 and 7). Although the blind extremity of alveoli can be described as being dome-shaped, the base of the dome as well as the shaft connecting the dome to the respiratory bronchiole or alveolar sac may not be cylindrical but hexagonal, quadrilateral or of irregular shape. The shaft may be wider near...
FIGURE 7. Microdissection of R_ac showing a great variability in the size and shape of alveoli. In some cases a cluster of large alveoli may, at first glance, appear to be an alveolar sac, but closer scrutiny reveals that they are individual alveoli.

the dome than at the proximal end. Many alveoli have the shape of an incomplete sphere, the incomplete portion representing the connection to the parent structure.

The length and width of 100 alveoli were measured. The length ranged from 0.125 mm to 0.375 mm, with an average of 0.212 mm. The width ranged from 0.125 mm to 0.325 mm, with an average of 0.205 mm.

DISCUSSION

The rather marked difference in the size and number of alveoli in the acini of the two lungs was of some interest. The alveoli in the acini from the lung of the elderly man were considerably smaller and fewer in number, a fact for which there is no apparent reason.

Differences were also noted between acini from the same lung, although in that event the differences were less marked.

When it was found that in the three acini, the ratio between the total number of alveoli of the respiratory bronchioles and the total number of alveoli from the alveolar sac was fairly constant the likelihood of a similar ratio constancy existing between the sums of the volumes of the same structures was explored.

In computing the volumes the respiratory bronchioles and alveolar sacs were treated like cylinders. The calculations were made by using the following formula:

\[ V = \pi \cdot \frac{lw^2}{4} \]

where "w" is the diameter and "l" the length of the cylinder. It was found that the ratio of the sum of the volumes of the respiratory bronchioles to the sum of the volumes of the alveolar sacs was not only remarkably constant for the four acini dissected, but also very similar to the ratio pertaining to the number of alveoli on these structures (Tables 2 and 3).

These ratios imply that the respiratory bronchioles play an important part in the function of the acinus. Since the alveolar sacs, in all probability, have a greater distensibility than the respiratory bronchioles the ratio of the volumes is subject to change depending on the depth of the inspiration.

It may also be postulated, in view of these ratios, that the alveolar sacs provide the functional reserve of the acinus.

Calculating the total volumes for the four acini from our data the following figures were obtained: 8.672 mm³, 1.330 mm³, 30.891 mm³ and 14.161 mm³, where the first two figures were for the acini from the elderly male lung (Table 3).

Von Hayek estimated that each lung had approximately 214 terminal bronchioles. Using this figure and a tidal volume of 500 ml, a respiratory rate of 12 per minute and a dead space of 150 ml we calculated the volume of air passing through one terminal bronchiole with each breath as follows:

\[ \frac{500 \text{ cm}^3 \cdot 150 \text{ cm}^3}{2 \cdot 2^{214}} = 0.0107 \text{ cm}^3 = 10.7 \text{ mm}^3 \]

Thus each normal acinus is distended approximately to a volume of 10.7 mm³ at the end of a normal inspiration at rest. Considering the marked variability which exists between acini, this average figure compares favorably with the volumes obtained for our acini. This means that our acini were distended approximately to the size obtained at the end of an inspiration of a tidal volume of 500 cm³. All the
The average alveolar surface is, therefore, equal to 0.170 mm². The total alveolar surface for the three acini in which the alveoli were counted is as follows:

Acinus 1 = 1535 × 0.17 = 261 mm² = 2.61 cm².

Acinus 3 = 3229 × 0.17 = 559 mm² = 5.59 cm².

Acinus 4 = 4041 × 0.17 = 687 mm² = 6.87 cm².

If von Hayek’s figure of 21⁴ is used as representing the number of acini present in one lung then, according to the above figures for the three acini, the total alveolar surface per lung would range from 4.28 m² to 11.26 m². For both lungs it would be 8.56 m² to 22.52 m².

Our figure for the average alveolar surface is slightly lower than that quoted by Weibel,⁵ who estimated the surface of one alveolus, in the fresh state, to vary from 0.155 to 0.311 mm². Furthermore, by assuming that there are 300 million alveoli he calculated the total alveolar surface, in the fresh state, to range from 43 to 80 m², the range depending mainly on the size of the lungs.

Although von Hayek also assumed there are 300 million alveoli he estimated the total alveolar surface to be 30 m² in expiration and a maximum of 100 m² in deepest inspiration.

Kulenkampff⁶ and Hieronymi⁷ quote a surface area of 25 to 30 m², whereas Schmidt⁸ calculated it to be 30 m² for the fixed lung and 32 to 76 m² in vivo depending on depth of inspiration.

Information available about the total alveolar surface would be enhanced if the dimensions of that part of the surface which is in close contact with the capillaries were known, for it is here where the exchange of gases occurs. It is quite possible that in the normal lung a fairly constant ratio exists between the dimensions of the alveolar surface and the interface between capillary and alveolus. Furthermore, it may be postulated that this ratio changes in a specific manner in pathologic states of the lung parenchyma.

It is not possible to estimate the number of alveoli present in the lungs from our data, unless we accept von Hayek’s figure that there are 2¹⁴ terminal bronchioles in the lungs. Granting that this number is correct the marked variability in the size of acini and thus in the number of alveoli in the acini makes calculations only approximate. Using the total number of alveoli in the three acini in which the alveoli were counted and von Hayek’s figure of 2¹⁴ the total number of alveoli for both lungs, arrived at by our calculations, ranges between 25 and 66 million. Elze and Hennig⁹ estimated that there were 70 million alveoli.

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NOBEL-LAUREATE IN BIOLOGY

Thomas H. Morgan (1866–1945) wanted to make biology more of an experimental science. So while others discussed Darwin and Mendel, Morgan launched experiments that he hoped would uncover new facts on heredity. He conducted his experiments at Columbia University, in New York City, in a room called the "Fly Room." There was hardly space for the eight desks it contained. Its walls were lined with shelves, and on each of these shelves were hundreds upon hundreds of milk bottles. Each bottle contained flies. They were ordinary fruit flies, Drosophila melanogaster. In 1913 Morgan published the first map of the supposed location of the genes along the length of the four pairs of Drosophila chromosomes. Over the next few years, as new mutations and linkages were found, as new crossovers were discovered, and as early mistakes were corrected, the map was revised. The first chromosome map of the Drosophila has been compared in importance to the first table of atomic numbers. In 1915 Morgan and his coworkers published The Mechanism of Mendelian Heredity. It restated Mendel's laws in terms of the modern knowledge of chromosomes with full explanation of linkage, crossing-over and linear arrangement of genes on the chromosomes.


MUSICIAN OF PHENOMENAL TALENT AND FABULOUS MEMORY

Arturo Toscanini (1867–1957), an incorrigibly modest man, honestly self-deprecating, would probably say that the quickening of lifeless symbols upon a page of music is only a matter of executing with the maximum fidelity the composer's recorded wishes. That sort of fidelity is first of the interpreter's necessary virtues, but it is only the first. To his scrupulous observance of the notes, the great interpreter, by virtue of the power that his genius gives him, adds the "unimaginable touch," the reality behind the notes: the music of which the notes are but the crude approximation. He ceases to be merely a devoted literalist, and becomes the inexplicable life-giver, the master of a secret vision and an incom-