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THE PATHOLOGY OF THE PNEUMONIA IN THE UNITED STATES ARMY CAMPS DURING THE WINTER OF 1917–18.*

BY WILLIAM G. MACCALLUM, M.D.,

Contract Surgeon, U. S. Army.

(*From the Pathological Department of Johns Hopkins University, Baltimore.*)

PLATES 1 TO 53.

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I. HISTORICAL SURVEY.

The gathering together of great numbers of men in the United States Army camps furnished conditions for an extensive outbreak of measles which was quickly followed by a rather unfamiliar form of pneumonia.

The Geographical and Historical Pathology of Hirsch, the volume on Epidemics in Haeser's History of Medicine, and other standard books that treat of the history of disease show that this is only one of a great number of epidemics of pneumonia which have been recorded

* These studies have grown out of the work of two Commissions sent out by the Surgeon General of the United States Army for the investigation of epidemics of pneumonia among the troops. The first Commission was composed of Rufus Cole, W. G. MacCallum, Oswald T. Avery, Contract Surgeons, United States Army, Captains A. R. Dochez and R. A. Kinsella, and Lieutenants F. G. Blake, T. M. Rivers, William C. von Glahn, J. John, and F. A. Stevens. The preliminary report of the activities at Fort Sam Houston, Texas, during February and March appeared in *The Journal of the American Medical Association*, 1918, lxx, 1146. The second Commission, which was composed of W. G. MacCallum, Contract Surgeon, Captain A. W. Sellards, and Lieutenants H. M. Thomas, Jr., and A. B. Lyons, worked at Camp Dodge, Iowa, during May, 1918. A brief summary of the activities of this Commission was presented at the meeting of the American Medical Association in Chicago, in June, and appeared in *The Journal*

since at least the 16th century. It is difficult to decide, however, as to the identity of the pneumonia with what was described by contemporary writers in those long past epidemics, since they usually limited themselves to the mention of a few symptoms followed by a lengthy discussion of their treatment of the cases. Few performed autopsies or recorded descriptions that can be recognized. Nevertheless, their writings suggest that in many of the epidemics they must have been dealing with the same condition that has existed during the past winter.

In the 16th century there were many epidemics throughout Italy, beginning in 1535 and sweeping over the whole peninsula. In Switzerland it was known as the malignant stitch, or *Alpenstich*, and by 1576 it had spread over Western Europe.

The attack began with a chill, pain in the head and chest, and a cough which was at first dry but afterwards attended with expectoration. The patient became delirious or fell into a stupor; loose evacuations followed, and death occurred on the 6th or 7th day, or if the disease was protracted over the 9th day the prognosis was good. Massa described pleural effusions, and Coiter states that in all the cases which he described he found the lungs filled with putrid blood, turgid, and indurated, while Dodonæus writes that abscesses were frequent in the lungs. In the 17th century there were similar epidemics, and several authors report finding serous and blood-stained effusions in the pleura and pericardium, and the lungs in part condensed, in part rendered diffluent by suppuration. In the 18th century, according to Hirsch, there were still epidemics of the same "typhoid pneumonic" character in Spain, England, Italy, Switzerland, France, and North America. In all these the malignant type of the disease is emphasized and the hepatization or purulent softening of the lungs is

of the American Medical Association (MacCallum, W. G., *J. Am. Med. Assn.*, 1918, lxxi, 704).

My grateful acknowledgment is due to the men who worked on these Commissions, for their aid, and to the various members of the staffs of the Base Hospitals at these two places. Especially are my thanks due to Major L. Clendening, of Fort Sam Houston, who furnished clinical data of most of the cases, and to Major Joseph L. Miller, of Camp Dodge, who did the same for the cases studied there. Major D. Glomset, who was in charge of the laboratory at Camp Dodge, also afforded us every aid in his power.

given as the characteristic anatomical feature. Morgagni describes the lungs as firmly hepatized. The disease prevailed widely in France in the latter part of this century. De Sauvages in 1790 describes peripneumonia typhodes, and Deplaigne an epidemic among soldiers at Valenciennes. They made postmortem examinations and found suppurative processes in the lungs with effusion of pus or gelatinous serum in the chest and sometimes in the pericardium. There were pleural adhesions too, but the other organs were normal except for swelling of the liver. In Great Britain and in Germany there were also severe epidemics.

In North America there were, as described by Webster, epidemics in Connecticut in 1712, 1719, 1760, and 1795. Bard tells briefly of a similar epidemic at Huntington, Long Island, in 1749, and recounts symptoms resembling those which we have seen recently, but he made no dissections. I have not been able to associate these epidemics with the gathering of troops during the Revolutionary War or to find any papers referring especially to this period.

In 1812, however, there began a great epidemic which, starting in Canada, spread throughout the Northern States and finally into the South. There is a great deal of literature about this, and the *Medical Repository* and the *American Medical and Philosophical Register* made a special point of gathering together communications and essays relating to it. There is also a book by James Mann, Hospital Surgeon of the Army, published in 1816 (Medical Sketches of the Campaigns of 1812, 1813, and 1814) which gives a good description of the condition, including a few postmortem observations. From these it may be learned that some of the soldiers died with extensive pleural effusion, sometimes of thick pus, as in the case of one man whose pleura was drained by an incision between the ribs, and sometimes of a thick yellowish whey-colored fluid, while a membrane of coagulated lymph lined the cavity of the thorax. In one case the lungs were dark purple, but on incision thick pus could be forced by compression out of the air cells. In another the lungs were contracted, compact, tough, and almost destitute of air vessels. Another showed the lung large, hard, and adherent to the upper part of the cavity. It appeared like the liver, tender and easily lacerated with the fingers, and entirely destitute of the spongy texture peculiar to healthy lungs. In its superior part

adjoining the clavicle and near the trachea was a large sphacelus, part of which had been coughed up. Pus was by compression squeezed out of the air cells. In another case the lung was adherent on all sides, and specks of pus were found throughout it, but no abscesses.

Still another case presented a lung in which a small portion had come to resemble the liver, and the cells contained pus. The other lung exuded pus on every incision. It was not much dissimilar to a honeycomb, if filled with pus. The last, or eleventh case revealed three pints of limpid glutinous serum resembling whey in each cavity of the thorax. The right lung was contracted to half its natural size. The upper part was consolidated and hardened, feeling and appearing like a piece of heart boiled. Adhesions had formed to the spine, ribs, clavicle, and pericardium. The lobe was so much drawn to the spine that no adhesion existed between it and the ribs of the anterior part of the thorax. In the upper part of the lobe immediately under the clavicle there was an abscess as large as a goose egg. There were found adhering to the pleura and lungs a membrane of coagulated lymph and some similar thick pieces resembling what is commonly called mother of vinegar. The left lobe appeared little diseased, but on cutting into the substance drops of pus were squeezed out of its cells. While one or two of these cases appear to have been instances of lobar pneumonia, the others in which there was such extensive pleurisy and from the lungs of which drops of pus could be squeezed resemble closely the cases found in the present day epidemic.

The descriptions of the clinical symptoms given by Mann, Bard, Eights, Matson Smith, Valentine Mott, McBride, and others agree closely, but by far the best is given by James Low who described the beginning of the epidemic in Albany in October, 1812.

"The onset is with a chill, prostration and a feeble pulse, horror and distress from pain in the head, back, and extremities. The tongue is furred, the breathing insupportably laborious even when the pain in the chest is not severe, and every muscle concerned in this function ceases to act until goaded on by volition. When the pain is acute the anguish is inexpressible. Every cell in the lung seems infarcted and weighed down by the load.

"Restlessness, distressing dreams, sudden frights, and starting from sleep attend most cases. Many are unable to endure the horizontal posture from a sense of suffocation which attends that position. Coma and delirium ferox are frequent symptoms and there are aphthæ and ulcers in the throat in some cases.

The disease sometimes terminates in scarlet fever, measles, or an anomalous rash, all of which prevailed, as was the case in other countries where the same epidemic has raged. Morgagni, Coiterus, and Wierus describe the same in Italy and Germany, Cleghorn in Minorca, Sydenham, Huxham, and Home in England."

Low saw gangrene of the leg in one case. Hosack also mentions autopsies in this epidemic in which he found an overloaded state of the vessels of the lungs. A large effusion of serum and sometimes purulent matter and the adhesions between membranes covering the lungs and those lining the chest show that there has been inflammation of the lungs. It was, he decides, a local inflammation with a typhous state of the whole system from which he refers to it as peripneumonia typhodes.

Mann, in another paper written from Plattsburg, states that the most prevalent disease was measles, which predisposed those who had it to pneumonia. He gave once more a description of the lungs which were inflamed with adhesions to circumjacent parts, with the surface covered with yellowish gelatinous semiputrid extravasation. The spongy texture of the lungs was lost and the organ assumed the compactness of the liver.

McReynolds in describing an epidemic among troops at Black Rock gives similar details of autopsies, and so does Hudson concerning an epidemic on the Niagara Front. Hudson was especially interested in the extension of inflammation through the diaphragm to the surface of the liver. A similar affection with pleurisy with serous effusion and pulmonary changes was observed in the New York Hospital in January, 1813.

After the disease had raged among the troops and inhabitants of northern New York it appears to have occurred with especial intensity in Dutchess County, East Chester, and West Chester, as well as in New York City, and Long Island, but there were also many cases in Connecticut, Vermont, and Maine. Nowhere are the pulmonary changes minutely described, but it is evident from the occasional clear descriptions of definite hepatizations and the vague descripition in other cases of congestion alternating with abscesses or with a form of consolidation from which one could squeeze pus from the bronchi that most of it perhaps was not definite lobar pneumonia but probably a form of bronchopneumonia with extensive pleural exudate. It

died out in these states in 1815, but passed into the Southern States and persisted until 1826.

Although there were many epidemics in various parts of Europe at this time I have not been able to learn so far that this type of disease was prominent in the armies engaged in the Napoleonic Wars.

From 1815 to 1862 there were occasional epidemics. Little information appears to be available regarding the troops during the Civil War. Bartholow described the occurrence of measles and its sequelæ in the camps, and Woodward gives statistical information showing that measles was prevalent, that pneumonia followed it, and that the mortality was considerable, but these conditions were greatly overshadowed by the colossal prevalence of typhoid fever and dysenteric disease, and Woodward's attention seems never really to have reached pneumonia. The following is abstracted from this history.

Measles.—During the years covered by statistics there were 67,763 cases of measles, with 4,246 deaths among white troops, with a mortality of 6.27 per cent. Most of this mortality was due to secondary pulmonary affections. Many deaths were referred to pneumonia without mentioning measles. Per 1,000 the average annual rate was 30.41, the maximum 77.57 in the 1st year, the minimum 1.98 during the last year. Many regiments suffered at recruiting stations.

In colored troops there were 8,555 cases, with 931 deaths, or 10.88 per cent of fatal cases.

In the Confederate Army of the Potomac there were 8,617 cases in an army of 58,360 during July, August, and September, 1861, 430 cases in October, 241 in November, 79 in December, 34 in January, 1862, and 8 in February. A succession of epidemic waves involved susceptible men of successive additions to strength of command.

As the new men came within the influence of the contagious focus the disease spread, giving a sudden elevation to the line of prevalence which thereafter fell until fresh additions occurred with a corresponding rise in its level.

Among the white troops the line of prevalence shows a seasonal influence as well as that due to the aggregation of susceptible individuals. The warm season operated favorably on these troops. The disease was especially severe among negroes, being characterized by bronchial inflammation, pneumonic congestion, and solidification, laryngeal congestion and edema, and sometimes affections of the intestinal mucous membrane.

Clinical records of measles show a return to duty 3 or 4 weeks after onset, but in many cases the stay in the hospital was prolonged for as many months by the continuance of bronchial inflammation or the supervention of broncho-pneumonia or diarrhea. In some cases the specific agency manifested its virulence

by a dark purple color of the eruption and symptoms of internal congestion. In general the point of interest is the consecutive disease. Sometimes pneumonic congestion was suddenly developed by exposure while the skin was affected, but more frequently pulmonary disorders, including consumption, appeared to be engrafted on the patient during convalescence. Laryngitis in some cases caused sudden death, and in others a temporary or even permanent aphonia. Cerebral meningitis sometimes occurred, and intercurrent or sequent attacks of erysipelas were common. Conjunctivitis was a frequent sequel and deafness followed the invasion of the middle ear by way of the Eustachian tube. Occasionally the ear became involved in the suppuration of the glands in its neighborhood. Edema of the feet, orchitis, and ischiorectal abscess including fistula *in ano* were among the sequelæ.

"Recruits from the city are more likely to have passed through the disease in childhood than those from the rural districts. City regiments are therefore to be preferred in this connection. When the call to service is urgent this becomes a secondary matter. The liability to disease under exposure to its causes must be accepted as a part of the danger to be faced. Measles will thus continue to be a subject of interest and anxiety to army medical men until the discovery of a means of protection against it independent of subjection to its influence in previous epidemics."

Later (page 788) he suggests the propriety of inoculation.

Pneumonia.—"61,202 cases of pneumonia occurred among the white troops during the war, with 14,738 deaths, so that the importance of pneumonia as a destroyer of life in our camps and hospitals can hardly be overestimated. The postmortem records of cases reported as pneumonia show that death in the majority of instances resulted not alone from hyperemic or inflammatory processes in the pulmonary tissues, but from these in conjunction with similar processes affecting particularly the pleural membranes, bronchial tubes, and pericardium. With the production of these congestive or inflammatory results the malarial, typhous, and tuberculous cachexias and the specific cause of measles were apparently often connected."

Of 435 cases recorded after postmortem examination, 300 were distinguished as lobar pneumonia, 135 as secondary or catarrhal inflammation. Of the 135 cases, 101 were associated with measles. These cases are inadequately described and as a rule it is merely stated that parts of the lung were hepatized, and in a few instances thickening with softening of the bronchi was mentioned. Pleurisy with effusion was common and there is slight mention of laryngitis. Pericarditis was present in a few cases but was by no means so frequently associated with secondary pneumonia as with the acute lobar cases. Pleurisy as such seems to have been recorded in 31,852 cases during the war, but although 590 were fatal only 45 were observed and described post mortem and of these 6 were connected with measles.

Of the cases of bronchopneumonia following measles the lungs of three have been preserved in the Army Medical Museum in

Washington, and Dr. Lamb was kind enough to allow me to study them and even to take portions for microscopic study. They are from Case 50 (Medical and Surgical History of the War of the Rebellion, Vol. I, Part 3, Medical Volume, page 789), Case 105 (page 794), and Case 134 (page 798). All these cases were observed by Surgeon E. Bentley, U. S. Volunteers, Third Division Hospital, Alexandria, Virginia.

The history in Case 50 states that Private J. B. Talbot, aged 23, was admitted Feb. 13, 1864, with pleuropneumonia following measles and died Feb. 29. Postmortem examination showed that the lower lobe of the right lung was hepatized, red, and presented on section a number of small superficial abscesses. The pleura was thickened (Specimen 345, now renumbered 7,792). The lung is covered with fibrinous exudate and most of it is spongy in texture, but it contains some distinct firm nodules which are branched at times.

Section of this lung no longer stains well, but the outlines of cells may be discerned. There is in the section a patch of consolidation and then one of air-containing tissue with two small foci of consolidation. These have central bronchioles which contain exudate and have lost their epithelium. The walls are very thick and infiltrated with mononuclear cells and are penetrated by many blood vessels distended with blood. The adjacent alveolar walls are similarly infiltrated and contain dense plugs of fibrin with desquamated epithelium.

The larger area of consolidation shows several bronchi with the same change. The walls of a rather large one are especially infiltrated. The more peripheral alveoli have dense contents of fibrin and epithelium. In the more central part of the patch the tissue is disintegrated and full of very small broken cells, possibly leucocytes. There is a mass of granular material at one spot resembling bacteria.

With Weigert's method the bacteria stain quite sharply and great masses of definite streptococci are found in the midst of the necrotic area. No other organisms were found.

This appears to have been a case of streptococcal bronchopneumonia in which certain areas of consolidated tissue have become necrotic in mass and contain large clumps of bacteria.

The history of Case 105 is as follows: Private Jacob Maust, aged 20, was admitted Mar. 26, 1864, moribund from pneumonia after measles. He died on the 28th.

