THESIS
FOR DEGREE OF B. S., IN COLLEGE OF NATURAL HISTORY,
MICRO-ORGANISMS OF THE AIR.

BY

F. K. VIAL.

ILLINOIS STATE UNIVERSITY, 1886.
Micro-Organisms of the Air.
Contents

The Air as a Medium for the Conveyance and distribution of bodies of minute size.  Page 1.
Sources of Impurities.  2.
Organic Matter of the air.  3.
The Germ Theory of Disease.  7.
Origins of the Germs.  11.
Relation of germs to Surgery.  14.
Number of Bacteria in the air.  16.
Variations during the year.  18.
Variation with the season.  19.
Variation with the direction of the wind.  23.
Daily Variation.  24.
Classification of Bacteria with respect to their Physiological Action.  30.
Relation of Bacteria to
  Nutrition.
  Fermentation.
  Disease.

Morphology of Bacteria.
  Description.
  Conditions of Growth.

Relation of Septic to Pathogenic Bacteria.

Relation of Bacillus subtilis to B. anthracis.

Growth of Non-Pathogenic Forms.

Growth of Pathogenic Forms.

Classification of Bacteria.

Descriptions of some of the more common species.
The air as a medium for the conveyance and distribution of bodies of minute size has lately been proven beyond a doubt. That matter of an extremely deleterious nature, exists as minute living organisms capable of being wafted through the atmosphere. In consequence of the perpetual motion of the air these minute organisms are continually raised from their source and buoyed hither and thither, eventually reaching localities remote from their starting place. It is therefore evident that owing to the nature of this peculiar infection, the atmosphere is an extremely efficient agent in securing their distribution over widespread areas.

The value of the examination of the atmosphere for sanitary purposes is apparent when we reflect that we are continually bathed by the air, and besides it is continually taken into the body in respiration hence this is the
medium through which injurious substances are most frequently conveyed to the system. This is not generally recognized for the evil results arise so insidiously that the cause escapes observation.

Sources of impurities of the air.

The impurities of the air are many and of diverse natures but they may be classified as emanating from one of the five following heads or processes:

1. Respiration
2. Combustion
3. Gases, vapors and suspended mineral, metallic or vegetable matters given off by trades and manufactories
4. Retrefactive processes, sewage,
5. Disease germs from animals suffering from various maladies.

It is with the last two of these classes that we shall deal, and only with that part that is of an organic nature.
The organic matter of the air.

All air contains organic matter of various sorts which has been classified as 1 Wholesome, 2 Neutral, 3 Putrid, and 4 Organized or the dangerous form. There is scarcely a shade of distinction between the first two classes; they might well be considered as one class and that the neutral, for it can scarcely be asserted that any impurity of this nature is wholesome.

It is the living organic impurities that are discussed in this thesis. This restriction drops the whole chemical side of the question and the microscope is need as a substitute, for we are now dealing with matter that eludes chemical research.
Dullative changes are accompanied by the emission of gases and small living organisms which cannot be distinguished from other organic matter by chemical methods. It is for this reason that chemical analysis alone is not sufficient. These organisms are wafted by the air with facility to distant localities, but since they grow and multiply in aqueous mediums containing organic matter, the vapors from drains and sewers are especially charged with living organisms. The air over marshes, especially when the air is quiet and evaporation rapid, contains large quantities of living organisms and organic debris, which are carried upward by the action of vapor of water and are only discernible when placed under the microscope.
The air often contains pollen grains, small eggs, spores of fungi, various seeds, spores of bacteria, particles of finely pulverized straw, fragments of rags, soil sand, oxide of iron, lime, etc.

The air of cities contains, in addition soot, crystals of certain salts, starch granules, particles of linen, cotton, wool, bits of wood, hair, etc.

Within buildings, scaly epithelium cells are common besides the before mentioned forms of dust.

Of all this array of organic matter, the spores of bacteria are of most importance from the sanitary point of view, we will therefore again restrict the subject to include nothing but bacteria.

Fig. 1. on page 4 is a group of organic matter commonly found in the air, magnified 1000 diameters

Fig. 2. As a growing bacterium whose spores are common in air
1. Crystals of Chloride of Sodium
2. Vegetable fibers
3. Starch grains
4. Epithelial cells
5. Soot
6. Crystals of Sulphate of Sodium
7. Pollen grains
8. Beanside
9. Fungi
10. Pseudococcus
The Germ Theory of Disease.