On postmortem examination it was found that the left pleural cavity contained a pint of serum and the lung was coated with thin pasty lymph, the lower lobe being partly hepatized.

Specimen 343, now numbered 7,790, shows the following. The pleura is greatly thickened and edematous with wide interlobular septa. The lymphatics are enormously wide and are distended with cell masses. In these and on the surface of the pleura there are large numbers of streptococci in distinct chains which stain well. No influenza bacilli could be demonstrated. The bronchi are distinctly thickened. New blood vessels in great numbers have formed in their walls, the epithelium is lost, and streptococci occur in their purulent contents. There is collapse, but not much consolidation about them.

This appears to be a case of interstitial bronchopneumonia with lymphatic transportation of the streptococci.

The history of Case 134 is as follows: Private John H. McMichael, aged 19, was admitted Mar. 11, 1864, with pleurisy and laryngitis, secondary to measles. He died on the 23rd.

On postmortem examination the larynx and trachea were found to be inflamed and filled with tenacious mucus; right lung collapsed and friable. Lower lobe thickly coated with pseudomembrane. Left lung slightly congested (Specimen 342, now numbered 7,789).

The lung shows a thin layer of fibrin; the pleural surface and the pleura itself are markedly thickened. Interlobular septa are prominent. At the base of the upper lobe there is a small area of diffuse consolidation. The rest is air-containing except for numerous small nodules of consolidation with central bronchioles.

Sections show numerous small bronchi filled with debris of leucocytes. The epithelium is desquamated and the underlying tissue necrotic. The alveoli round about are filled with fibrin and cells, some of which are leucocytes. There is no great interstitial change in most of the lung. Definite cocci in pairs and short chains are found in the bronchioles. In other places bronchial and blood vessel walls are markedly infiltrated with cells. The intervening lung substance is air-containing.

This is a focal streptococcal pneumonia in which there is little interstitial change but chiefly small peribronchial foci of lobular pneumonia.

It is evident that in these three cases we have representatives of the types of streptococcal pneumonic lesion which occur in the epidemic of today. The first case is one of interstitial bronchopneumonia with large areas of necrosis, the second belongs to the same type but without the necroses, while the third is an earlier stage with much less interstitial change. It is especially interesting that after 54 years in alcohol the streptococci still stain brilliantly.

Surgeon Ira Russell also reported that there had been 784 cases of pneumonia at Benton Barracks, Mo., in 1864, of which 156 died. Beside these there were 675 cases of measles, of which 130 died of pneumonia. He distinguishes congestion, typhoid, and pleuropneumonia. There is a marked difference in the morbid appearance of the lungs in the pneumonia following measles from their appearance in pneumonia produced by other causes. Hepatization is less marked, the lung tissue oftener edematous or filled with serosanguineous fluid and containing a sufficient quantity of air to make it float on water. When pressed between the fingers a large quantity of bloody serum exudes. The lung frequently passed from this edematous condition, without going through the stages of red and grey hepatization, into that of purulent infiltration.

Since the Civil War other epidemics of pneumonia have been described, but it is generally difficult from the clinical descriptions to determine the nature of the disease, and practically none of the authors in this country appear to have recorded postmortem examinations.

In Europe many such epidemics were briefly described also (Laveran, Bard), without adding perceptibly to the comprehension of the disease. But with Bartels there began a more accurate anatomical study of the peculiar form of bronchopneumonia which follows measles, whooping cough, diphtheria, and perhaps other acute infectious diseases.

Delafield in various publications in this country has given clear descriptions of the peculiarities of this form of bronchopneumonia in children and in adults, emphasizing its interstitial character and the lateral involvement of the alveoli which adjoin the bronchioles together with the accompanying atelectasis. His understanding of the contrast between this type of pulmonary affection and the sort of

exudative process which follows the aspiration of infected materials into the bronchi, or the other examples of terminal patchy pneumonia characterized by the filling of the alveoli which are connected with the infected bronchioles with an exudate of polymorphonuclear leucocytes, is satisfactory and his descriptions form a model of conciseness. At this time there was a prevalent doctrine which distinguished between croupous or lobar pneumonia in which there is an exudate of leucocytes and fibrin, and catarrhal or bronchopneumonia in which fibrin was less in evidence and the alveoli contained large mononuclear cells mixed with others. This seems to be an inadequate basis for the anatomical distinction, and more recent writers have not accepted it, although these terms are still used.

Since Bartels' paper, a series of German publications has appeared, describing more clearly the interstitial form of bronchopneumonia in children after diphtheria, measles, and whooping cough, and from an anatomical point of view these leave little to be desired, although none except those of Dürck and Finkler are concerned with the bacteriology of the disease. From these are derived no doubt the description found in most of the text-books, although the description given by Orth is evidently from his own observations. Wagner, Jürgensen, Aufrecht, Kromayer, Koester, Wygodzinski, Dürck, Honl, Steinhaus, Hart, Jochmann and Moltrecht, and Hecht have all contributed papers which are easily accessible.

These papers agree closely in their descriptions of the pathological anatomy of this form of bronchopneumonia, the best of which are those of Steinhaus and Hecht. Wygodzinski distinguishes lobular and confluent forms in which the alveoli are filled with a fibrinous and leucocytic exudate, from peribronchitic inflammation, but he also recognizes combinations. Honl points out the resemblance of the small firm nodular consolidation in these lungs to miliary tubercles, but insists that tuberculosis is not of frequent occurrence after measles, and that the common impression that it is, may depend upon the erroneous interpretation of these peribronchial nodules as tubercles. He saw the peculiar epithelial giant cells upon which later writers have laid stress.

Steinhaus reviews the earlier German literature, gives a clear description of the pulmonary lesions, and summarizes his paper as follows:

Measles pneumonia is in the beginning not a lobular inflammation but appears in minute foci, of which several are found in a lobule. It is never catarrhal, since fibrin is abundantly present.

The focal consolidations result from a primary bronchiolitis and peribronchiolitis through a propagation of the inflammatory irritant by way of the lymph vessels. There are several types of lesions. (*a*) The acute focus with exudation into the alveoli. This may arise by extension of the inflammation from the bronchioles to adjacent alveoli which do not belong to its respiratory district or by propagation along its lumen to its own alveoli. In the zone of fresher exudate fibrin is always present. (*b*) The more chronic focus, proceeding in the form of an interstitial peribronchitis with advanced changes in the interstitial tissue but no exudation in the alveoli.

This change appears to be related in its origin to the peribronchial and perivascular lymph follicles. The interstitial change arises very early in measles pneumonia and distinguishes it from the croupous form. The distinction between the acute and the more chronic foci of pneumonia lies in the presence of a leucocytic infiltration in the first, a lymphatic infiltration in the second. He apparently saw no giant cells, but Hecht who also studied the lungs of children lays especial stress on their presence in his paper which has the title "The giant cell pneumonia of children." This is a form of pneumonia which occurs only in young children after measles and whooping cough in connection with a hypertrophic bronchitis. The giant cells arise from the epithelium either by incomplete division or by coalescence. They could never be produced experimentally in rabbits by intrabronchial injections of staphylococci or pneumococci, but could be imitated closely in animals injected intratracheally with various metallic salts (especially silver nitrate and copper sulphate) or ammonia. Karsner and Meyers described and discussed a similar case in a child and reference will be made to this later in connection with one of our cases.

All these papers have dealt with children and I have found little referring to such bronchopneumonia in adults. Delafield recognized it in adults, but his attention was chiefly directed to the disease in children.

Mathers describes an epidemic of pneumonia occurring in Chicago during the season 1915–16 in which he isolated *Streptococcus pyogenes* in a majority of instances. His description of the lung refers to

the gross appearance only. There were extensive pleuritis and pericarditis and the cut surface of the lung was smooth and mottled greyish red and dark red. The greyish areas varied in size and consistency, some being firm and dry while others were moist and viscid. They had no relation to bronchi and were sharply outlined like infarcts. Other dark red areas were soft and hemorrhagic. The description is too indefinite to allow one to recognize the condition with certainty.

During the present war, epidemics have been studied in the north of France by Hammond, Rolland and Shore, and at Aldershot in England by Abrahams, Hallows, Eyre, and French. They describe a purulent bronchitis which is fatal and from which they isolated the influenza bacillus from the sputum in most of the cases. They found other organisms at times, including the pneumococcus, streptococcus (five times), *D. catarrhalis*, staphylococcus, *M. tetragenus*, etc. Pleurisy appears not to have been common and mention is made of only eight cases in which a clear yellow fluid had accumulated in the pleural cavity. The bronchi are filled with pus and there is a peribronchiolitis. Photographs of sections of the lungs show the peribronchial infiltration distinctly, and the anatomical description which is given with these makes it seem evident that the lesion is practically the same as that which we are about to describe for the epidemic in this country. The lack of pleurisy is one great point upon which they differ from our cases, and the second is in the predominant rôle of the influenza bacilli.

In a letter dated June 22, 1918, from a hospital in France, Dr. Archibald Malloch writes me concerning such an epidemic in which he had studied nine cases at autopsy. He says nothing of empyema in these cases.

"Clinically the cases were generally like capillary bronchitis, and as a rule no dulness could be made out, although sometimes this was present. There were marked dyspnea and cyanosis. At autopsy there was often no consolidation of any extent but grey-white pus was found even down to the finest bronchioles (swarming with *B. influenzæ* and there obtained in pure culture). At other times there were small areas of atelectasis with tiny yellowish abscesses in them. On the other hand, some of the lungs showed confluent bronchopneumonia. Two of these cases showed an endocarditis with vegetations, from the cultures of which Major Rhea grew *B. influenzæ* in pure culture."

II. THE EPIDEMIC IN THE UNITED STATES ARMY CAMPS.

The conditions existing in these ancient epidemics have in a sense been repeated on a magnified scale in the course of the assembling of the troops from all parts of the United States in the present war, and the results with respect to disease of the respiratory organs have been much the same. It is obvious that the sanitary conditions surrounding the cantonments and camps have been extremely good as far as forms of disease which were especially destructive in the Civil War and in many other wars are concerned, and the result is that with the aid of vaccination against typhoid fever, paratyphoid, and smallpox, those diseases have not appeared. Even diphtheria is now practically under complete control. But sanitation and preventive medicine are as yet helpless against measles and pneumonia, and therefore these diseases have swept through the well ordered camps as they did in 1812.

The draft brought together large numbers of men of ages from 21 to 31 years from all conditions of life. Many of them had lived in cities, accustomed all through their lives to close intercourse with the densest populations and these had passed through all the ordinary diseases of childhood and had acquired immunity. Others, however, and especially perhaps those from the South, had lived in remote rural districts under entirely different conditions with but little contact with any great number of other people. These came to the camps unprotected from any disease except smallpox and typhoid fever. The compulsory vaccination conferred this protection and eliminated these diseases from the army in a way which could not be paralleled by any measures of sanitation which aimed at their exclusion by even the most rigid control of all the recognized channels of infection.

To the remaining acute exanthematic diseases and to respiratory infections these men were highly susceptible. To other infections they were also susceptible, but these have assumed such a prominent place in the history of disease in the camps that the rest appear rather insignificant.

It must not be stated that the respiratory diseases occurred exclusively in the troops of rural origin, since they gained such virulence as to affect all, but it does seem clear that immunity acquired by exposure and infection in early life has played a great part in protecting the men of some of the camps from disease.

Emphasis should be laid, I think, upon the importance of measles in the inception of this epidemic. Measles has prevailed to an extraordinary degree in many of the camps in the South, and there too have arisen the greatest epidemics of bronchopneumonia. When pneumonia taken as a whole and including lobar and all forms of bronchopneumonia is plotted out on a map, as was done in the office of the Surgeon General, so as to show the camps in which the greatest number of cases occurred, as black circles, and especially when the position of these camps is indicated according to the district from which they drew their troops, all the black circles are in the South. Any such statement is necessarily somewhat inaccurate. Measles is not absent in the northern camps nor is pneumonia. Lobar pneumonia caused by the pneumococcus, which no one suspects of being especially a sequel of measles, probably occurs in much the same proportion throughout all the camps. But the form of bronchopneumonia which has for years been recognized as a common sequel of measles has appeared in enormous proportions in the southern camps in which hundreds and even thousands of cases of measles developed. It is true that this type of pneumonia in these camps frequently occurred in patients who had not had measles, and it is clear that it is due to some second infection and not to the measles itself. It was not altogether surprising, therefore, to find large epidemics of the same type of bronchopneumonia arising later in northern camps where measles had not existed to a great degree and in troops which had not been in contact with the few cases of measles which were isolated in distant barracks.

Briefly stated, the great epidemic seems to be an epidemic of bronchopneumonia, with measles as the most important predisposing cause, but the bronchopneumonia, which itself is due to a secondary infection, later arose independently of measles in individual cases and in other camps when the agent which caused the secondary infection became virulent enough to give rise to the disease independently.

The following study of the forms of pneumonia which prevailed makes no attempt to outline the extent of these diseases in the various camps, since that information will be available from the reports of the office of the Surgeon General. Nor is it intended to trace the course of the various epidemics or to give statistics of the incidence of pneumonia or the number of deaths caused by it. Instead it is an attempt to analyze the character of the respiratory diseases observed at Fort Sam Houston, Texas, during February and March, and at Camp Dodge, Iowa, during May, from the standpoint of the student of their etiology and pathological anatomy.

In the study of the respiratory disease in these camps a consistent plan was followed. In a large number of cases observed clinically, cultures were made from the sputum, swabs from throat, and cultures from the circulating blood and fluid aspirated from the pleural cavities. These were, of course, of great importance in diagnosis and threw much light upon the condition found at autopsy. The most satisfactory information was derived, however, from the cases in which the bacteriological results could be confirmed and controlled by cultures from the tissues at autopsy, and in as far as these cases were concerned we endeavored to tabulate the records in such a way as to show at once the results of cultures made during life and after death from all these sources. It was interesting to find that repeated cultures made during life and after death sometimes showed the disappearance of one organism and its replacement or overgrowth by another. Our information is sufficiently complete for this purpose in about 49 cases of pneumonia which are therefore given in Table I. The cases which were studied clinically only need not be included, since they have been discussed in other papers.

It will be seen from this table that a great variety of lesions and several types of infection are represented here with various combinations. In general, analysis of the cases shows that there were two main forms of infection, that in which the pneumococcus was the etiological agent and that in which this part was played by *Streptococcus hæmolyticus*.

The influenza bacillus was frequently found in the sputum and occasionally in the lungs and pleural fluid. It was always associated with the streptococcus, however, and it is difficult to assign it a pre-

dominant part in the causation of the pneumonia. In general the pneumococcus of whatever type produced lobar pneumonia, and the streptococcus either what we shall describe as interstitial bronchopneumonia, or another lesion to which for convenience we assign the name lobular pneumonia.[1] The exact biological nature of this streptococcus and its identity in different camps are still subjects which are actively discussed. It seems to be the same wherever it has been found, but it will require time to determine whether there are several strains at work. Indeed, from many camps there come reports of numerous cases due to a non-hemolytic streptococcus. All these important points must be settled by further study, which must also decide the significance of the influenza bacillus, staphylococcus, and other organisms in the production of the disease. Our own experience has led us to believe that a fairly constant hemolytic streptococcus is the important factor.

In practically all the cases of streptococcus infection there appears, if there is sufficient time before death, a serofibrinous or fibrinopurulent pleurisy. This sometimes persists as an empyema even after the earlier pulmonary lesions from which it originated have completely or almost completely disappeared. All possible combinations of these forms of pneumonia occur, and it has therefore seemed best to consider all the cases in six groups into which they readily fall as follows: (1) interstitial bronchopneumonia; (2) interstitial bronchopneumonia with lobular pneumonia; (3) lobular pneumonia; (4) lobar pneumonia; (5) lobar with interstitial bronchopneumonia; (6) old empyemas.

It is, of course, possible that lobar and lobular pneumonia may occur together, but I do not think that we have met with this combination.

Cases 14 to 58 were studied at Fort Sam Houston, Texas, Cases 165 to 205 at Camp Dodge, Iowa.

[1] It has been pointed out by various writers that the term lobular pneumonia should be applied to a consolidation involving a lobule, but such accurate limitation does not take place. On the other hand, it is difficult to find any other convenient term which will designate a patchy consolidation in which the alveoli are filled with an inflammatory exudate of leucocytes and fibrin. Such an exudate is similar to that which when diffusely distributed over a whole lobe constitutes a lobar consolidation, and it seems permissible to employ the term as a conventional name for this condition.

1. Interstitial Bronchopneumonia.

Case 14.—J. McL., age 22 yrs. Entered hospital Jan. 1, 1918, with typical measles. Discharged Jan. 10. Second entry Jan. 16. Has not felt well since leaving hospital, still coughs, has a fever and headaches. *Diagnosis.*—Acute bronchitis until Jan. 22, when he became worse and was transferred to the pneumonia ward delirious, very ill, and coughing. Signs of consolidation in right lower lobe and râles over left lower lobe. Inspiration difficult. Marked cyanosis. Leucocytes 16,000. Temperature ranges from 99–104° F., pulse 100–150, respiration 20–55. Died Feb. 2. Autopsy Feb. 2.

Anatomical Diagnosis: Bilateral interstitial bronchopneumonia with hemorrhage and atelectasis; serofibrinous pleuritis (right).

Left pleural cavity.—There is no excess of fluid. Pleural surfaces smooth. No adhesions. *Right pleural cavity.*—The cavity contains about 1,000 cc. of slightly turbid brownish fluid with floating shreds of fibrin. Pleural surfaces covered with thick, shaggy, yellow exudate of fibrin. Lymph glands in the mediastinum enlarged. *Left lung.*—Surface is smooth. The lung is voluminous, but the lower part of the upper lobe and the lower and posterior portions of the lower are collapsed and pasty. Insufflation distends most of the upper lobe and part of the lower. On section some of the bronchi of the upper lobe stand open and are conspicuous as empty, thick walled grey tubes. They are surrounded by areas of hemorrhage. In the lower lobe all the bronchi appear as thick walled tubes with opaque yellow contents and are surrounded by hemorrhagic areas which become confluent. In the larger bronchi the deeply congested mucosa is covered by a thin opaque grey film. The bronchial glands are not greatly enlarged. *Right lung.*—Greatly compressed by the pleural effusion. It is covered by a layer of fibrin which varies from 2 mm. to 2 cm. in thickness. The lymph glands at the hilum are greatly enlarged. All the lobes of the lung are completely collapsed, but the upper lobe and the anterior portions of the lower lobes may be distended by insufflation. In the lower and posterior portions of the lower lobe there are numerous firm grey areas each of which shows a central bronchus and a surrounding zone of hemorrhage. These foci become confluent in places or stand out separately so that several may be seen in each of the lobules of the lung. The lobules are sharply outlined by the interlobular septa which are edematous and therefore conspicuous.

Cultures failed to grow through an accident. Smears from the lung showed Gram-positive cocci in chains.

Microscopic Examination.—The left lung contains air and most of the alveoli are unchanged, but many of the smaller bronchioles are filled with an exudate of polymorphonuclear leucocytes among which a few streptococci are found. The epithelium of such bronchioles is in places intact, in other places broken and partly desquamated (Fig. 1). The wall is greatly thickened and its connective tissue and smooth muscle elements are spread apart by red corpuscles and mono-

nuclear wandering cells of various types. Wherever lymphatics are visible in these walls they contain red corpuscles and mononuclear cells. The adjacent alveoli are filled with blood, desquamated epithelial cells, and mononuclear wandering cells together with a few polymorphonuclear leucocytes. The alveolar walls are infiltrated with mononuclear cells and thickened. Both bronchi and alveoli contain networks of fibrin. The alveoli which open directly into the bronchi contain leucocytes in greatest abundance; those which lie adjacent to the wall of the affected bronchioles appear to contain blood and mononuclear cells rather than leucocytes. Organization of the exudate in the bronchi is found in an early stage in some places (Fig. 2).

The right lung shows a more advanced change. The pleura is covered with fibrin upon the surface of which streptococci are found. The pleura itself is densely infiltrated with blood. It is markedly thickened by the formation of a vascular granulation tissue which has not destroyed all the remnant of the pleural lining cells. The whole framework of the lung has become conspicuous through the widening of the interlobular septa, peribronchial and perivascular tissues, and the alveolar walls themselves by the most extensive infiltration of mononuclear wandering cells. The lung is partly collapsed, but the enormously thick walls of bronchi and alveoli are very distinct. It is especially in the neighborhood of the infiltrated bronchi, interlobular septa, and pleura that the alveolar walls are distended with cells. In the walls of blood vessels and bronchi and in the interlobular septa lymphatics are easily seen. Most of them are thrombosed and contain streptococci as well as lymphocytes and fibrin coagulum. The more distant alveoli contain only masses of desquamated epithelial cells. Those nearer the bronchioles and participating in the formation of the peribronchial consolidation are filled with dense fibrin together with the cellular elements described. In this firm fibrin as well as in the bronchioles there is already visible a rather extensive growth of connective tissue. Definite strands of vascularized tissue are seen in the lumen of some bronchi. In one there is a mass of such tissue covered completely by a continuous growth of bronchial epithelium. The mediastinal lymph glands are swollen, their marginal sinuses filled with large mononuclear cells among which are many streptococci. These are entangled in a dense fibrin network.

The other organs show nothing abnormal.

This is a typical case of interstitial bronchopneumonia following measles and showing on one side empyema, collapse, peribronchial nodules with great interstitial infiltration, thickening of pleura and septa, and advanced organization of bronchial and intraalveolar exudate.

Case 15.—B. H., age 19 yrs. No history of measles. Since Jan. 3, 1918, cough and expectoration with pain in chest and fever. Entered hospital Jan. 14. No rash, no sore throat. Dulness and râles over whole right lung. Râles but no dulness over left. Leucocytes 16,800. Temperature 100–104° F., pulse 100–150, respiration 30–60. Died Feb. 1. Autopsy Feb. 2.

Anatomical Diagnosis: Bilateral interstitial bronchopneumonia with fibrinopurulent pleuritis.

Left pleural cavity.—Contains very little fluid. The surfaces are covered with a thin exudate of fibrin which glues them together. *Right pleural cavity.*—Contains about 1,500 cc. of turbid khaki-colored fluid with floating shreds of fibrin. The lung is adherent in its upper posterior aspect; the lower lobe is collapsed and flattened. *Left lung.*—In both upper and lower lobes there are collapsed areas, those in the lower lobe occupying the whole lower and posterior portion. In the upper lobe there are a few bronchi filled with yellow plugs, especially in the collapsed area. In the lower lobe these are much more numerous and toward the hilum they are thickened and embedded in yellowish opaque areas. There is no definite hemorrhage about them. The larger bronchi are deeply congested. *Right lung.*—The pleura is thickened and covered with a dense layer of yellow fibrin. The lung is completely collapsed and flabby. It is studded throughout with yellowish areas of consolidated tissue in the center of which there is generally to be seen the ragged lumen of a bronchus. Such areas vary from 2 to 7 mm. in diameter, but in the lower lobe they become confluent, in one place to form a mass 3 cm. in diameter. They are surrounded by grey atelectatic lung substance. The bronchi are distinctly dilated toward the periphery of the lung. Bronchial and peritracheal glands much enlarged.

Microscopic Examination.—The left lung shows the bronchioles throughout their extent filled with a debris of epithelial cells, red corpuscles, and great numbers of leucocytes among which streptococci are found in pairs and chains. Gram-negative bacilli, apparently influenza bacilli, are also present. The epithelium is greatly desquamated. The walls are thickened partly by the great distension of the small blood vessels and the separation of the connective tissue fibers, but chiefly by the infiltration of mononuclear cells. The lymphatics are distended and contain mononuclear cells, red corpuscles, and streptococci. The surrounding alveoli contain a few leucocytes, red corpuscles, desquamated epithelial cells, and fibrin. Mononuclear cells are also present. There is much coagulated fluid in these alveoli. There are also a few areas in which the alveoli are packed with polymorphonuclear leucocytes with little fibrin. In these areas streptococci are found, although they are rare in the alveoli which contain mononuclear and epithelial cells.

The right lung is much more extensively altered as though by a process of longer standing. The pleura is converted into a thick granulation tissue with blood vessels growing straight up into the hyaline fibrin. The bronchi are dilated, filled with leucocytes and disintegrated epithelium. The epithelial lining is largely destroyed and the walls are very greatly thickened and converted into a sort of vascular granulation tissue densely infiltrated with mononuclear cells. For some distance round each bronchus the alveolar walls are greatly thickened by the infiltrating mononuclear cells (Fig. 3). Elastic tissue stains show that the framework of the alveolar wall is spread apart by these cells. The alveolar con-

tents are composed of dense fibrin with desquamated epithelial and mononuclear cells. Much of this exudate has undergone complete organization or replacement by new vascular connective tissue which extends from the bronchi into many alveoli. This gives added density to the consolidated areas. The walls of the blood vessels are spread apart and thickened through the infiltration of their adventitial coats. The interlobular septa are greatly widened by infiltration with fluid and cellular exudate and apparently also by the new formation of connective tissue. However, lymphatics appear in the walls of the bronchi and of the blood vessels and in these interlobular septa they are very wide and filled with a coagulum of fibrin with blood corpuscles, leucocytes, and especially mononuclear cells. These fibrin plugs are densely sown with streptococci which are to be found there in enormous numbers even though search through the lung tissue elsewhere fails to reveal them. This tends to support the view that they are in this way transmitted to the pleura.

Bacteriological cultures revealed *Streptococcus hæmolyticus* in the heart's blood and lung.

This is a typical case of interstitial bronchopneumonia with empyema. There is interstitial new formation and organization and streptococci show well in the lymphatics. There is great thickening of alveolar walls and great density of the exudate. In places there is lobular pneumonia.

Case 16.—J. W., age 18 yrs. Entered hospital Jan. 24, 1918, with painful cough which began 10 days previously. Had a chill 4 days ago. No history of measles. On entry lungs showed dulness and râles in the right back, otherwise clear. Leucocytes 22,200. Temperature 99–104° F., pulse 120–150, respiration 30–50. Died Feb. 2. Autopsy Feb. 2.

Anatomical Diagnosis: Bilateral interstitial bronchopneumonia with fibrinopurulent pleuritis and pericarditis.

Left pleural cavity.—The lung is bound to the pleura by fresh fibrinous adhesions. There is no fluid exudate. *Right pleural cavity.*—The surfaces are hemorrhagic and covered with a thick layer of fibrin which binds them together anteriorly. In the posterior part of the cavity there is an accumulation of yellow turbid fluid. Between the upper and lower lobes behind the midlobe there is an enclosed pocket filled with this turbid exudate (Fig. 4). *Pericardial cavity.*—Contains 500 cc. of turbid fluid. The surfaces are covered with a thick shaggy layer of fibrin. *Left lung.*—The upper lobe is greatly distended with air and the bronchioles are normal except in the lower part where they become the centers of small grey nodules surrounded by hemorrhage. The lower lobe is completely collapsed, and on section dark purple in color but studded with small grey nodules about 2 mm. in diameter which in places become confluent. *Right lung.*—The bronchial glands are much enlarged, the lung is very bulky and heavy and covered with thick fibrinopurulent exudate. Most of the lung except the apical portion is collapsed. The smaller bronchi are grey and thickened, especially in the lower lobe where they form innumerable small grey nodules, several to each

lobule. The interlobular septa are prominent and grey. *Liver.*—Surface smooth and mottled, lobules large and very distinct with grey margins and dark red centers.

Microscopic Examination.—The right lung is most extensively affected, practically all the alveolar walls being much thickened by the mononuclear infiltration. The changes in this lung are thus not exclusively in the bronchi. The pleura is thickened by a vascular granulation tissue over which lies the fibrinous exudate. This is best seen in the interlobar space where the fibrin loses its staining power where the bacteria become most abundant. Streptococci are present in great numbers in certain rarefied areas and there many of them are enclosed in phagocytes so that they look like little balls of organisms. The interlobular septa are much thickened both by edema and new formation of connective tissue cells and by infiltration of mononuclear cells. The lymphatics are often greatly distended and thrombosed and loaded with streptococci. The bronchi are filled with leucocytes among which streptococci may be found. Many have lost their epithelium. In others the bronchial epithelium is lifted up by a rich granulation tissue which has developed beneath it. In all, the wall is greatly thickened and very vascular and densely infiltrated with mononuclear cells. The alveoli in the neighborhood but also throughout rather wide areas of the lung substance contain much free blood. This hemorrhage is widespread. They also contain dense fibrin, desquamated epithelial cells, and mononuclear cells, but in many places this type of exudate is replaced by newly formed connective tissue which is richly vascular and which runs from one alveolus to another. In the alveoli which enclose the denser masses of fibrin no bacteria are found. There are, however, a few alveoli which contain polymorphonuclear leucocytes and these are full of streptococci. In the bronchi the exudate is frequently replaced by long branching cylinders of fresh vascular connective tissue. These may stretch from one wall of the bronchus to the other (Fig. 5). The infiltration of the whole framework of the lung with mononuclear cells and its general thickening through new formation of connective tissue cells are a striking feature.

The bronchial lymph glands are swollen and hyperemic, their peripheral lymph sinuses are full of large phagocytic cells, and often plugged by a fibrin network. Bacteria are present, but not in great numbers and not in phagocytes.

The liver shows extensive fresh focal necroses mostly in a midzonal position. They are irregular in form and extent. All the liver cells remain in position as red necrotic cords, and leucocytes are packed among them.

The pericardium shows a rather fresh fibrinopurulent exudate without any organization. The layer of lining cells is still intact.

Cultures from the heart's blood, lungs, and pericardial exudate showed *Streptococcus hæmolyticus.*

This is a typical case of interstitial bronchopneumonia with empyema and pericarditis with exceptional infiltration and induration without very extensive or marked peribronchial consolidation. Bacteria numerous in lymphatics.

Case 32.—R. S., age 25 yrs. Patient had a cold with cough dating from Dec. 15, 1917. Illness began with measles about Feb. 2, 1918; entered another hospital Feb. 4. Transferred to this hospital Feb. 7. Still shows a fading macular eruption and marked conjunctivitis. Throat injected and covered with whitish membrane in patches. Dulness at the bases of both lungs behind. Breathing not distinctly tubular. Râles over the whole lung. Temperature 99.6° F., pulse 120, respiration 32–34. Very restless and delirious. Died Feb. 9, 1918, 4.25 a.m. Sputum showed influenza bacilli and a few streptococci. Culture from circulating blood gave no growth. Autopsy Feb. 9, 1918.

Anatomical Diagnosis: Clinical history of measles. Bilateral interstitial bronchopneumonia. Subacute fibrinous pleuritis.

Left pleural cavity.—The cavity contains a little yellowish fluid, about 150 cc. At the apex of the lung are a few fibrous adhesions and denser ones exist between the lower lobe and diaphragm. The pleura over the posterior surface of the lung is dark greyish red and roughened by exudate. *Right pleural cavity.*—Largely obliterated by old adhesions especially in the lower part. There is no accumulation of fluid and no fresh fibrinous exudate, but the surface is covered by a pleura thickened to the consistency of stiff kid leather. *Left lung.*—The lung is voluminous and in general distended with air except for one area of collapse in the lower lobe. On section it is studded throughout with minute nodular areas of consolidation which project like tubercles. The bronchi are somewhat reddened, the bronchial glands moderately enlarged. *Right lung.*—This lung is insufflated with air in all three lobes. The upper lobe shows some atelectatic patches which are firmer than the remainder of the lobe. These are 2 cm. in diameter. On section there are found scattered over the whole cut surface of the upper and lower lobes small grey nodules 1 to 2 mm. in diameter which resemble miliary tubercles. On close examination many of these nodules have a central depression which appears to be the lumen of a bronchiole. Many of them are pale yellowish grey with a surrounding paler grey zone. A few are surrounded by distinctly collapsed areas. There are lobules in which a dozen or more of these nodules are visible on the cut surface and in which hyperemia with some hemorrhage makes them stand out prominently. In the more insufflated areas they are less conspicuous and it seems possible that the thin grey halo may be due to collapse or obliteration of the immediately adjacent alveoli. The bronchi are reddened but not dilated.

Epiglottis, uvula, larynx, and trachea show no especial abnormality, although the lymph glands about the larynx are enlarged.

Microscopic Examination.—The pleural surface of the right lung shows a dense vascular fibrous tissue beneath which is a looser tissue. There is a strand or two of fibrin in its most superficial part. The interlobar space is obliterated by similar tissue.