According to the ancient idea of contagious disease, infections maladies were disseminated by some subtle misty vapor, later the current belief became a little more definite; it was thought that organic matter in a state of decay was the pernicious agent to which diseases owed their existence. This organic matter was designated by the general term malaria. It was maintained that when particles of this infectious matter found lodgment in the system, they were capable of setting up the peculiar process of decay in the living tissue with which they themselves were attacked. Yeast was cited as an example of the action outside of living tissue. But the discovery of the real nature of yeast made a great
advances toward the real nature of contagious disease, until lately the infection of certain diseases has been but imperfectly understood. There were but few who could pierce the vagueness with which the subject was surrounded; now, however, the mistiness is rapidly vanishing, and the view is clear and distinct. In 1837 Schwann of Berlin announced that when a decoction of meat is effectually screened from the air or supplied with pure (calcined) air only, putrefaction does not set in. He therefore asserted that putrefaction was not caused by the action of the air but by something in the air that is destroyed by heat. These results were confirmed by Helmholtz, Pasteur and others. Fermentation was held to be a purely chemical process for a long time after this by chemists and they maintained
the point so strongly that it required a good deal of investigation to prove the idea a false one. Sately, however, it has been thoroughly demonstrated that fermentation is caused only by means of organisms which use the fermenting material as food. The microscope shows that putrefaction and fermentation are always accompanied by living organisms and when these organisms are not allowed to gain access to organic material, putrefaction or fermentation cannot take place.

With these facts, the "Derm Theory of Disease" sprang into existence. The theory maintains that the germs of contagious disease are minute living organisms capable of floating in the air and when entering the system, growing, and multiplying, producing the grave disorder of the special disease of which they are the germs.
This theory is strongly strengthened by the fact that the germs of a specific disease, invariably produce that disease and nothing else just as surely as a kernel of corn produces corn. Since the development of the microscope the germs are readily seen. They can be propagated outside the living body in suitable media and used to produce disease in the lower animals in order to test the theory. In this manner the absolute truth of the theory has been established with respect to many contagious diseases. The germs of most diseases that have thus been worked out are bacteria which will be described presently.
Origin of the Germs

According to the natural classification these germs belong to the vegetable kingdom. Reasoning from analogy then it would follow that the existing germs must have been produced by previous organisms like themselves.

Everybody knows that exposure to scarlet fever produces scarlet fever and not the mumps and smallpox produces smallpox and not yellow fever and the same throughout the whole list of diseases. But it is often believed that the first case of some infectious disease in a locality arose spontaneously but this doctrine is untenable for no one has yet been able under any circumstances to produce bacteria spontaneously, indeed the idea is in direct
opposition to all the workings of nature.
Why not produce an apple tree spontaneously as easily as to produce a lower form of plant life?
The era of belief in spontaneous generation has passed, hence we cannot believe that one of these diseases ever arises spontaneously.
Decaying organic matter is often charged with producing disease but this cannot be unless the germs of the disease were first sown in the organic matter. Sewage and such offensive matter form a medium in which many of the various germs can propagate and they are often stocked with these germs of various kinds from the cities and sewer gas in these instances contain these germs in abundance, and they are thus disseminated through the adjacent neighborhood. But sewage of itself cannot
produce the germs. We cannot however believe that the number of specific germs has remained unaltered since the time of their first introduction into the economy of nature. The species of animals and plants now existing on the earth are not the same as those existing ages ago. Now if higher forms of life undergo these evolutionary changes it is at least probable that the lower forms may become differentiated in the course of a thousand years.

There are now several kinds of inert bacteria i.e. they are not capable of growing in living tissue but is known that these organisms can be changed in physiological action by gradually changing the condition with which they are surrounded. It is probable therefore that these inert varieties
may in the course of time become dangerous forms.

There is however no abrupt transition. The change requires a longer period of time so this theory does not invalidate the germ theory of disease.

**Relation of Bacteria to Surgery**

Before the discovery of bacteria it was known that in order for a wound to heal rapidly, extreme cleanliness must be observed; this was sought after and good results followed.

After the nature of bacteria became known and their relation to putrefaction and fermentation studied, it occurred to Prof. Lister of Edinburgh that bacteria must be the pernicious agent causing the formation of putrescent pus and the evil consequences which
often follow. He found upon microscopical examination that pus swarmed with living organisms. Therefore he assumed that if the wounded surface be kept entirely free from bacteria or if the bacteria be killed as soon as they light upon the wounded surface. To this end he flame his knife before commencing a surgical operation, keeping a spray of dilute carbolic acid playing upon the parts while the operation was being performed and immediately bound up the wound with cloth soaked in carbolic acid which kills the bacteria. By this treatment it was found that a limb could be amputated and healed again without the formation of pus and no pain from inflammation. In this manner the death rate of the patients under his care in the hospital was much reduced.
The benefits of cleanliness is principally in keeping bacteria away, as all dust and dirt is extremely likely to contain these organism.