The bronchi are only slightly altered (Fig. 6). They are in their smaller branches filled with leucocytes among which a few streptococci can be found. No influenza bacilli can be found in the sections. The epithelium is irregularly

interrupted, and in some cases extensively desquamated. In places leucocytes have accumulated beneath it. The walls of these bronchi and bronchioles are infiltrated with cells among which there are a few leucocytes. Most of the cells, however, are mononuclear wandering cells of the type of lymphocytes, a few plasma cells, and cells of somewhat larger size with paler nucleus. The adjacent alveolar walls are similarly distended and thickened with mononuclear cells. The epithelium of the alveoli is partly desquamated. The alveoli contain leucocytes in the areas round the terminations of the bronchi but there is very little hemorrhage. Also there is very little fibrin and there are no solid plugs such as are seen in more advanced cases. There is, however, coagulated fluid which fills the alveoli round the minute areas of consolidation. There are a few rather more extensive patches of consolidation in which for some distance the alveoli are filled with leucocytes, ragged networks of fibrin, blood, and coagulated fluid, but these too are distinguished by the marked infiltration of the bronchial and alveolar walls and the walls of the blood vessels with mononuclear cells (Fig. 7). Apart from these the alveoli are filled with air and have thin, delicate walls until the pleura or larger blood vessels are approached. There the thickening of the walls again appears. The interlobular septa are not very conspicuous and microscopically are not much infiltrated. Lymphatics can be injected from the pleura, and although they contain some small plugs of fibrin and cells, the injection is fairly complete. The mucosa of the trachea is much inflamed and infiltrated with mononuclears. There are a few streptococci upon its surface. The tonsils show many streptococci in their crypts.

Cultures from both lungs showed *Streptococcus hæmolyticus* and the influenza bacillus.

Case 34.—J. W. G., age 18 yrs. Said to have had measles at the age of 7. Began to feel ill on Jan. 27, 1918, with coryza, conjunctivitis, sore throat, malaise, and fever, but no chills. On Feb. 1 measles rash appeared and the patient entered the hospital with a bad cough and abundant sputum. There was difficulty in breathing, insomnia, and delirium. Pharynx reddened, old Koplik spots on buccal mucous membrane, dark purplish papular crescentic rash on face, neck, chest, arms, and back. This later became confluent in places and assumed a purpuric appearance. The rash began to fade on Feb. 5, but could be seen also in the mouth. Breathing difficult especially on inspiration when accessory muscles are brought into play. No definite localized dulness in the thorax nor any tubular breathing; moist râles heard everywhere. Feb. 6, (Dr. Cole) respiratory movements slight, breathing almost entirely diaphragmatic. Marked retraction of lower chest on inspiration. Percussion note resonant over both sides anteriorly and posteriorly. On auscultation, inspiration is loud and accompanied everywhere by numerous coarse and medium mucous râles, but expiration is practically not heard. Examination reveals no areas of definite impairment or blowing breathing. Leucocytes 28,000. Temperature 100–104°F., pulse 100–140, respiration 25–50. Died Feb. 10 at 2.30 a.m., 14 days after onset of measles. Culture of sputum shows *Streptococcus hæmolyticus*. Autopsy Feb. 10.

Anatomical Diagnosis: Bilateral interstitial bronchopneumonia with fibrino-purulent pleuritis.

Left pleural cavity.—Contains a moderate quantity of fluid which is turbid and yellowish with a little floating fibrin. The pleura over the lung is distinctly thickened and white. *Right pleural cavity.*—Contains no excess of fluid. The surfaces are smooth and glistening except over the posterior and diaphragmatic surfaces where the gloss is lost. *Left lung.*—There are no adhesions although the pleura is thickened and dull looking. The posterior and lower part of the upper lobe is dense and on section it is found that in this region, which extends about 4 cm. inward from the pleura, the interlobular septa are greatly thickened and stand out prominently as greyish yellow ridges. The bronchi are very much thickened and are filled with purulent exudate. In each of the sharply outlined lobules there are several focal consolidations which correspond with the terminal branches of the bronchi. The surrounding lung tissue is greyish yellow, edematous, and rather translucent. The uppermost part of the lung is air-containing (Figs. 8 and 9). *Right lung.*—The lung is voluminous and its surface is smooth except over the base of the lower lobe where there is a thin fibrinous exudate. In the upper lobe the interlobular septa are prominent and there are a few projecting nodules which correspond to the bronchial branches. The bronchi are very much thickened although the surrounding lung substance appears to be air-containing. The lower part of the lower lobe shows the same marking out of the lobules and thickening of the bronchi with small peribronchial areas of consolidation. The upper portion and anterior parts of all the lobes are air-containing. The bronchial glands are much enlarged.

Other organs appear normal.

Microscopic Examination.—The lungs show the most advanced changes. The pleura over the left lung is thickened so as to form a layer of dense granulation tissue upon the surface of which there is a thin interrupted layer of very compact fibrin. The lymphatics in the pleura are not especially conspicuous. The interlobular septa are very wide, as was observed in the gross specimen and are the seat of a great quantity of fluid and a network of fibrin. There are streptococci scattered in the meshes of this fibrin in small numbers. This edema and infiltration of the interlobular septa is not universal. In places the septa while greatly thickened are quite dense and composed of new connective tissue. The most striking feature of the sections is the presence of enormous lymphatics which lie in the course of these interlobular septa or in one margin of the septum (Fig. 10). They form broad beaded canals often 2 mm. in width, each segment adjoining the next by a truncated end across which the septum can be seen. These compress the adjacent alveoli. The endothelial lining can be seen clearly in places. They are filled with leucocytes, fibrin, and coagulated fluid, and mingled with these are enormous numbers of streptococci in rather long chains.

The bronchi are altered in extreme degree (Fig. 11). Few of them retain their epithelial lining in anything like its normal arrangement. In some it is com-

pletely desquamated, in others lifted up as a whole and collapsed together (Fig. 12). In still others it is stretched out so that the cells are much flattened. Some of the bronchi show a high columnar epithelium which appears to form a layer several cells deep. The lumen of the bronchus is filled with leucocytes or a mixture of leucocytes, red corpuscles, and desquamated epithelium with many streptococci, but no other organisms. The walls are greatly thickened and extremely vascular. Many new vessels must have been formed, and there are evidently many newly formed connective tissue cells. The wall is thus composed of a loose vascular tissue which is densely infiltrated with mononuclear cells of various types. None of these is ever very large, however. The same is true of the alveolar walls in a decreasing degree as one passes from the bronchus, large vessel, interlobular septa, or pleura into the lung substance. Nevertheless there are many areas in which the alveolar walls are thickened and infiltrated over a wide extent of tissue. In the alveoli near the affected bronchi there are desquamated epithelial cells and mononuclear wandering cells together with a dense mass of fibrin. In many places this fibrin is distinctly invaded by new connective tissue cells and in places even by blood vessels. The organization is nowhere complete, however. The fibrin tends to decrease as one passes from the bronchus, and the more outlying alveoli are filled with fluid and red corpuscles. These together with the degenerated and desquamated epithelial cells probably give the yellowish color to the wide zones surrounding the affected bronchi. There are, however, in connection with some of these bronchi considerable areas of alveoli which are packed with leucocytes held in a delicate network of fibrin and heavily loaded with streptococci. The organisms in these patches are as numerous as one ever sees pneumococci and are enclosed in phagocytes in the same way. That they are streptococci is seen from their occurrence in long wavy chains, although most of them are in pairs or short chains. The blood vessels are not markedly affected. Thus in this case the advanced stages of the interstitial bronchopneumonia are pretty well developed in association with patches of a more distinctly lobular pneumonia, extensive collateral edema, and great distension of the lymphatics. The enormous filling of the lymphatics with streptococci seems to afford the best explanation of their transportation to the pleura. It is evident that the lymph stream is stopped and that they must extend by their own growth.

The bronchial gland is densely infiltrated with large mononuclear cells so that its architecture is almost obliterated. It is very hyperemic and contains enormous numbers of streptococci in the sinuses.

Case 37.—A. H., age 24 yrs. Had pneumonia in 1914 when he underwent an operation for resection of a rib for empyema. For several days prior to Jan. 28, 1918, had a cold. On that day felt sick, aching all over, chill with fever and vomiting. Entered hospital Jan. 29. Examination Feb. 11 showed extreme respiratory difficulty with cyanosis. Measles rash over whole body. Conjunctivitis. Inspiration seems especially difficult and cyanosis is out of proportion

to the signs in the chest. No definite dulness or tubular breathing anywhere. Large moist râles over the entire chest. Patient remained in same condition extremely sick until Feb. 13 when he died, 16 days after the onset of measles. Sputum was yellow, mucopurulent, and contained influenza bacillus and *Streptococcus hæmolyticus*. Blood culture taken Feb. 11 was negative. Autopsy Feb. 13, 1918, 1 hour after death.

Anatomical Diagnosis: Clinical history of measles. Bilateral interstitial bronchopneumonia with fibrinopurulent pleuritis.

Left pleural cavity.—Contains 500 cc. of turbid fluid with thick floating shreds of fibrin; between the lung and the pericardium there are slight adhesions. *Right pleural cavity.*—Obliterated by firm adhesions. There is a scar in the posterior axillary line on the right side over the 9th rib, part of which was removed in the old empyema operation. The two ends of the rib are connected by fibrous tissue, and spicules of bone have grown out into this portion which evidently contained periosteum. *Left lung.*—The lung is not very voluminous, the lower lobe being partly collapsed. The upper lobe is air-containing throughout, the apex and anterior border being especially distended. At the upper posterior tip of the lower lobe there is a firm area. *Right lung* (*Fig. 13*).—Voluminous and in general air-containing. There are, however, some collapsed patches in which one can feel nodules. On section the lung is found to be studded throughout with small greyish nodules which project in groups of two or three. One can readily see with the naked eye that they are the branches of the bronchioles with greatly thickened opaque yellowish white walls and central lumen. Some of them are surrounded by zones of collapse, others by a halo of dark greyish red. The bronchi when opened are grey, not especially reddened or distended with exudate. The bronchial glands are enlarged. Trachea and main bronchi are somewhat reddened.

Cultures at autopsy from the blood gave no growth. From the right lung *Streptococcus hæmolyticus* and the influenza bacillus were recovered.

Microscopic Examination.—The left lung shows a pleura slightly thickened and composed of edematous new tissue covered with a dense layer of fibrin. The bronchi are dilated and are quite large even near the pleura. The epithelium is stretched out into thin flat cells. They contain leucocytes with very few streptococci in chains but great numbers of influenza bacilli. The walls of the bronchi are extraordinarily thick. They are loose in texture as though spread out by edema. The original tissue can no longer be recognized but is replaced by the lattice work of new fibers among which there are many mononuclear wandering cells. The adjacent alveolar walls are distinctly widened by the infiltration of such mononuclears, but they are not very thick. The alveoli contain dense networks of fibrin, many desquamated epithelial cells, and some mononuclears. In places there are alveoli filled with leucocytes. The interlobular septa are not conspicuous, and lymphatics are hardly to be found. The blood vessels are practically unchanged in appearance. Such a portion of

the lung appears solid because of the confluence of the areas of consolidation from one bronchiole to another.

In the right lung the striking feature is that the alveolar tissue between the bronchi is air-containing and made up of very thin walled alveoli. The pleura is thickened, but the thickening is produced by many frayed out layers of old fibrous tissue which formerly bound the lung to the chest wall. There is no fibrin. The interlobular septa are thick, dense, and fibrous without much evidence of recent inflammatory change. The bronchi are greatly altered, and contain in most cases a mass of leucocytes, but the epithelial lining is usually intact, at least in part. The wall is very thick and dense and is somewhat infiltrated with mononuclear cells. In many cases the great thickening of the bronchial wall is all that attracts attention because the adjacent alveoli are normal. In other places the epithelium is partly desquamated; the surrounding alveoli are filled with organizing dense fibrin and mononuclear cells (Fig. 14). The organization of the fibrin appears to begin in, or extend into the bronchi, for the exudate is often found partly replaced by new connective tissue. There are in other places still patches of alveoli directly associated with an affected bronchus which are filled with leucocytes or fibrin. These give the character of lobular pneumonia, or would if they were extensive or numerous enough.

The dense old thickening of pleura, interlobular septa, and bronchial walls, in contrast with the changes in the opposite lung, suggests that these more chronic or finished changes may have dated from the time of his previous empyema with operation. Nevertheless most of the small peribronchial foci of infiltration in this lung which project like tubercles over the whole surface are undoubtedly the result of the present infection.

Case 39.—C. L. A., age 19 yrs. Had whooping cough when a baby, measles at the age of 9, diphtheria at 12, and mumps and scarlet fever at 14. Began on Jan. 23, 1918, with a chill, fever, headache, and nosebleed. No conjunctivitis, coryza, or sore throat. Has had no rash at any time, although on his transfer card was the diagnosis measles. Entered hospital Jan. 25 with cough and shortness of breath, with pain over left chest and left side of abdomen. Is extremely sick, cyanotic, and cold. Breathing shallow and rapid. Clear mentally. Eyes bright with no conjunctival hemorrhages. Physical examination of the chest shows shifting flatness on the left side with tympany in the axilla and a definite splash on shaking. Breath sounds over the tympanitic front are amphoric. On the right side there is dulness over the lower back. Breath sounds distant; expiration is indistinct. Numerous moist and sonorous râles. Heart is greatly displaced to the right. On Feb. 13 aspiration of the left chest yielded a thin purulent fluid which in films and cultures showed *Streptococcus hæmolyticus* in pure culture. Sputum foul, greyish white, purulent, and tenacious. Contains *Streptococcus hæmolyticus* and *B. influenzæ*. Blood culture negative. Died Feb. 14, 1918, 4 a.m. Autopsy Feb. 14, 1918, 10 a.m.

Anatomical Diagnosis: Doubtful clinical history of measles. Bilateral interstitial bronchopneumonia with fibrinopurulent pleuritis and pneumothorax (left).

Left pleural cavity.—Contains air. There are also 1,500 cc. of thin turbid brownish fluid with very little floating fibrin. The sediment settles leaving the fluid almost clear. *Right pleural cavity.*—Contains no excess of fluid. Pleural surfaces anteriorly smooth and glistening, but over the posterior part of the lung they have lost their gloss. *Left lung.*—The lung is small and heavy and appears to be entirely collapsed. The pleura over it is grey, slightly thickened, and studded here and there with hemorrhages over its slightly roughened surface. The uppermost part of the upper lobe can be distended with air, but the lower and posterior parts remain collapsed. The bronchi are dilated and thickened and the small branches are surrounded by a grey-yellow zone which is solid. The upper part of the lower lobe can be distended. The lower part is solid, but it can be seen easily that each tiny branch of the bronchi is thickened and surrounded by its own yellowish solid nodule and there it is the confluence of these nodules which gives the solidity to the whole. In the lowermost edge there is even a portion which can be distended with air although most of the bronchioles are packed with exudate. The bronchi are widened and their walls thickened there also, and one has the sensation of cutting a rubber tube when they are opened with scissors. *Right lung* (*Fig. 15*).—The lung is voluminous and shows a smooth pleural surface. When distended with air it is found that a patch in the upper lobe at the lower margin and one in the lower lobe above the middle remain dense and nodular. Each bronchiole on section is thickened and yellow and surrounded with a little zone of consolidation and a wider zone of hemorrhage. The large bronchi are reddened, but the lung otherwise seems normal.

Cultures at autopsy from the pleural fluid, pericardial fluid, blood, and both lungs show *Streptococcus hæmolyticus.*

Microscopic Examination.—The lesion in the left lung is rather more advanced than in the right, but of the same character. The pleura is thickened, but interlobular septa are not greatly widened. The bronchi in the left lung have in many instances retained their epithelium, although the wall is greatly thickened and infiltrated. Hemorrhage is common in this wall and in the adjoining tissue. The infiltration and thickening of the alveolar walls extend quite wide of the bronchi. In places there is complete loss of the epithelium, and a bronchus except for its orderly arrangement of blood vessels in the wall would resemble an abscess. Very few streptococci are visible even in the bronchi. The surrounding tissue is consolidated not only by the interstitial thickening of the alveolar walls, but by the alveolar exudate which is composed partly of fibrin, blood, and epithelial cells, and is partly already organized into a loose connective tissue. Hemorrhage is abundant in the alveoli and in the tissues. There are several areas where the alveoli are filled with an exudate of polymorphonuclear leucocytes. These are somewhat richer in bacteria.

Case 41.—P. A. I., age 20 yrs. Began Jan. 28, 1918, with chill, fever, and cough. Rash appeared Jan. 31, but there was no conjunctivitis or coryza. Admitted to hospital Feb. 2. Sweats profusely, complains of difficulty in breathing, and coughs a great deal. There is marked cyanosis, patient half sitting up in bed and bringing into play the accessory muscles of respiration. Face flushed, rash well marked over the body. Pharynx very red. Dulness over left axilla and lower back and in right interscapular region. Breathing distinct but not tubular. Numerous sonorous râles. Left chest aspirated Feb. 13, but no fluid obtained. Sputum grey and purulent and tenacious; contains *Streptococcus hæmolyticus* as predominating organism. Blood cultures made on Feb. 13 and 14 when patient was dying gave pure culture of *Streptococcus hæmolyticus*. Died Feb. 14, 1918, 17 days after the onset of measles. Autopsy Feb. 14, 1918.

Anatomical Diagnosis: Clinical history of measles. Bilateral interstitial bronchopneumonia with serofibrinous pleuritis.

Left pleural cavity.—Contains about 300 cc. of turbid fluid with shreds of fibrin. The pleural surface of the upper lobe of the lung is smooth, while that over the posterior part and lower lobe is roughened by fibrin. *Right pleural cavity.*—Contains about 500 cc. of turbid fluid. The surfaces are roughened by fibrin. *Left lung.*—The bronchial lymph glands are very soft and large. The bronchi contain a greyish mucoid material. The upper lobe of the lung is pale and air-containing, the lower lobe partly airless and dark red. On section the upper lobe is studded with small yellowish grey nodules 2 to 3 cm. in diameter with a central lumen. These are prominent, but when the lung has been hardened and freshly cut they appear as small branching bronchi with thickened walls and opaque purulent contents. In the lower lobe the bronchi are thick, dark red, and prominent, and stand open. The nodules surrounding the small ones are larger than in the upper lobe, granular, yellowish grey and red, and confluent. Alveolar contents can be seen to project in these nodules. On longitudinal section of the bronchi the yellow opaque contents contrast with the thick grey wall and the outer zone of hemorrhages followed by the grey granular consolidation. The walls of these bronchi in the smaller branches are 1 mm. thick (Fig. 16). *Right lung.*—The anterior portions of the lobes are air-containing, while the posterior parts are dark red, heavy, and airless. The upper lobe can be partly insufflated. It is studded with yellowish grey peribronchial nodules. Interlobular septa broad and conspicuous. In the posterior part the lung becomes solid, the peribronchial nodules are large, 1 to 2 cm. in diameter, and of a uniform yellow color (Fig. 17). They have a ragged central bronchial lumen and are separated from neighboring consolidations by a deeply hemorrhagic solid lung substance. This contrast between bright yellow nodules of homogeneous consistency and the deep red intervening areas is very striking and gives a peculiar marbling not seen in other cases. Nevertheless this is only an exaggeration of the conditions found in other lungs. The lower lobe is firm and densely studded with rather large peribronchial nodules about the smaller

bronchi. It is the smaller branches of the bronchi whose walls become greatly thickened. One finds on passing to the larger ones that their walls are practically unaffected. Bronchial glands are large and soft.

Cultures from the blood, lungs, and pericardial fluid showed *Streptococcus hæmolyticus* in pure culture.

Microscopic Examination.—The same general condition is found throughout both lungs. It is the interstitial bronchopneumonia described so often, but developed to its maximum. The pleura is not greatly thickened, but is covered by a thin layer of dense fibrin in most places. The interlobular septa are wide and contain large lymphatic channels choked and distended with masses of cells and fibrin. Many of these cells are polymorphonuclear leucocytes, while others are mononuclear cells.

The bronchi are dilated, often to such an extent as to reduce their lining epithelium to a flattened layer throughout. It is probable that this is not a mere effect of stretching, but is caused in part by this. The lumen is full of leucocytes with relatively few streptococci. These organisms do not in this case penetrate into the tissue in any great numbers and are scarcely to be found in the alveoli, although they are found in the distended lymphatics. No other bacteria are found. The wall of the bronchus is sometimes colossally thickened (Fig. 18) and forms a dense mass of mononuclear wandering cells embedded in a meshwork which is composed of the original connective tissue and muscle of the bronchus. But to this there has evidently been added a great deal of new connective tissue which is extremely vascular, especially just beneath the epithelium (Fig. 19). Possibly this great vascularity represents only the extreme hyperemia of the preexisting tissue. One might regard this as the result of enormous hyperplasia of the minimal supply of lymphoid tissue which exists in the normal bronchial wall. Possibly that is a correct interpretation for some of it, since in other less advanced cases it is sometimes seen that the lymphoid tissue is much increased in bulk, and even becomes continuous to form a mantle about the bronchus. Occasionally these bronchi are surrounded by air-containing tissue whose alveolar walls are then almost normal. But usually they are surrounded by a considerable area of lung tissue consolidated by the filling of the alveoli with blood, desquamated epithelial cells, and fibrin, together with a few mononuclear cells (Fig. 20). In such areas the alveolar walls are greatly thickened by mononuclear invading cells, and this is especially true of the tissue about blood vessels and septa. The appearance is similar to that seen in other cases except that everything is exaggerated in this case.

The large dense yellowish white areas described in the upper lobe of the right lung represent the extreme of this exaggeration. They have central bronchi and are made up of tissue whose framework is densely infiltrated but whose alveoli are filled with solid masses of fibrin enclosing very few cells. There are no leucocytes and only a few remnants of epithelial or mononuclear cells. Blood has ceased to exist in these alveoli, but there is a beginning organization of the fibrin.

In the periphery of such areas red blood corpuscles become very numerous in the alveoli and still farther out are the predominant elements. It gives the impression that red corpuscles were at one time present in the alveoli which are now so densely filled with fibrin. The blood vessels in these lungs are not altered except by the great infiltration of their walls with mononuclear cells, and in the larger ones by the thrombosis of their adventitial lymphatics. They are never thrombosed.

Case 49.—C. P., age 21 yrs. No previous history of exanthematic disease. On Feb. 9 vomited, after which he began to have fever. Next day noticed a faint redness over the skin of the chest. Entered hospital Feb. 11 with a bright red rash over chest, neck, face, abdomen, and arms. Diagnosis of scarlet fever was made. Feb. 18, the urine showed a faint trace of albumin, no casts. Became restless and delirious. Dulness with râles over upper and midlobes of right lung. Died Feb. 21, 1918. Autopsy Feb. 21, 1918, at 2 p.m.

Anatomical Diagnosis: Clinical history of scarlatina. Interstitial bronchopneumonia with empyema (right). Bilateral lobular pneumonia.

Left pleural cavity.—Contains no excess of fluid. Surfaces of the pleura smooth and glistening. *Right pleural cavity.*—The lower lobe of the right lung is adherent by fibrinous adhesions to the costal pleura and diaphragm. The anterior margin of the lung is adherent to the pericardium by light fibrinous adhesions. Between the lower lobe and the pericardium there is a pocket containing about 75 cc. of greenish yellow turbid fluid with shreds of fibrin. The upper lobe is collapsed and between it and the chest wall there is an accumulation of slightly turbid greenish fluid in which there are large floating shreds of fibrin. The surface of all the lobes is covered by a fibrinous exudate which in places measures 3 mm. in thickness. *Left lung.*—The surface is smooth and the lung is in general air-containing and easily inflated. In the anterior portion of the lower lobe there are several small areas in which the alveoli are filled with an exudate of greyish red color. There are also a few bronchi which show a thickened wall and are surrounded by a hemorrhagic zone. *Right lung.*—The lung is small and collapsed with a thickened pleura. The lobes are bound together and covered by a thick yellow coat of fibrin. The upper lobe is air-containing in its apical portion but in the lower part the bronchi are thickened and surrounded by greyish zones of consolidation which tend to become confluent. The intervening lung substance is grey and rather translucent. The lower lobe is uniformly studded in its posterior portion with thickened bronchioles with grey confluent halos partly separated by a darker grey-red intervening lung substance. The interlobular septa are wide and prominent. The bronchial lymph glands are large and softened. *Kidneys.*—No gross abnormality.

Cultures from pleural fluid, right lung, and heart's blood all show *Streptococcus hæmolyticus.*

Microscopic Examination.—The right lung shows a thickened pleura with granulation tissue covered with fibrin. The interlobular septa are wide and infiltrated

with fluid, fibrin, and mononuclear cells. The lymphatics are not very conspicuous. The bronchi contain leucocytes and show desquamation of epithelium with thickening, infiltration, and hyperemia of the wall. The adjacent and even quite far distant alveoli present similar infiltration and thickening of their walls. They contain much fluid with desquamated epithelial cells or are filled with dense fibrin. Organization of this exudate has occurred in places. There are a few areas in which the alveoli are filled with an exudate of leucocytes and fibrin, but these are not so numerous as might be expected from the gross appearance. This is essentially an interstitial bronchopneumonia following scarlatina, with very few foci of lobular pneumonia. The sections show few streptococci but contain large bacilli resembling *B. subtilis* and many Gram-negative bacilli which appear to be *B. influenzæ*.

Case 167.—W. J. H., age 27 yrs. Began with scarlet fever on Mar. 18, 1918, and after recovery from that developed measles on Apr. 11. On Apr. 21 suffered from severe pain in chest. Aspiration of the right pleura gave a turbid fluid which contained *Streptococcus hæmolyticus*. The diagnosis of lobar pneumonia with consolidation of the right lower lobe was made on Apr. 22, and confirmed by x-ray. Empyema on the right side was recognized on May 1, and the patient died on May 4, at 6.15 p.m. Cultures at autopsy were contaminated, but the blood showed *Staphylococcus aureus*, the left lung and right pleura a non-hemolytic streptococcus. Autopsy May 5, 1918.

Anatomical Diagnosis: Interstitial bronchopneumonia with abscess formation. Empyema (right).

There are two needle puncture wounds in the midaxillary line on the right side, one over the 6th, the other over the 7th interspace. *Left pleural cavity.*—Contains no fluid. Surfaces smooth and glistening. *Right pleural cavity.*—The anterior portions of the pleural cavity are free from adhesions and the surfaces are smooth. Posteriorly there are adhesions which can be easily broken through and there is then found behind the posterior part of the lower lobe a cavity thickly lined with fibrinous exudate and containing about 50 cc. of turbid brownish fluid. The lower part of the lower lobe is adherent. *Left lung.*—Air-containing throughout except for a few obsolete tubercles. *Right lung.*—The anterior portions of the upper and lower lobe and the whole of the middle lobe are air-containing. The posterior part of the upper lobe is solid; the area of consolidation measuring about 4 cm. in diameter is, on section, grey, smooth, and elastic, with thickened pleura. Over the flabby, heavy posterior part of the lower lobe there are large irregular areas where the pleura is smooth and glistening but apparently necrotic. These areas are easily broken through, disclosing ragged confluent cavities half filled with soft shreddy necrotic lung substance. On section much of this lobe is collapsed without definite consolidation, but the cavities are formed in a greyish red, smooth, and elastic area of consolidation. They are crossed by bridges containing large blood vessels and are sharply outlined by a yellowish necrotic layer. A bronchus entering one of these cavities loses its wall abruptly.

Microscopic Examination.—The consolidated portion of the right lung shows a great deal of thickening and infiltration of the alveolar walls, of the bronchi, and of the interlobular septa. In places the interstitial thickening of the tissue especially of the alveolar walls is great and there is much infiltration of polymorphonuclear leucocytes in addition to the mononuclear wandering cells. Many of the alveoli are reduced to very small cavities lined with high cubical epithelium or filled with desquamated epithelium. There is widespread organization of the exudate. There are also some rather small patches of lobular pneumonia with the alveoli filled with leucocytes. The cavities are formed, however, independently of these in the more indurated tissue in which there is chiefly desquamation of epithelium. Their walls are made up of a layer of vascular granulation tissue lined with necrotic material and fibrin. In other places there is no such granulation tissue and merely the sudden cessation of the dense lung tissue and its replacement by coagulated necrotic material. This is loaded with chains of streptococci, but no other organisms are seen.

Case 171.—C. S., age 28 yrs. Had no predisposing disease. No history of recent measles. Began suddenly on Apr. 21, 1918, with a pain in his chest. The diagnosis of lobar pneumonia involving the right lower lobe was made upon entrance into the hospital and confirmed by x-ray. The diagnosis of empyema was made later and a resection for drainage was performed on Apr. 24. The pleural fluid gave a culture of *Streptococcus hæmolyticus*. Died May 5, 1918. Autopsy May 6, 1918.

Anatomical Diagnosis: Interstitial bronchopneumonia (right). Empyema (bilateral). Acute nephritis.

Left pleural cavity.—Contains about 350 cc. of reddish brown liquid with floating flakes of fibrin. The surfaces posteriorly are deep red in color and covered with fresh shaggy fibrin. *Right pleural cavity.*—In the right back 4 cm. below the angle of the scapula and in the line of the 10th rib there is a wound 6 cm. long which extends into the pleura. The right lung is displaced far upward, the lower lobe being adherent behind between the 2nd and 3rd ribs. The apical part of the lung is densely adherent. The pleural cavity extends about the back of the lung as high as the second rib and is widely open below the lung. Its surfaces are covered with a thick yellow fibrinous exudate. *Left lung.*—The posterior portions of the upper lobe and most of the lower lobe are collapsed but can be inflated easily. There are no areas of consolidation. The smaller bronchi are slightly reddened and contain sticky mucus in the lower lobe but they are not thickened. *Right lung.*—The lung is completely airless except for a small part of the upper lobe. The lower part of the upper lobe feels firm, the lower lobe flabby and soft. On section it is found that the lower part of the upper lobe is uniformly consolidated through an area about 5 cm. in diameter. The middle lobe can be completely inflated. The lower lobe presents in its posterior part some bronchi with purulent contents which are surrounded by irregular grey patches of consolidation. The remainder of the lung

is smooth and satiny on section but quite collapsed. *Kidneys.*—Alike and measure about 12 by 6 by 3.5 cm. They look rather swollen. The capsule strips off smoothly leaving a greyish surface. On section the cortex measures 7 cm. in thickness. It is pale and the labyrinthine portions of the striations are opaque and yellow but straight. The glomeruli are visible as pale dots.

Cultures at autopsy from the right lung and both pleural cavities showed *Streptococcus hæmolyticus.*

Microscopic Examination.—The consolidated portion of the upper lobe of the right lung is found to be covered with a thick exudate of fibrin which overlies a vascular granulation tissue. This tissue becomes very wide and edematous at one point where it extends over the lung and connects with a broad interlobular septum. Blood vessels are numerous in this tissue and the lymphatics are wide but not thrombosed. The bronchi are very wide, their lining layer thrown up into many folds. The epithelium is preserved and as a rule the lumen is filled with leucocytes among which are streptococci. The walls are moderately thickened, hyperemic, and infiltrated with mononuclears. The lung substance is in large part collapsed. The alveolar walls are not greatly infiltrated or thickened but contain desquamated epithelial cells and fluid. There is nowhere any exudate of leucocytes and nowhere much fibrin, although a little is to be seen here and there. There are many alveoli in one part which contain strands of a hyaline compact fibrin. In other sections the thickened bronchi are conspicuous in a less atelectatic lung tissue.

The kidney shows in general a cloudy swelling of the epithelium. The glomeruli are often rather enlarged and show capillaries distended with leucocytes and blood, these elements being also found in the tubules. There is much interstitial infiltration of the tissue with mononuclear cells and leucocytes in patches which occur in both cortex and the outer zone of the pyramid.

In this case the lung is compressed by the pleural effusion, but itself shows relatively little pneumonic alteration. Nevertheless there is a distinct infection of the bronchi and a characteristic alteration of their walls.