Number of Organisms in the air

The estimation of the number of bacteria in the atmosphere is accomplished by aspirating a small volume of distilled water or other sterilized material, and then finding how small a volume of the material is required to produce a growth in sterilized beef broth, or by mixing a part of the material with some sterile gelatin and spreading the mixture on a plate of glass under a bell jar and noting the number of colonies which develop. The second method is more likely
to become accidentally contaminated from the air, but is perhaps as accurate as the other method. The first method requires a large number of flasks of beef broth to verify the results. Extreme caution must be exercised in transferring the water to the broth to prevent outside contamination. By knowing the fraction of the whole water that is required to produce a growth in the broth, the number which has been obtained by aspiration is known at once and the number in any volume can easily be computed. Dr. Miguel at the experimental station situated at Montsouris just outside Paris has done more than any one else in determining the number of bacteria in a certain volume of air. The following are some of the results obtained by him.
For the years 1880 to 1885 he found the following per cubic meter at the park of Montmorency:

<table>
<thead>
<tr>
<th></th>
<th>1880</th>
<th>1881</th>
<th>1882</th>
<th>1883</th>
<th>1884</th>
<th>1885</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>250</td>
<td>315</td>
<td>440</td>
<td>110</td>
<td>145</td>
<td>90</td>
<td>225</td>
</tr>
<tr>
<td>February</td>
<td>105</td>
<td>220</td>
<td>270</td>
<td>75</td>
<td>140</td>
<td>95</td>
<td>155</td>
</tr>
<tr>
<td>March</td>
<td>650</td>
<td>520</td>
<td>245</td>
<td>160</td>
<td>240</td>
<td>380</td>
<td>495</td>
</tr>
<tr>
<td>April</td>
<td>390</td>
<td>335</td>
<td>420</td>
<td>430</td>
<td>360</td>
<td>390</td>
<td>420</td>
</tr>
<tr>
<td>May</td>
<td>1370</td>
<td>570</td>
<td>280</td>
<td>405</td>
<td>400</td>
<td>490</td>
<td>575</td>
</tr>
<tr>
<td>June</td>
<td>270</td>
<td>645</td>
<td>150</td>
<td>620</td>
<td>580</td>
<td>710</td>
<td>490</td>
</tr>
<tr>
<td>July</td>
<td>380</td>
<td>1330</td>
<td>300</td>
<td>1000</td>
<td>490</td>
<td>940</td>
<td>740</td>
</tr>
<tr>
<td>August</td>
<td>330</td>
<td>780</td>
<td>520</td>
<td>580</td>
<td>490</td>
<td>410</td>
<td>600</td>
</tr>
<tr>
<td>September</td>
<td>900</td>
<td>735</td>
<td>520</td>
<td>380</td>
<td>490</td>
<td>410</td>
<td>600</td>
</tr>
<tr>
<td>October</td>
<td>990</td>
<td>800</td>
<td>160</td>
<td>430</td>
<td>370</td>
<td>240</td>
<td>500</td>
</tr>
<tr>
<td>November</td>
<td>740</td>
<td>490</td>
<td>90</td>
<td>175</td>
<td>185</td>
<td>185</td>
<td>335</td>
</tr>
<tr>
<td>December</td>
<td>340</td>
<td>365</td>
<td>90</td>
<td>190</td>
<td>140</td>
<td>140</td>
<td>225</td>
</tr>
<tr>
<td>Average</td>
<td>360</td>
<td>390</td>
<td>320</td>
<td>440</td>
<td>330</td>
<td>450</td>
<td>465</td>
</tr>
</tbody>
</table>
Variation in number of bacteria according to the season.

(1) at Montsouris (2) Centre of Paris

<table>
<thead>
<tr>
<th>Season</th>
<th>1883</th>
<th>1884</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>150</td>
<td>270</td>
<td>220</td>
</tr>
<tr>
<td>Spring</td>
<td>530</td>
<td>490</td>
<td>515</td>
</tr>
<tr>
<td>Summer</td>
<td>910</td>
<td>670</td>
<td>735</td>
</tr>
<tr>
<td>Fall</td>
<td>230</td>
<td>335</td>
<td>280</td>
</tr>
<tr>
<td>Average</td>
<td>440</td>
<td>480</td>
<td></td>
</tr>
</tbody>
</table>

(2) Centre

<table>
<thead>
<tr>
<th>Season</th>
<th>1885</th>
<th>1884</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>4340</td>
<td>2690</td>
<td></td>
</tr>
<tr>
<td>Spring</td>
<td>950</td>
<td>5350</td>
<td></td>
</tr>
<tr>
<td>Summer</td>
<td>505</td>
<td>470</td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>230</td>
<td>280</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>5520</td>
<td>5020</td>
<td>4900</td>
</tr>
</tbody>
</table>
The air in central Paris contained the following number of microbes per cubic meter for the years 1881-1885:

<table>
<thead>
<tr>
<th></th>
<th>1881</th>
<th>1882</th>
<th>1883</th>
<th>1884</th>
<th>1885</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>3290</td>
<td>1120</td>
<td>1820</td>
<td>1080</td>
<td>2090</td>
<td>1880</td>
</tr>
<tr>
<td>February</td>
<td>2310</td>
<td>1400</td>
<td>980</td>
<td>1140</td>
<td>5390</td>
<td>2480</td>
</tr>
<tr>
<td>March</td>
<td>5250</td>
<td>3920</td>
<td>2360</td>
<td>1680</td>
<td>3350</td>
<td>3710</td>
</tr>
<tr>
<td>April</td>
<td>6790</td>
<td>5950</td>
<td>2150</td>
<td>2420</td>
<td>7210</td>
<td>4905</td>
</tr>
<tr>
<td>May</td>
<td>7800</td>
<td>6790</td>
<td>1740</td>
<td>1860</td>
<td>11260</td>
<td>5760</td>
</tr>
<tr>
<td>June</td>
<td>10780</td>
<td>2190</td>
<td>1800</td>
<td>1810</td>
<td>11100</td>
<td>5535</td>
</tr>
<tr>
<td>July</td>
<td>9890</td>
<td>4970</td>
<td>4640</td>
<td>2960</td>
<td>6000</td>
<td>5205</td>
</tr>
<tr>
<td>August</td>
<td>6720</td>
<td>4970</td>
<td>3410</td>
<td>1650</td>
<td>5270</td>
<td>4425</td>
</tr>
<tr>
<td>October</td>
<td>7490</td>
<td>2760</td>
<td>3330</td>
<td>2050</td>
<td>3500</td>
<td>2825</td>
</tr>
<tr>
<td>November</td>
<td>5460</td>
<td>2080</td>
<td>8760</td>
<td>2320</td>
<td></td>
<td>2650</td>
</tr>
<tr>
<td>December</td>
<td>3710</td>
<td>1330</td>
<td>860</td>
<td>2670</td>
<td></td>
<td>2015</td>
</tr>
<tr>
<td>Average</td>
<td>6295</td>
<td>3435</td>
<td>2845</td>
<td>1865</td>
<td>(5620)</td>
<td>3910</td>
</tr>
</tbody>
</table>
From these tables it is seen that the number of bacteria in the air are at a minimum in winter though never entirely disappearing. Toward the middle of summer they reach a maximum. The number at any time is dependent on the condition of the atmosphere. Rains carry many to the ground or may even purify the atmosphere entirely. Immediately after a shower in April I exposed 5 flasks of sterile beef broth and although the wind was blowing briskly only one of the flasks subsequently showed any signs of decomposition. From the exposures the next day I obtained copious growths of moulds and half the flasks contained microbes. During all this time the experimental laboratory was laden with bacteria. The latter part of April I determined the number to be about 2000 per cubic meter.
Besides rain, the barometric pressure and condition of the air in regard to moisture causes variations in the number. The number in houses varies according to the ventilation from a few to 10,000 per cubic meter. How we breathe during the day on an average about 11 cubic meters of air then in a city or close room we may take into our lungs as high as 110,000 bacteria, and if one of these should be a disease germ and should happen to become lodged evil consequences would follow. It is thus impossible to escape if these germs are allowed to fill the air. Besides the irregular variations spoken of above there is a regular daily variation. Miguel has worked out these daily variations and finds them quite independent of the direction of the wind.
The time of day for maximum and minimum number for different directions of the wind was found to be as follows:

<table>
<thead>
<tr>
<th>Direction of Wind</th>
<th>Minimum</th>
<th>Max</th>
<th>Minimum</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>2.30</td>
<td>8.00</td>
<td>2.00</td>
<td>7.00</td>
</tr>
<tr>
<td>North-East</td>
<td>2.00</td>
<td>7.45</td>
<td>1.30</td>
<td>7.30</td>
</tr>
<tr>
<td>East</td>
<td>1.30</td>
<td>6.30</td>
<td>1.00</td>
<td>6.00</td>
</tr>
<tr>
<td>South-East</td>
<td>2.30</td>
<td>7.00</td>
<td>1.30</td>
<td>8.00</td>
</tr>
<tr>
<td>South-West</td>
<td>2.00</td>
<td>7.00</td>
<td>2.00</td>
<td>8.00</td>
</tr>
<tr>
<td>West</td>
<td>2.30</td>
<td>8.30</td>
<td>1.30</td>
<td>7.00</td>
</tr>
<tr>
<td>North-West</td>
<td>1.00</td>
<td>6.30</td>
<td>12.30</td>
<td>8.00</td>
</tr>
</tbody>
</table>

The following table shows the primary and secondary variation during the summer of 1885.
1885.