Case 174.—G. R., age 28 yrs. No history of measles or other predisposing disease. Began gradually on Apr. 5, 1918, with a pain in the chest and cough. On Apr. 8 diagnosis of lobar pneumonia involving right lower lobe was made. Radiograph on Apr. 12 showed involvement also of the right upper lobe with possible accumulation of fluid in the pleural cavity. This was confirmed by aspiration on the same day and the patient was referred to the surgeon for operation. The 8th rib was resected and drainage established. Died May 7, 1918. Autopsy May 7, 1918, 5 hours after death.

Anatomical Diagnosis: Interstitial bronchopneumonia (right). Empyema with operative drainage and multiple encapsulated residual collections of pus. Fresh fibrinopurulent pleurisy (left).

Left pleural cavity.—Contains about 1,500 cc. of opalescent yellow fluid, with shreds of fibrin. The surface is covered with a very thick layer of loose shaggy

fibrin which stretches across the cavity in great ropes. The lung is slightly adherent at the apex and that portion is fairly voluminous. The rest of the lung is plastered against the mesial surface of the cavity and is entirely collapsed. The lower lobe is adherent to the diaphragm and to the posterior wall of the pleura by fresh fibrinous adhesions. *Right pleural cavity.*—The upper lobe of the lung is adherent by frail adhesions obliterating that part of the pleural cavity. There are dense adhesions over the lower posterior border of this lobe and the posterior part of the lower. There is a pocket of greenish yellow pus between the pericardium and the mesial border of the middle lobe. Over the 2nd and 3rd ribs there is a distinct pocket of pus which on removal of the lung is left between two layers of the parietal pleura. Small pockets exist between the base of the lung and the diaphragm. *Left lung.*—The lung is practically completely collapsed except at the apices of the lobes and is covered with a thick fibrinous exudate. Inflation with air does not completely distend the whole lung, leaving patches of collapse in the lower and posterior parts of both lobes. There are some indefinite projecting greyish nodules in the posterior part of the lower lobe, but otherwise there is no consolidation. *Right lung.*—The lung is heavy. The anterior portions of all lobes appear to be air-containing. The bronchial glands are large, dark greyish red, and pigmented. The surface of the lung is torn by separation of old adhesions and cannot be inflated. On section the upper lobe is normal in texture and air-containing. The lower lobe is also air-containing except in the lower part which is pasty and airless and presents some pale yellowish grey projecting nodules. The bronchi are not conspicuously thickened in the rest of the lung.

Cultures at autopsy showed *Streptococcus hæmolyticus* in the heart's blood and right and left pleura. Those from the lungs were sterile.

Microscopic Examination.—The left lung is fairly well distended. The pleura is thickened and freshly vascularized and has lost its covering layer of cells. The fibrin has been rubbed off in the section. The tissue itself shows no conspicuous interlobular septa, but all the bronchioles contain purulent exudate and show infiltration of their walls which is sometimes quite marked. The alveoli contain some fluid and some desquamated cells, but except in the neighborhood of the bronchioles they are little altered.

The right lung is covered with a thick layer of granulation tissue with fibrin. The interlobular septa are much more prominent than those of the left. The bronchi in a section from the lower border of the lower lobe are all much infiltrated with mononuclears and filled with purulent exudate. The alveolar walls are greatly thickened everywhere and infiltrated with mononuclear cells, but they are all collapsed and contain no exudate except a few desquamated epithelial cells. The lymphatics are in places filled with leucocytes, but are not prominent. This appears to explain the gross appearance of such a lung which is soft and flabby and rather satiny upon the cut surface. It is easy to recognize the fact that it is collapsed and not filled with a fibrinous exudate, but the thickening of the alveolar walls is likely to escape the unaided eye.

Case 178.—C. A., age 28 yrs. Began Apr. 22, 1918, with typical measles, coryza, conjunctivitis, and red macular rash over body and face. On May 5, began to have cough with sputum, and some dyspnea with cyanosis. There was no definite dulness over the lungs, but râles could be heard everywhere. Voice became husky and at times was only a harsh whisper. By a great effort he could produce a tone. Sputum yellow, mucopurulent; loaded with Gram-positive cocci which grew with slight hemolysis, thought to be staphylococcus. Influenza bacillus also present. Blood cultures on May 7 and 9 negative. Died May 9, 1918, 4 days after the onset of the cough. Autopsy 13 hours after death, May 10, 1918, 9 a.m.

Anatomical Diagnosis: Clinical history of measles. Interstitial bronchopneumonia (bilateral). Lobular pneumonia. Ulcerative laryngitis.

Left pleural cavity.—Contains no excess of fluid; surfaces are smooth and glistening. *Right pleural cavity.*—Contains no excess of fluid. Surfaces are bright and glistening throughout. There are no adhesions. The lungs are voluminous and do not collapse. *Left lung.*—Readily inflated in all parts. On section it is air-containing everywhere except for a few small areas in the upper lobe which stand up above the surrounding lung tissue as greyish red elevated patches. In these the alveoli appear to be filled with exudate. Throughout the remainder there are small grey nodules which project slightly and are surrounded by hemorrhage. These prove to be bronchi with purulent contents, thickened grey wall, and hemorrhagic halo. They become more numerous in the lower lobe and are especially striking in the posterior part of the lung. *Right lung* (*Fig. 21*).—There are firm nodules to be felt all through the lung. Some appear on section as greyish red elevated patches with surface roughened by alveolar plugs. In the upper lobe there are a few greyish nodules with central depression surrounded by a broad hemorrhagic zone. These nodules which are much more numerous in the lower lobe are traceable to the termination of the bronchi which upon being opened are found to be filled with a purulent fluid. In the anterior portion of the upper lobe and through the middle lobe these nodules are visible but appear to be in an even fresher state and are represented by small bronchioles with slightly thickened walls and no hemorrhages. *Organs of the neck.*—The whole pharynx, including the base of the tongue, the tonsils, the posterior wall, and the pyriform sinuses, is intensely reddened. The epiglottis is also bright red, but on its posterior surface this color is mottled with small yellowish opaque areas with fairly smooth surface. There are deep ulcerations of the vocal cords on each side (Fig. 22), extending into the sinuses and on to the false vocal cords.

Cultures at autopsy gave *Streptococcus hæmolyticus* from the heart's blood and right lung. Streptococci were abundant in the film from the ulcer of the vocal cords. Cultures from the spleen were sterile.

Microscopic Examination.—The lungs are about alike. The pleura is only slightly altered in that it is hyperemic and sparsely infiltrated with mononuclear cells. There is nothing left of the covering layer of cells, but no fibrin can be seen

on the surface. The interlobular septa are very wide and large lymphatics can be traced from the pleura into them. One or two of these show plainly by the direction of their valves away from the pleura at a point about 2 mm. from the pleural surface (Fig. 23) that the direction of the lymph stream is from the pleura towards the hilum. They contain only fluid, but streptococci are to be found in them in short chains and pairs. In places streptococci in numbers can be traced into the substance of the pleura. The interlobular septa as they pass deeper into the lung are edematous and contain a dense network of fibrin in which are entangled many mononuclear cells. Two types of lesions are found in the lung, one representing the acute lobular pneumonia, the other an early stage of interstitial bronchopneumonia. There are only a few patches of the former, while the latter is almost universal throughout the lung. Where the lobular pneumonia occurs the changes in the bronchioles tend to be the same as elsewhere, but are rather masked by the diffuse pneumonia.

These patches are fairly sharply outlined by small interlobular septa. They show a uniform filling of the alveoli with an exudate composed of blood, fibrin, and nucleated cells. Most of these cells are polymorphonuclear leucocytes, but some are desquamated epithelial cells, while many are similar to lymphocytes or are rather larger. The alveolar walls are not thickened as a rule, but in the neighborhood of the interlobular septa they, like these septa, are infiltrated with similar mononuclears. Streptococci are present in great numbers and appear in chains entangled in the fibrin, loose among the cells, or sometimes enclosed in cells. They are especially numerous in the alveoli which border on the septa. Where they lie amid red corpuscles, these have lost their hemoglobin and contrast sharply with those in the adjacent blood vessels.

In other parts of the lungs the lesions (Fig. 24) are concentrated about the small bronchi leaving considerable intervening patches of air-containing tissue with thin walled alveoli; the bronchioles are packed with a mass of cells and streptococci. The bacteria are ranged along the walls in clumps and strands. The cells in this exudate are much fragmented and distorted and it is difficult to determine their nature, but it is certain that while many of them are polymorphonuclear leucocytes nearly as many are mononuclear wandering cells. They are held in a network of fibrin. The epithelium of the bronchi is lost and they are lined by a thin layer of coagulated necrotic material. The wall is edematous and spread out and densely infiltrated with mononuclear cells. The blood vessels are distended, but the process is fresh and the wall does not look like granulation tissue with radially arranged blood vessels, as is the case in some instances in which the disease has been of long duration. The lymphatics in the outer part of the bronchial wall are wide and closely packed with leucocytes, mononuclear cells, and bacteria. The adjacent and continuous alveoli have walls which are slightly thickened by mononuclear infiltration. They are filled with dense fibrin containing distorted cells, some of which are polymorphonuclear, while many can be recognized as mononuclear cells. Red blood cells are frequent in these,

and in the more distant alveoli are present in great quantities. Practically no bacteria are found in the exudate in these alveoli. The blood vessels are not especially changed. The bronchial glands are large, the lymph cords very wide and evidently containing many new cells. But the sinuses are especially widened and packed with mononuclear cells and leucocytes. They contain great quantities of streptococci often scattered diffusely but quite often in dense clumps. Streptococci are strewn along the surface of the mucosa of the trachea and are undoubtedly present in enormous numbers in the ulcerations of the vocal cords and other parts of the larynx. This specimen has not been cut for microscopic study.

Case 184.—J. B., age 22 yrs. Negro. On Apr. 29, 1918, had measles. On May 2 he was found to present the physical signs of lobar pneumonia with consolidation of the left lower lobe, dulness, bronchial breathing with a few large râles. Sputum bloody. Sputum on May 8 was mucopurulent and nummular, containing Gram-positive cocci. Cultures showed *Streptococcus hæmolyticus* and *Staphylococcus aureus*. Blood culture was negative on May 7. Temperature high at the beginning, 104–105°, later reduced to 101°. Leucocytes 9,000. Died May 10, 1918, at 9.45 p.m. Autopsy 38 hours after death. The body had been embalmed so that cultures failed to grow.

Anatomical Diagnosis: Interstitial bronchopneumonia (bilateral) with disseminated lobular pneumonia. Ulcerative laryngitis.

Left pleural cavity.—Contains about 10 cc. of fluid. The surfaces are clear and smooth. *Right pleural cavity.*—Contains no fluid. The surfaces are smooth. *Left lung.*—The lung is blue and heavy in the posterior portion, but both lobes are air-containing anteriorly. Upon artificial insufflation both lobes are pretty well distended but firm nodules can be felt which on section project above the cut surface (Fig. 25). They are grey, rough, and granular, and when cut in certain directions show a central lumen. In the lower part of the lung they are almost confluent and are embedded in deeply hemorrhagic collapsed patches. The bronchi are deeply reddened and dilated in their peripheral parts where they are filled with a bloody purulent exudate. The nodular consolidations which lie about their terminal portions are much more numerous and more nearly confluent in the posterior part of the lung. The bronchial glands are enlarged, greyish red, and firm. *Right lung.*—The lung is smooth superficially, but there are a few hemorrhages in the pleura between the lobes. The lower lobe is heavy and nodules can be felt throughout it. The middle lobe is collapsed posteriorly but inflated anteriorly. The upper lobe is more air-containing but also feels nodular. In the upper lobe on section it is found that the bronchi are thickened, reddened, and dilated at their ends. They are accompanied or surrounded by elevated consolidated areas which are ragged in outline and rough and spongy. The bronchial walls are opaque and lined with a dull grey material. The finer bronchioles still appear as lumina in the centers of consolidated areas which are surrounded by hemorrhagic zones. Such lesions are found in the posterior part of the middle lobe and

more abundantly in the lower lobe where they tend to become confluent. *Pharynx and larynx (Fig. 26).*—The tonsils are not especially enlarged. The pharyngeal wall is reddened and the left side of the epiglottis and left arytenoepiglottic fold and adjacent tissues are edematous. There is definite ulceration of the vocal cords and there are other ulcerations below them which extend on the walls of the larynx. There are quite deep ulcerations at the base of the epiglottis. The tracheal mucosa is much reddened.

Microscopic Examination.—The lung shows a combination of the lesions of interstitial bronchopneumonia and lobular pneumonia. The pleura is not thickened and shows no evidence of fibrin on its surfaces. The interlobular septa are quite inconspicuous and none of them shows any special edema or infiltration, or even the distension of the lymphatics.

The bronchi on the contrary are wide and very conspicuous (Fig. 27). Each branch is surrounded by a denser lung tissue, but there are some other patches of consolidation which extend away from the bronchi. There is a ragged mass of debris in the lumen of each. This contains many red corpuscles, polymorphonuclear leucocytes, as well as fragments of necrotic cells. Streptococci in tangled masses are ranged along the walls of the bronchi, but there are no influenza bacilli. The epithelium is entirely destroyed and in its place there is a rather thick layer of coagulated necrotic tissue. Outside this in the larger bronchial branches there are remains of mucus glands, etc. In general the wall has assumed the character of a loose edematous granulation tissue with abundant wide blood vessels arranged more or less radially and a profuse infiltration with mononuclear wandering cells of various sizes. If this granulation tissue is in any way derived from the swelling and spreading apart of the lymphoid tissue in the wall of the bronchus, which has occurred to me as a possibility, it must at least have undergone an extraordinary change. Lymphoid tissue can be seen at certain points, but it does not form in this case as in some others a complete mantle about the bronchi, and most of the bronchial wall seems actually to be composed of granulation tissue. The lymphatics in the outer layer of the wall are wide and generally filled with a clot which entangles red corpuscles, mononuclear cells, and chains of streptococci. The adjacent lung tissue is consolidated by the filling of the alveoli with dense fibrin in which there are to be found a few desquamated epithelial cells and mononuclear wandering cells. It is striking that the epithelial cells when not desquamated are much more nearly cubical than normal, and among these plump cells one may find mitotic figures (Fig. 28). The alveolar walls are thickened also and are infiltrated with mononuclear cells. This is not extreme, however, and a much more remarkable infiltration of this sort is found in the walls of small vessels in such a neighborhood.

The other areas of consolidation mentioned above as not so intimately related to the bronchial thickening are patches in which the interstitial changes are slightly developed but in which all the alveoli are filled with dense masses of polymorphonuclear leucocytes in a delicate network of fibrin or alone (Fig. 29).

Among these there are enormous numbers of streptococci, although there are none in the denser plugs found in the alveoli about the bronchi. These areas fade at the margin into patches of edema. There are quite extensive areas in which the thin walled alveoli are distended with fluid without any cells and in these alveoli too, chains of streptococci are found.

Case 191.—S. F., age 22 yrs. Negro. No history of previous illness. No record of measles. Began suddenly on Apr. 13, 1918, with pain in chest and chill. Diagnosis of lobar pneumonia involving left lower lobe was made, and later, on May 5, there was found also a lobar consolidation of the right lower lobe. The existence of empyema on the right side was recognized by aspiration on May 13. A yellow serum with greenish white sediment loaded with streptococci in short chains was removed. These proved to be *Streptococcus hæmolyticus*. Blood cultures on May 11 were negative. Died May 14 at 5.30 p.m. Autopsy May 15, 1918.

Anatomical Diagnosis: Interstitial bronchopneumonia (left lower and right upper and lower lobes). Disseminated lobular pneumonia. Empyema (right).