24 June
3 July
16 July
3 Aug
4 Aug

The letter B designates the time of maxima and H that of maxima variations. 6 and 10 represent the minima and maxima of secondary variations. From the table it is seen that the number is smallest at about 10 o'clock at 4 o'clock both morning and evening, while the greatest numbers appear at 7 o'clock both morning and evening.
Another remarkable fact is that the strength of the wind, provided it remain constant, has no effect on the variation in its daily increase and decrease holds true for the whole season.

The cause of these diurnal variations is unknown. Dr. Miguel suggests however that the oblique currents of air which are governed by the heating and cooling of the soil, have great effect in connection with these phenomena. In meteorological records no mention has been made of these oblique currents. To test the validity of the theory it would only be necessary to construct an anemometer to measure the inclination of the winds and a comparison made between these records and those of the daily variation.
Besides investigating the air under various conditions on land, Miguel examined the air at sea at various points and found it almost free from bacteria. The following table gives his results:

<table>
<thead>
<tr>
<th>Locality</th>
<th>State of Sea</th>
<th>Sitre's aspirated</th>
<th>Na g Bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rio de la Plata</td>
<td>Very Calm</td>
<td>15.18</td>
<td>1</td>
</tr>
<tr>
<td>Coast of Brazil</td>
<td>Rough</td>
<td>10.40</td>
<td>3</td>
</tr>
<tr>
<td>At Sea</td>
<td>Calm</td>
<td>22.77</td>
<td>0</td>
</tr>
<tr>
<td>At Sea</td>
<td>Calm</td>
<td>25.20</td>
<td>1</td>
</tr>
<tr>
<td>At Sea</td>
<td>Calm</td>
<td>26.36</td>
<td>0</td>
</tr>
<tr>
<td>At Sea</td>
<td>Calm</td>
<td>32.76</td>
<td>0</td>
</tr>
<tr>
<td>At Sea</td>
<td>Rolling</td>
<td>18.50</td>
<td>4</td>
</tr>
<tr>
<td>Coast of Africa</td>
<td>Very Calm</td>
<td>16.12</td>
<td>6</td>
</tr>
<tr>
<td>At Sea</td>
<td>Calm</td>
<td>13.19</td>
<td>1</td>
</tr>
<tr>
<td>Location</td>
<td>Condition</td>
<td>Pressure</td>
<td>Count</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------</td>
<td>----------</td>
<td>-------</td>
</tr>
<tr>
<td>At Sea</td>
<td>Calm</td>
<td>1390</td>
<td>1</td>
</tr>
<tr>
<td>Madère</td>
<td>Very Calm</td>
<td>904</td>
<td>0</td>
</tr>
<tr>
<td>At Sea</td>
<td>Storm</td>
<td>2239</td>
<td>4</td>
</tr>
<tr>
<td>Coast of Spain</td>
<td>Calm</td>
<td>1681</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total aspiration</strong></td>
<td></td>
<td><strong>27041</strong></td>
<td><strong>26</strong></td>
</tr>
</tbody>
</table>

This table shows how nearly pure the air of the ocean is. Surely a sailor's life must be a healthy one, considered from this standpoint. We who dwell on the land are unavoidably surrounded by numerous varieties of these low organisms. We take them in at almost every breath, they are intimately mixed in our food, they become lodged on all portions of the body. It is therefore of importance to understand their relation to our wellbeing. Some bacteria are beneficial some inert and some
noxious. They are classified according to their physiological action into three classes:

I. **Septic**, which includes all that are purely putrefactive in their nature.

II. **Zymogenic**; this includes those that produce specific chemical compounds; they are commonly known as fermenta.

III. **Pathogenic** is used to designate those that produce disease.

The septic and zymogenic varieties are much more commonly distributed than the pathogenic varieties.

It is owing to the septic bacteria that a balance between the organic and the inorganic kingdoms is maintained. For it is through their agency that the organic is broken up into...
its elementary compounds, and were it not for
them, the life forces which work in the opposite
direction would in time use up all the available
inorganic matter, then all life would necessarily end.

It was formerly supposed that organic compounds
broke up spontaneously as soon as life departed
from them. This idea is common today
among those that have not had an opportunity
to learn otherwise; this is not strange when
even so high an authority as the latest edition of
Encyclopedia Britannica says of Putrefaction—"In
olden times it was assumed that organized matter
(the tissues of plants, and animals, blood corpuscles etc.)
could hold together even chemically only as long as
supported by vital force. But this is a long exploded
notion. In absolute absence of water or very low
temperature, dead organized matter remains chemically (and even structurally) unchanged. In support of this assertion we need only to refer to the well-known case of the Mammoth of the Siberian cave which was found sweet and fresh thousands of years after extinction of life. And since the time of Appert who discovered the now so extensively used process of preserving meats in sealed casks we know that prolonged exposure to boiling heat and subsequent absolute exclusion of air prevent putrefaction even in the presence of liquid water and at the ordinary temperature as long as the air remains excluded. From this statement the inference is unavoidable that air is the destructive agent. That this is erroneous can be shown by a simple experiment. Take a
small flask of fermentable fluid and after plugging the neck of the flask with cotton, heat the fluid to the boiling temperature three or four times at intervals of twelve hours, then allow to at the ordinary temperature and it will be found that the liquid will not putrefy although the cotton plug allows free access of air but the air that enters the flask has the micro-organisms strained from it. After the fluid has remained pure for some time it is only necessary to remove the plug for a minute or two and putrefaction is certain to ensue. The is conclusive proof that putrefaction is not due to the air but to organisms in the air. This experiment should be repeated several times inorder to prevent accidental contamination. The experiment is not successful every time.
This class of organisms must be considered as beneficial not only in a manner indicated above but it is owing to their agency that the fertility of the soil is maintained. They may also prove of much importance in the deposition of metallic veins. There are two methods by which metals are deposited in veins. First: A metallic sulphate in solution percolating through the rock coming in contact with decaying organic matter is reduced to the sulphide and is precipitated immediately hence the ore accumulates in the vicinity of this organic matter. Second: Many of the metallic sulphides are soluble in alkaline sulphide waters but such a solution coming in the neighborhood of decaying organic matter would be neutralized by the products of putrefaction and the metallic sulphide would at once
be thrown down and an ore body would thus be formed. It is through the agency of decaying organic matter that gold in a solution of sulphate of iron, which is its natural solvent, is crystallized and deposited in the placer mines. Nuggets of gold are produced by the deposition at one place.

So also with iron, there are no beds of this metal except in strata rich in organic matter and the reverse is also true, i.e. in beds containing much organic matter the iron is collected in beds while the iron in strata void of organic matter is evenly distributed throughout the whole formation and never collected in ore beds.

In order for organic matter to precipitate these metallic sulphates it must be in a state of decay and the only known method of decay is through the
agency of bacteria, yet it is possible that organic matter may slowly oxidize when buried in the earth without the aid of these organisms but as it is we may give bacteria the benefit of the doubt. So much for septic bacteria.

Most of the symbiotic class are directly beneficial. Many of these are found in the air. We now turn to the injurious or pathogenic class. These are not as generally disseminated as the other two classes. Their nature has only lately been discovered.

It is now known that many infectious diseases owe their origin and propagation to specific forms of bacteria which grow and multiply in living tissue. Although these germs are not as common as the other bacteria yet they
cause more suffering to the animal kingdom than all causes combined. An enumeration of diseases which they are known to produce will suffice to show their terrible character: thus Anthrax, Cholera, Spleen, Hog cholera, Hydrophobia, Leprosy, Septicaemia of mice, Diphtheria, Whooping Cough, Tuberculosis, Typhoid Fever, Dental Caries, Chicken Cholera, Encephalitis, Yellow Fever, Variola, Measles, Small Pox, etc.

Show with what dire calamities the higher animals are afflicted by these minute pests. nor do the lower animals escape; they have their epidemics. In each case myriads upon myriads of these germs are produced and sent out into the air and when we remember how easily these spores are carried by the air it would seem that our
chance of escape is indeed small, but owing to the unceasing research of several investigators complete control has been gained over a few of the above diseases. Indeed when the cause of a malady is determined the methods of prevention or cure can be worked out intelligently.

Not all diseases are produced by bacteria, the specific cause of Ague has lately been determined to be a minute Amoeba infecting the red corpuscles. Quinine kills these animals.
Morphology of Bacteria

Bacteria are exceedingly small one-celled organisms without chlorophyll, multiplying by fission, hence the name given by Nägeli — Schizomycetes. The cell wall is composed of cellulose. The contents is clear and transparent (small particles of sulphur is said to have been seen in some varieties). It is owing to the woody cell wall that acids and alkalies do not destroy them. Many are capable of locomotion, darting hither and thither with perfect freedom. This motion has been demonstrated to be accomplished by means of a cilium at each end of the cell but this has only been seen in two or cases and then only by the best manipulation of the best microscopes. Some have no
motion except the Brownian, as in the genus Micrococcus. In some cases colonies are formed when multiplying rapidly, in this case the individuals are embedded in a gelatinous membrane and of course can have no motion. This is called the Googolae stage. For their best development they require to be left undisturbed. Some require free oxygen for their growth; they are then said to be aerobic; others grow without free oxygen and are then said to be anaerobic. All require a nutritious medium containing carbon and nitrogen, water is indispensable. The temperature must be between certain limits, 100° Fahr. is the most propitious; they obtain nitrogen from simple compounds such as
ammonium nitrate or tartrate. It is this fact that is one of the characteristics that places them in the vegetable kingdom. Animals require nitrogen for their nutrition but they obtain it from higher compounds as albumoide, this is one of the chief distinctions between the vegetable and animal kingdoms. The carbon is obtained from carbohydrates such as sugar, starch etc.