Left pleural cavity.—Contains no excess of fluid. There are a few fresh adhesions over the lower edge of the upper lobe. The surface of the pleura is dull. *Right pleural cavity.*—Contains about 700 cc. of thick greenish yellow pus which is distributed in the space between the lung and the pericardial sac, in the meshes of adhesions between the lung and diaphragm, and about the apex of the lung. There are easily torn adhesions over the back of the lung which seem to separate into spaces which are filled with purulent fluid. *Pericardium.*—Contains no excess of fluid and the lining surfaces are smooth, but there are bright petechial hemorrhages over the posterior surface of the heart with shreds of fibrinous material overlying them. *Left lung (Fig. 30).*—The posterior surface is roughened by fibrin especially over the lower lobe and between the lobes. The upper and anterior part of the upper lobe is air-containing, but the posterior and lower part is firmer. On section, although this lobe is easily inflated, there are found in the lower portion numerous firm projecting nodules surrounded by hemorrhagic zones. The lower lobe contains only a little air-holding lung tissue and is not inflated by attempts to blow air into it. On section it is found to be thickly studded almost everywhere, but especially in the lower part, with nodules which are surrounded by hemorrhage and show a central depression which corresponds with the lumen of the bronchiole. The bronchial glands are enlarged and greyish red. *Right lung.*—The surface and the interlobar spaces are occupied by fibrin as described. The whole lung is collapsed and flabby except for a small portion of the anterior half of the upper lobe. Even after inflation the lower portion of this lobe is collapsed and shows numerous bronchi with thickened walls which appear as definite nodules. In the lower lobe collapse is extensive and there are many greyish nodules which surround the lumina of bronchi. There is also some patchy consolidation of a deep greyish red color rather different in appearance from the nodules. *Pharynx and larynx.*—There is slight reddening throughout, but no

ulceration of the vocal cords although there is a discoloration as though from a healed ulceration just below the cords.

Cultures at autopsy gave *Streptococcus hæmolyticus* in pure culture in the heart's blood, right and left lung, right pleura, and pericardium.

Microscopic Examination.—The right lung shows a thick pleura composed of highly vascularized granulation tissue covered with fibrin. There are streptococci on the surface of the fibrin. The interlobular septa are not much widened but the lymphatics are slightly distended with clots which contain leucocytes and fibrin.

The bronchi are full of half necrotic leucocytes with abundant streptococci and influenza bacilli. The epithelium is largely desquamated and the walls are converted into a vascular granulation tissue which is much infiltrated with mononuclear cells, evidently derived in part from a thickening of the lymphoid tissue of the wall.

The alveolar walls are not thickened or infiltrated. The alveoli are mostly collapsed, their walls very hyperemic. Those near the bronchi are free of blood and their walls are sometimes infiltrated with red corpuscles. Many of the nearby alveoli are partly filled with desquamated epithelial cells, but there is also a great deal of fluid. Some contain dense plugs of fibrin which have undergone little or no organization. Hemorrhage is widespread about these bronchioles.

In many places the bronchi are surrounded by patches of lung tissue in which the alveoli are filled with leucocytes whose polymorphous nucleus is plain. These are often studded with streptococci. Indeed in some places the alveolar walls have become necrotic. Some of these areas of lobular pneumonia are extensive and no doubt necrosis of the tissue occurs commonly in the larger ones.

Case 193.—A. M. M., age 23 yrs. Began suddenly without previous illness or history of measles on May 3, 1918, with chill and fever. On May 5 the diagnosis of lobar pneumonia was made with involvement of the left upper lobe. Sputum on May 8 was tenacious and mucoid without blood, and contained Gram-positive diplococci which proved to be Pneumococcus Type III. *Staphylococcus aureus* was also present. Blood culture on May 8 showed a few non-hemolytic streptococci. Another on May 9 was negative. Died May 16, 1918, at 8.15 a.m. Autopsy May 17, 1918, 21 hours after death.

Anatomical Diagnosis: Old interstitial bronchopneumonia with abscess formation (left upper lobe). Fibrinous pleuritis. Hyaline degeneration of rectus abdominis muscle.

Left pleural cavity.—Contains no fluid. The surfaces are smooth except that the posterior part of the upper lobe is adherent to the costal pleura by easily broken adhesions, and the base of the lung to the diaphragm by old adhesions. *Right pleural cavity.*—The cavity is almost entirely obliterated by old adhesions which are especially dense between lung and pericardial sac, and between the base of the lung and the diaphragm. *Left lung.*—The lung is voluminous and in the upper lobe there can be felt a solid mass occupying the upper

posterior part. The pleura has lost its gloss over the solid part but is smooth over the anterior part which is air-containing. On section the consolidation is fairly uniform, pale greyish red, and presents a rather rough surface which is distinctly translucent. The lower part is perhaps slightly redder than the upper. About the middle of this lobe there is a large abscess cavity reaching practically to the pleura but not perforating it. This cavity measures 5 cm. in diameter, is of extremely irregular outline with lateral excavations, and communicates widely with the large bronchus which opens abruptly into it. It contains a yellowish purulent exudate and there is a shreddy dark greenish grey necrotic tissue hanging from the wall. The wall is made up of a thin line of opaque yellowish material. In the anterior part of the upper lobe the interlobular septa are quite distinct. In places there are small grey projecting nodules related to the bronchi. The lower lobe is air-containing throughout. The bronchial glands are large, pale, and greyish, and studded with pigment. The large bronchi contain a thick frothy mucopurulent exudate. *Right lung.*—The lung is torn in removal and roughened by old adhesions, but it is air-containing throughout and of normal texture. The bronchial glands are not enlarged. *Pharynx and larynx.*—Normal.

Cultures taken at autopsy showed *Streptococcus hæmolyticus* in the heart's blood and left lung.

Microscopic Examination.—The tissues of the upper lobe of the left lung show most advanced changes. The pleura is thickened and dense and is covered with a thin layer of fibrin. The interlobular septa and the whole connective tissue framework of the lung are enormously thickened and condensed. There has evidently been a great new formation of connective tissue, for this widening is not due to edema but to the formation of closely knit fibrous tissue. The lymphatics are wide and in places contain some free cells, but most of them are partly or completely obstructed by masses of vascularized connective tissue which have evidently resulted from the organization of thrombi formed in the lymphatics at an earlier stage. The bronchi are filled with purulent exudate which contains large numbers of streptococci. The epithelium is in general preserved, but the walls are greatly thickened both by new formation of connective tissue and a dense infiltration of mononuclear cells. Lymphatics in their walls are in places obliterated by newly formed connective tissue. The alveolar walls are thickened everywhere, partly by infiltration of wandering cells but partly by newly formed connective tissue. They are in most places filled with a mass of desquamated epithelium, some mononuclear cells and leucocytes, and fluid. Fibrin is not so conspicuous as usual, but perhaps chiefly because most of it is replaced by strands of connective tissue which fill the alveoli in places. The epithelium when it is preserved is high and cubical. Red blood corpuscles are abundant in places so that the alveoli are full of blood. The most striking feature, therefore, is the advanced interstitial infiltration and induration together with the organization of the exudate both in the alveoli and lymphatics. One section passes

through the abscess which is filled with polymorphonuclear leucocytes with bacteria. The lining layer of the cavity is densely infiltrated with large vacuolated cells. Outside this layer the lung tissue for some distance is much indurated and every alveolus is filled with a solid plug of connective tissue. Organization has evidently proceeded rapidly here. Sections through other parts of the lung show it to be air-containing, but the septa and perivascular and peribronchial tissues are greatly thickened and some alveoli are filled with desquamated cells and wandering cells. Lymphatics in the septa in this part of the lung (lower left lobe) contain abundant leucocytes and fibrin.

The rectus abdominis muscle which appeared normal to the unaided eye shows most extensive hyaline degeneration and disintegration of the muscle fibers which are broken into formless clumps. These are surrounded by nuclei many of which are undoubtedly the nuclei of the sarcolemma. These sometimes appear to coalesce into giant cells. But there is also a definite reaction on the part of the interstitial tissue and blood vessels and numerous mononuclear phagocytes are present.

In attempting to present these diseased conditions according to their etiological agents, if we group the cases of pneumonia which are caused by the hemolytic streptococcus in several classes so as to emphasize one or the other of the predominant lesions, it is only to facilitate the description of that lesion, as one might describe separately tuberculous pneumonia and miliary tuberculosis of the lung. The combination of the streptococcal lesions is almost as common as the occurrence of several types of tuberculous lesion in the same lung. In the group of cases just described the attempt has been made to select those which show in its purest form the so called interstitial bronchopneumonia, but even so some trace of lobular pneumonia can be found in all but a few. Nevertheless, in whatever combination they occur, even when associated in the same lung with the lobar pneumonia caused by the pneumococcus the characteristics of the interstitial bronchopneumonia stand out distinctly.

The typical change in the pleura consists in the effusion of a large quantity of thin turbid fluid into the pleural cavity. This is usually brownish with a fine granular sediment which is stirred up on moving the lung, but there are generally also floating shreds of fibrin. The surface of the pleural membranes is covered with fibrin under which hemorrhages are often visible. It is remarkable, however, that thickening of the pleura by the formation of new granulation tissue

takes place very rapidly. This is a common condition, but there are cases, especially those in which adhesions had existed, in which there is no exudation, and others of recent origin in which although the lungs are diffusely affected the pleural surfaces are perfectly smooth and the cavity is practically dry. There are various later modifications of the character and distribution of the effusion leading to its encapsulation and to a more definitely purulent character which forms the rule in cases which survive long enough. In view of the interest devoted by surgeons to the question of empyema, an analysis of the condition in all the cases in this series will be given later in this paper.

The gross appearance of the lungs in the cases of interstitial bronchopneumonia varies with the age of the lesion. The powers of resistance of the individual doubtless have much to do with this also, and it seems that in those with little resistance the type of lesion is different and tends to the lobular form. At first it seemed merely a surmise that the lesions confined to the bronchioles and their immediate environment were early changes, since some cases, such as No. 14, showed these very slight alterations in one lung in a patient in whom the other lung was in an advanced stage. Nevertheless, the occurrence of death after 7, 4, 8, and 7 days of pulmonary involvement in Cases 32, 178, 184, and 194 has shown that what appeared to be fresh lesions really do occur in the cases of briefest course. The early lesions in the opposite lung in older cases must simply represent fresh lesions in a case in which elsewhere similar changes have long been developed.

The lung may be collapsed, since that is largely an effect of the pressure of a large pleural effusion, or, as in Case 32, both lungs may be distended with air.[2] In such a case as No. 32 the lesions appear as minute projecting nodules often grouped in twos and threes, several being found within the area of a lobule. In Cases 14 and 194 these small lesions show the branching of the terminal bronchioles and are

[2] When the lung is inflated artificially with air it is easy to see the lesions which are submerged in the general blue-grey of the collapsed area. For that reason we have frequently blown up these lungs with a bulb tied into the bronchus spreading open the collapsed alveoli and aerating the blood in their capillaries so that it becomes bright red. Then the actual lesions become very distinct.

rendered conspicuous by their halo of hemorrhage. In Case 178 this became very brilliant since each bronchus could be traced often in complete longitudinal section by the grey thick wall, its yellow contents, and its envelope of hemorrhage.

In Case 37, which was of 16 days duration, there was no extensive peribronchial consolidation, but the bronchi were so greatly thickened as to project in firm tubercle-like nodules.

In Cases 29 and 34, of 20 and 14 days duration, the lesions expand from the bronchi into patches of firm yellowish consolidation 3 to 5 mm. in diameter which project as nodules on the cut surface. The intervening lung substance in such cases, aside from the hemorrhage spread around these peribronchial nodules, is greyish, elastic, and edematous, while the interlobular septa are thickened, yellow or white, and opaque, and stand up like low stone walls which separate fields. They divide the cut surface into startlingly distinct lobules and in each of these there are several nodules. In Case 41 there are the most advanced lesions, although the course of the disease was only 17 days. Not only are the bronchi enormously thickened, but the peribronchial nodules of consolidation are larger than in any other case and stand out as firm dense and perfectly homogeneous yellow elevated patches, each with its central bronchiole and its halo of hemorrhage. In one or two of the cases of long duration, Nos. 167 and 181, which lasted 23 and 46 days, and in one of the fresher cases, No. 193, which lasted only 14 days, we found abscesses with actual cavity formation, the contents of the necrotic areas being discharged through the bronchi. This is a frequent occurrence in the cases of lobular pneumonia and remains to be described in other cases, but it is not so frequent in those in which the lesion takes the form of the interstitial bronchopneumonia. The essential features, therefore, in the gross appearance of the lungs in interstitial bronchopneumonia lie in the filling of the bronchioles with opaque exudate, the thickening of their walls, and the consolidation of the adjacent lung tissue which appears in cross-section as a nodule, in longitudinal section as a branching mantle of dense tissue bordered with hemorrhage accompanying the bronchiole. Atelectasis of the intervening lung substance, great thickening and prominence of the interlobular septa and pleura, and usually pleurisy with abundant effusion make up the whole picture.

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The bronchial glands are somewhat enlarged and soft. The mucosa of the large bronchi is deeply reddened and covered with purulent exudate, sometimes with a necrotic pseudomembrane. Some writers have insisted that this should be called purulent bronchitis or bronchiolitis, but the involvement of the whole lung takes place so promptly, including the framework and the pleura, that I think the term bronchopneumonia is better justified.

The microscopic study of the early changes shows essentially an infection of the bronchi with streptococci. The greatest stress should be laid upon the staining of bacteria in the tissues because it is only in that way and not by mere report of the presence of cultivable streptococci that we may determine the exact topographical relation of these organisms or others to the lesion.[3] It is found that in every

[3] A new stain which is a combination of Goodpasture's and the Weigert fibrin stain has served well to demonstrate in the tissues Gram-negative organisms, such as the influenza bacillus, in red and Gram-positive bacteria in blue. During the correction of the proof of this paper the cases have been restudied with this stain. It is as follows:

1. Stain for 10 minutes to ½ hour or more in Goodpasture's stain, which is:

	cc.
30 per cent alcohol	100.0
Basic fuchsin	0.59
Aniline oil	1.0
Phenol crystals	1.0

2. Wash in water.
3. Differentiate in 40 per cent formaldehyde solution (pure formalin). This requires only a few seconds. The bright red color washes away and gives place to a clear rose color.
4. Wash in water.
5. Counterstain in saturated aqueous picric acid. The section should remain until it assumes a purplish yellow color, about 3 to 5 minutes or less.
6. Wash in water.
7. Differentiate in 95 per cent alcohol. The red color reappears and some of it is washed out. Some of the yellow of the picric acid is also washed out.
8. Wash in water.
9. Stain in Stirling's gentian violet 5 minutes or more.
10. Wash in water.
11. Gram's iodine solution.
12. Blot dry without washing.
13. Aniline oil and xylol (equal parts) until no more color comes away.

instance the streptococci are present in numbers among the leucocytes which fill the bronchioles. They can be traced along the mucosa of the larger bronchi up into the trachea where possibly other bacteria may also be found, but in the terminal bronchioles there are in many instances only streptococci. In some cases there are relatively few, while in others, such as Nos. 184 and 178, they are present in tangled masses strewn along the mucosa but in smaller numbers in the center of the bronchial lumen. Recent papers from England and France, already referred to, declare for the preponderant part played by the influenza bacillus. A glance at the table given above will show that it has been found quite commonly in the sputum in these cases too, sometimes in the lung and pleural fluid. Its relation to these lesions must be left in some doubt since it is present in only part of the cases while the streptococcus is invariably present. The British writers describe a purulent bronchitis or bronchopneumonia which resembles this most closely and regard it as due to the influenza bacillus, although they frequently found an associated *Streptococcus pneumoniæ* (pneumococcus) and *Streptococcus longus*.[4]

The epithelium of the bronchus is usually intact, but in some cases, Nos. 178 and 184, it is quite destroyed and even the underlying tissue is necrotic for a considerable depth. This appears to the naked eye as an opaque greyish yellow pseudomembrane lining the bronchus down to the finest ramification and extending out to the largest branches. In the earliest stages, as in Case 32, the respiratory bronchioles are the ones affected, while the larger bronchi show little

14. Two changes of xylol.

15. Balsam.

Gram-negative organisms are red, Gram-positive blue.

Dr. Goodpasture's own method is not yet published but he kindly allows me to use his formula in describing this method. Goodpasture's stain corresponds with the first seven maneuvers given above.

[4] During the epidemic of influenza which raged through September and October, 1918, we have encountered cases in which the influenza bacillus occurred in pure culture in the lungs and bronchi. In these the lesions resembled very closely those which are described here under the name interstitial bronchopneumonia. (Note made during the correction of the proof.)

change. Leucocytes with streptococci extend out into the lateral vestibules and into the terminal ones and even into the ultimate alveoli. There is little other change, but although the more distant alveoli are not altered, the bronchial wall and the adjacent alveolar walls even at this stage are infiltrated with wandering cells. There are few of them at this stage, but they give a distinct character which comes out clearly in later stages.