It is also necessary that the fluid contain other salts essential to plant growth.

Many bacteria of the septic class originate chemical compounds which stop their growth or may even kill them. A temperature some what less than that of boiling water kills all growing bacteria but their spores may resist boiling for several hours. It is said that 120° below 0 Cent.
kills the spores but they are incapable of growth unless the temperature is raised above freezing. Many chemicals known as antiseptics, unlikely to prohibit their growth, the most remarkable of these is corrosive sublimate which completely stops their growth in solutions of 1:300,000.

With this hasty review of the morphology of bacteria we will look a little more closely at the relations between different classes of bacteria to each other.

Relations of Septic to Pathogenic Bacteria

An important field of inquiry will ever be found in the life histories of the specific organisms both within and outside the body. It is of great importance to study the conditions which affect the growth
and dissemination of these micro-organisms for it is right here that methods will be found to control the spread of contagious diseases. Although the physiological action of each species is fixed yet there is some evidence that certain species may change their customary mode of action. It is known that variations in temperature and culture media will in some cases alter the character of the organism. Several have experimented in this important field of research among whom may be mentioned Schütz, Doux, Roux, Pussain, Pasteur, Chavean, Koch and Buchner. These eminent investigators have noted numerous instances of changes in special organisms, but the question as to whether an organism which
commonly only act upon dead organic matter may
under under certain conditions, multiply within
living tissue producing disorders or disease has
not been satisfactorily demonstrated.
Such a change can no doubt be produced in the
course of long periods of time but what concerns
us is whether there is any sudden transition.
The rapid evolution of one form to another is claimed
for three common species: 1. Bacillus subtilis
to Bacillus anthracis, 2. Bacillus subtilis
when grown in a decoction of the seeds of certain
plants is endowed with the power of causing
severe opthalmia, 3. A common mold
harmless in itself but becomes very poisonous
when grown in alkaline media.
Since Bacillus subtilis is of such common
occurrence in the atmosphere it may be well to describe the experiments made by Dr. van Buchner in which he claims to have succeeded in changing this organism to Bacillus anthracis. A few of the morphological differences between these two organisms may be summed up as follows: A thread of B. subtilis is composed of cylindrical elements with rounded ends while B. anthracis they are more nearly cubical, with square ends. not quite as thick as in the former. When growing in a fluid culture B. subtilis forms its characteristic telltale at the top while B. anthracis forms its cloudlike compact mass in the fluid leaving all the rest of the fluid clear, its elements are motionless while the other species perfectly motile. Buchner states that by a constant variation in the culture fluid he
found it possible to gradually change B. anthracis
to B. subtilis. The result would be more conclusive
if the experiment were carried on in the opposite
direction for then the danger of accidental contamination
with which the species which he was trying to
produce would be very much reduced although
it is possible to have these rarer forms in
the air of the experimental laboratory where
they are propagated. Koch and Klein do not
believe that this transformation can be accomplished
but that Buchner's results were brought about
by accident, coupled with misinterpretation
Klein states that accidental contamination in a
laboratory where different varieties of organisms
are kept is of frequent occurrence. The results
of this experiment must be taken with a large
degree of allowance.
It would indeed be dreadful to contemplate what
dire calamity would befall the animal kingdom
should the harmless ever present B. subtilis be trans-
formed to the deadly anthrax.

Growth of Non-Pathogenic Bacteria

Non-Pathogenic bacteria include the septic and
zymogenic varieties, they act on dead organic
matter but are incapable of acting on living tissue
In the process of putrefaction certain compounds
are produced which are destructive to animal
life when introduced into the system in sufficient
quantities, it is undoubtedly due to the growth of organisms that poisonous foods are produced. The application of antiseptics to large wounds must have a great effect in preventing "blood poisoning" for bacteria thrive in wounds, and if the wound is large and the bacteria allowed to grow they will produce enough poison to cause the death of the patient. The economic value of these bacteria has been discussed in a previous chapter.

Growth of Pathogenic Organisms

These organisms live and multiply in living tissue and are intimately connected with various maladies as consumption, anthrax
glande etc.  This is proven in the various maladies by 1st finding the organisms abundantly in the diseased patient 2d by growing the organisms in artificial cultures in order to free them from any chemical virus and by inoculating an animal with these organisms producing the specific maladies. One organism is able to produce the whole disorder, yet a specific organism cannot grow with equal facility in all animals. Klein states that anthrax while destructive to life in the human family and herbivorous animals it cannot be developed in carnivorous animals or the swine plague does not affect man. This seems a little peculiar for grow with equal readiness in broth made from any flesh what ever, there must be some peculiarity in the living
animal that prevents the growth of one organism while other organisms are not impeded by the same conditions. What these peculiar conditions are is entirely unknown.

Classification

The classification of bacteria is still in an unsettled condition although several attempts have been made, all of which are more or less artificial. The classifications prepared by Cohn Flügge and Bopp are the most important, that of Dr. Ferdinand Cohn has had the greatest popularity. The three principal genera in his classification are Micrococcus, Bacterium, and Bacillus.
The separation into these genera is simple depending largely on size and shape, but the division into species is mainly dependant on physiological action. The genus Micrococcus consists of organisms whose cell is spherical or slightly ovate, single or united into two (dumbbell) or forming a filament of many individuals having no motion except the Brownian.

They are sometimes united in masses as "mother of vinegar" this is called the Zoöglæna stage. I have found members of this group at all times in the air of the laboratory.

Their determination is exceedingly difficult owing to their slight variation in size which is at most exceedingly small, often no greater than 5000 of an inch in diameter, at that rate it would take
1,000,000 of them to fill a sphere—the size of a common writing period. Some of the varieties that are sometimes found in the air are enumerated below.

Micrococcus prodigiosus
Micrococcus diphtheriae
Micrococcus enzepelatius
Micrococcus variolæ vaccinæ
Micrococcus pneumoniae
Micrococcus endocarditice
Micrococcus scarlatinae
Micrococcus of cattle plague (or swine plague etc.)
Micrococcus actin.

Most of these are quite rarely found in the air, being found in fluctuating localities. Some of these are propagated in filthy fluids.
as for example "Micrococcus diphtheriticus"
the organism associated with diphtheria.
Such fluids as contained in the Illinois and
Michigan Canal make magnificent media for
their growth. The waters of this canal are
well stocked with such germs of the disease in
Chicago. The results of its flow through the country
is made only too evident in the deadly virulence
of these maladies along its banks.

The members of the genus Bacterium are
elliptical or approaching cylindrical in shape, usually
single, sometimes in pairs, rarely in fusing, never in
filaments, sometimes in rosettes. Very active,
there are several species which are mostly septic
or gasogenic. The one that is of most importance
is a term. It is everywhere present where organic matter putrefies producing foul odors. It may be said to be the great putrefactive bacterium. There are two that belong to the fermentative class that deserve mention. 1st, Bacterium lactis. Lister has proven their causal relation to the souring of milk or lactic fermentation, evidently then its distribution is as wide as that of sour milk. 2d. Acet, (Mycoderma aceti) is claimed by Pasteur to be the acetic acid ferment.

In the genus Bacillus the cells are cylindrical, sometimes single, often joined end to end forming long filaments, sometimes in groups. The species of this genus are quite numerous, many of them are instrumental in producing some
of the most terrible of diseases but it will not be necessary to discuss them here. There are two species that are so common and so characteristic that we cannot pass without mentioning them. The first and probably the most widely disseminated and most numerous of the bacteria. Its individual rods vary from .0005 to .00015 of an inch in length and .0002 of an inch in diameter. The rapidity of fission depends on the temperature, according to Cohn it takes only 20 minutes at a temperature of 95° Fahr. Often the new cells do not part but divide again and again forming long threads called leptothrix filaments. Generally the length of the threads is not very great. The individual rods and short threads have an active motion. Klein asserts that each cell has a flagellum or
sometimes two attached at each end.

After swarming through a nutrient medium they gradually rise to the surface, and form a thick, convoluted, dry, pure white resistant pellicle within which spore formation takes place. The specific gravity of the pellicle is considerably greater than that of the liquid. The spores are oval shining bodies about 1/2 the diameter of the bacillus, they do not stain in dyes and consequently can easily be distinguished from the bacillus which is stained very readily. I have found this variety very common in the air of the experimental, being more prevalent at the top of the room than all other varieties put together. It will grow in all nitrogenous organic substances left free to the atmosphere, occurs
the form of its pellicle which is heavy, wet and extremely thick with no convolutions, as opposed to that already described of B. subtilis.
in sour milk and is credited with causing the
ripening of cheese and making butter "strong" but
the principal agent in rancid butter is B. butyricus
(Butyricum butyricum according to Joff's classification)
This variety is difficult to distinguish from B. subtilis
by use of the microscope. (Compare figures 4 and 2)
It occurs in long or short threads or in Gourdon (12)
they convert lactic acid in milk to butyric acid,
and are the active agent in the fermentation of
Sauerkraut. This species was very abundant
in the atmosphere after some milk had been
allowed to sour and produce butter. An exposure
of beef broth to the air for one minute was generally
sufficient to procure the organism.
When growing in a fluid culture, on potatoes, or in
gelatin it is easily distinguished from B. subtilis by
Fig. 3. x 500  
*Common bacillus*

Fig. 4. x 500  
*Bacillus anthracis*

Fig. 5. x 600  
*Bacillus anthracis*

Fig. 6. x 600  
*A. Bacillus*