In all the later stages this change in the connective tissue, elastic tissue, and musculature which make up the wall of the bronchus is striking. The normal elements are spread apart by great numbers of mononuclear cells which intercalate themselves between the fibers and often form a mass which lifts up and dislodges the epithelium. Most of these cells are small like lymphoid cells, but many are larger, occasionally assuming the character of plasma cells or the various types of larger mononuclear wandering cells. Edema accompanies them and aids in the spreading apart of the connective tissue. The blood vessels are distended with blood and evidently new ones are formed with associated fibroblasts, for in many cases the wall assumes the appearance of a highly vascular granulation tissue in which the blood vessels come to be radially placed. In some cases the bronchi become dilated, occasionally to a marked degree, as in Case 181, and to a less extent in Cases 41 and 184. In the most advanced conditions, as in Case 41, the walls of the bronchioles become enormously thickened and form a compact tube of infiltrated tissue, but in most instances the wall is rather relaxed and loose in texture. With dilatation the epithelium may be stretched and flattened or it may disappear by being desquamated, leaving the surface of the new granulation tissue exposed.

The normal wall of the smaller bronchi contains only a relatively small amount of lymphoid tissue, scattered in thin strands in its outer layers, except at certain places such as the points of division where somewhat more compact masses often occur. About the same may be said of the adventitia of the blood vessels and the interlobular septa. It seems possible, however, that much of the infiltration which has been described, and a part of the thickening of the bronchial wall may be due to the swelling and spread of the lymphoid tissue all along the wall of the bronchus, and its appearance of being a new growth of

granulation tissue with radially arranged and abundant blood vessels may well be explained in the same way, since with a greatly thickened mantle of lymphoid tissue there would arise a more conspicuous vascular supply for that tissue.

The lymphatics which run in the bronchial wall are distended with leucocytes, mononuclear cells, and blood, and usually thrombosed with great quantities of streptococci entangled in the thrombus. Before discussing other parts of the lymphatic network, however, we must describe the alveolar structure of the lung.

It has been said that in the earliest stages the alveoli about the terminal bronchioles contain leucocytes and streptococci. That seems to be a transient condition, however, for in stages only a little older a different condition is found. Even in the early lesions in Case 14, in which the opposite lung showed old lesions, the bronchiole is distinctly infiltrated and thickened, and the affection extends through the wall to the adjacent alveoli. These are filled with blood, the lining epithelium is beginning to desquamate, and there are some mononuclear cells.

In the later stages a uniform process appears which is a combination of these. The alveolar walls contiguous to the bronchi become widened and thickened by an invasion of mononuclear cells just as in the bronchial wall itself. The alveoli are partly filled with fluid and with desquamated alveolar epithelium. Many of them a little farther removed are quite filled with red corpuscles and all contain dense masses of compact fibrin in which cells are partly entangled. Mononuclear cells escape into the alveoli, but in small numbers. It is strange that although streptococci are found in the lumen of the bronchus among the polymorphonuclear cells which persist there, and in still greater numbers in the thrombosed lymphatics of the wall, they are not to be found in these distended alveoli, which seems to show that this process has a certain protective influence.

A later stage, as in Cases 29, 15, 16, 34, or best of all 41, shows the wide extension of this process of filling up the alveoli with dense fibrin in solid but rather contracted plugs which occupy only part of the space, epithelial cells, fluid, and blood. The fluid which extends far wide of the actual area of consolidation is evidently very thick and viscous, for it coagulates in fixation into a brittle mass

which takes a deep stain. The infiltration of the alveolar walls sometimes produces a great thickening. The cells accumulate on each side of the centrally placed layer of capillaries and lift away from them the delicate structureless membrane which on each side forms the wall of the alveolus upon which the epithelial cells are laid. This is very distinct in spite of the text-book statement that there is but one structureless membrane in each alveolar wall. This infiltration is most marked in the immediate neighborhood of the bronchiole, in the neighborhood of blood vessels whose adventitial walls are thickened in the same way, and again in the neighborhood of the pleura and the interlobular septa. In other parts of the lobule the alveolar walls maintain their proper thickness for a long time and in many cases are air-containing and normal in appearance where they lie apart from the foci of consolidation. Where the alveolar walls are rendered dense and not easily stretched, the alveolar epithelium becomes thick and cubical; frequently one may find mitotic figures in these cells, indicating plainly their active multiplication which must be necessary to produce such numbers as are found shed into the cavities of the alveoli. It is astounding to find that even before the later stages just described have been reached, organization of the exudate has begun. In the bronchioles of the tiny hemorrhagic foci in Case 14, and in the alveoli and bronchi of many of the other cases, new blood vessels are found to have grown into the exudate carrying fibroblasts and replacing the fibrin with vascular connective tissue. The origin of this from the walls of the bronchioles and its extension into many alveoli is often seen. Connective tissue may spring up through a defect in the epithelium of the bronchial wall and stretch across the lumen to connect with the opposite wall or it may form a column which reaches down into the alveoli and forms a sort of mold of the original air spaces. Epithelium grows over it rapidly and whole fields may show the alveoli fairly occupied by strands of pretty dense connective tissue, supplied with blood vessels and clothed in epithelium.

The blood vessels of the lung are not especially altered. I have found none thrombosed, and the circulation is unimpaired. The circulation is indirectly embarrassed in two ways by the same means. The obstruction of the bronchi by infected material need not extend

into the alveoli of its own respiratory district, although the inflammatory process extends through the wall to the neighboring alveoli, but it does prevent the entrance of air. The atelectasis which results from this is rendered general and complete by the pressure exerted on the lung by an effusion of fluid into the pleura, and the lung as it appears when removed from the body is commonly a flabby pasty soft grey-blue mass which has been plastered against the vertebral column and compressed into an airless substance. The blue color at once indicates its filling with venous blood, for when it is distended it quickly becomes bright red. This must be due to the angular kinking of the venules which prevents the proper egress of the blood. This is supported by the fact that in old cases of empyema in which the condition has lasted a long time the alveoli are filled with epithelial cells loaded with iron pigment which are so characteristic of chronic passive congestion. One may conclude that there is a chronic passive congestion, caused by local pressure which indicates that the passage of blood is impeded and necessarily the whole circulation in some degree obstructed.

The pleural changes have been mentioned. The pleura itself is sometimes smooth, sometimes covered with a thin film of fibrin, but most often with a thick shaggy layer of fibrin into which it throws up blood vessels and connective tissue, by this process converting itself into a thick layer of granulation tissue. This is, of course, continued into the pleural surfaces of the interlobar spaces where, however, it is limited by the ready formation of adhesions.

The interlobular septa which run downward into the lung from the pleura have become especially interesting in this disease because of their own changes and because of the lymphatics which run in their substance. The septa themselves become edematous and their connective tissue fibers are spread wide apart. A coagulum of fibrin in which there are entangled numerous mononuclear wandering cells forms in the fluid in the meshes of this tissue. At a later stage this condition which renders the septa very conspicuous, as in Cases 34 and 29 and others, gives place through abundant formation of new connective tissue to one in which the widened septa are found to be composed of dense fibrous tissue, as in Cases 35, 193, 57, 58, and others.

The lymphatics of the lung have been the object of much study (Miller, Cunningham, and others), but even yet there is not perfect unanimity of opinion about their arrangement and more especially about the course of the stream of lymph. According to Miller's description, they run in the septa and in the walls of the blood vessels and bronchi toward the hilum of the lung where they empty into the sinuses of the bronchial glands. On the pleural surface, or rather in the substance of the pleural membrane, lymphatic channels which form a dense network are connected with those in the substance of the lungs. Miller states that the current from the superficial layers of the lung is directed away from the hilum and toward the pleural network and that this is supported by the direction of the valves toward that network. I have made some injections in distended lungs after having first filled the blood vessels with carmine gelatin. The lymphatics were injected with Berlin blue through a fine hypodermic needle inserted into the substance of the pleural membrane. A most extensive and complete injection of this network can be seen to shoot out over the surface of the lung and from it larger trunks dipping into the substance of the lung suddenly appear as they are filled with the blue mass. A fairly complete injection of the perivascular and peribronchial and septal lymphatics as far as the hilum of the lung can be made in this way, showing the latter channels to be very wide. It seems probable from experience with the injecting of lymphatics elsewhere that no such complete injection could be made with moderate pressure if many valves had to be forced backward. Further a fortunate section or two showing the lymphatics of the interlobular septa in direct connection with those of the pleural network reveals the fact that the undisturbed valves actually open away from the pleura even at a distance of only a few millimeters from the surface. This is shown in Fig. 23. I think, therefore, that in the lymphatic apparatus of the lung the natural current is from the pleural surface toward the hilum of the lung.

In all the cases of interstitial bronchopneumonia, the lymphatics as seen in section, whether in the walls of the bronchi and blood vessels, in and about the interlobular septa, or in the pleura, become conspicuously dilated and are frequently filled with a thrombus. These thrombi are entirely analogous to thrombi which might form

in veins except that they contain no red corpuscles and are not constructed on the peculiar framework of platelets which appear so regularly in the venous thrombi. Platelets, of course, must be practically absent from the fluid lymph in such peripheral lymphatics so that the materials for the construction of an elaborately formed thrombus are lacking. The lymphatic thrombi are mere formless coagula of fibrillated fibrin in which leucocytes and many streptococci are entangled. They must effectively obstruct the channel when they are large enough and thus divert the current into other paths.

In many cases the lymphatics distended in this way with opaque yellowish pus or clots loaded with leucocytes become most conspicuous on the cut surface of the lung. They are sometimes 2 to 3 mm. in width and distinctly beaded as they run along the course of the interlobular septum. Many of them can be traced to their connection with the pleural network which may be similarly distended with a yellowish white mass. On section, as shown in Fig. 10 from Case 34, they appear as huge varicosities in the course of the interlobular septum and are filled to distension with leucocytes and streptococci. In one lung which was shown me they were so large as to be mistaken for bronchi.

It seems that this constant infection of the peribronchial and other lymphatics in the early stages of the disease, with a real concentration of bacteria in the lymphatics, must play a part in the early production of pleural infection. Of course the idea of transportation of the bacteria by the lymph to the pleura is opposed by the statement made above that the current is all in the opposite direction, but with the entrance of the bacteria the lymphatics become obstructed and the current stops. Direct extension by growth is visible in these lymphatics in sections, and that seems to afford the most plausible explanation of the early infection of the pleura. Other arguments concerning pleurisy may be more satisfactorily discussed later in connection with empyema.

These then are the main points in the anatomy of the interstitial bronchopneumonia in as far as the lung is concerned. It appears as a primary infection of the bronchioles. In the course of the affection thickening and infiltration of the bronchial and alveolar walls, of the interlobular septa, perivascular adventitial tissue, and of the pleura

occur. The lymphatics are widely infected and thrombosed. The alveoli about the infected bronchi are filled with fluid and blood, dense coagula of fibrin appear, the epithelial cells multiply and are shed into the lumen, a few mononuclear cells appear, and organization takes place in this exudate until bronchi and alveoli contain strands of fibrous tissue. In the meanwhile the infection probably extending by growth along the lymphatics reaches the pleura and sets up a pleurisy with effusion, one effect of which is to cause extensive collapse of the lung. It is important to consider at this point the distribution of the bacteria in the lung in this affection. The exudate in the lumen of each bronchiole always contains streptococci in considerable numbers; the lymphatics in the bronchial wall and those seen elsewhere contain them in numbers in the thrombi; the superficial layers of the exudate on the pleural surface contain a perfect feltwork of these organisms sometimes enclosed in leucocytes; but the contents of the alveoli and the substance of the tissue contain none. Even in the bronchial wall it is generally impossible to trace the bacteria into the crevices of the tissue. In the pleural exudate it is the superficial layers which contain them; the fluid exudate is a thick suspension of bacteria, but they are found in rapidly decreasing numbers as one passes into the substance of the fibrinous exudate, and in the pleural granulation tissue there are none. Since they find the conditions for their life so unsuitable in the depths of a fibrinous exudate there must be rapid additions to those in the lymphatics to maintain their numbers. It is interesting to observe their behavior upon the surface of the lobulated mediastinal fat which hangs in the pleural cavity near the apex of the heart. Wherever the surface was exposed the streptococci were numerous; where two folds had adhered so that the crevice between them was obliterated by a fibrinous adhesion the bacteria descended to the depth of the open crevice, but there were none in the deeper obliterated part, nor anywhere in that tissue.

All this must signify a definite power of resistance on the part of the tissues in these cases, indicating their ability to destroy the organisms whenever they come into sufficiently close contact with the living cells, for as we shall see in the next two groups of cases a different lesion is developed in those patients, apparently because they have little of this power of resistance. While streptococci are present in

relatively small number in the interstitial form, in which bulwarks are built up against them, they swarm in direct contact with the tissues in the lobular pneumonia and cause extensive necrosis. The contrast between their distribution in interstitial bronchopneumonia and that of pneumococci in lobar pneumonia is also striking because the pneumococci are scattered evenly throughout the depths of a pleural exudate and everywhere in the contents of the alveoli.

Small foci of lobular pneumonia occur in many of these cases, but the next group is set apart as illustrating more fully this combination.

2. Interstitial Bronchopneumonia and Lobular Pneumonia.

Case 24.—A. G. C., age 25 yrs. Measles and mumps in childhood. Taken sick Jan. 15, 1918, with sudden pain in the right side. Next morning fever and extreme weakness. Entered hospital Jan. 16. Dulness over right lung in front with tubular breathing and râles. Left lung hyperresonant. Leucocytes 18,800. Temperature 98–105° F., pulse 94–155, respiration 20–55. Died Feb. 4. Autopsy Feb. 5, at 5 p.m.

Anatomical Diagnosis: Interstitial bronchopneumonia with disseminated lobular pneumonia.

Left pleural cavity.—Contains no fluid; surfaces are dull and hyperemic over the posterior portion of the lung. *Right pleural cavity.*—Contains no fluid. There are light fibrous adhesions easily broken through over the posterior portion, and the surfaces are injected. *Heart.*—The pericardial cavity contains a few cc. of fluid; its surfaces are glistening. The heart is of moderate size, flabby, and soft. The endocardium of the right side is smooth, tricuspid, and the pulmonary valves are delicate. The mitral valve is thickened and shortened but not definitely stenosed. The chordæ tendineæ are also involved in this thickening, but the mitral ring measures 8.5 cm. in circumference. On the anterior leaflet there are several massed vegetations which form a clump about 1 cm. in height. These are rough and crumbly. There is a smaller vegetation at the middle of the leaflet while the large mass extends somewhat on the posterior leaflet. The aortic valves are delicate and competent. The coronary arteries are smooth. In the myocardium of the septum beneath the endocardium is a small pale fleck surrounded by hemorrhage. *Left kidney.*—Contains an anemic infarction about 1 cm. in diameter. *Left lung.*—Voluminous. The upper lobe is easily and completely insufflated, the lower lobe less so, leaving superficial collapsed areas. On section the upper lobe is air-containing throughout. Lower lobe is spongy and apparently largely air-containing. There are coalescent grey spongy patches surrounding blood vessels or bronchi which are separated especially near the surface of the lung by deep red areas. There are no definite nodules nor

even any definite consolidation. No distinct thickening of bronchial or blood vessel walls is to be observed and there is no pleurisy. *Right lung.*—Edematous and densely studded with greyish nodules of consolidation which are conspicuous on a dark red background.

Microscopic Examination.—The lung shows no change in the pleura. There is but slight thickening of the interlobular septa. The bronchi are filled with an exudate of leucocytes. The walls are somewhat thickened and infiltrated. The alveolar walls are very slightly infiltrated. They are filled with fluid and desquamated epithelial cells and with dense plugs of fibrin which are in places organized. The organization does not extend to the bronchi. Certain areas show the alveoli filled with leucocytes in a fibrin network, but these are only scattered patches. Other areas are loaded with bacteria and are necrotic, the necrosis involving the walls of the alveoli. Such bacteria are partly streptococci but partly large Gram-positive spore-bearing bacilli.

Therefore the changes are probably in part due to postmortem decomposition. Bacteriological cultures showed Gram-positive gas-producing bacilli in blood and lungs.

Case 29.—C. B. D., age 20 yrs. Began Jan. 18 with nosebleed, cold in head, and painful eyes, photophobia, fever, and chilliness. Entered hospital Jan. 23, 1918, with sore throat, reddened pharynx, no tonsillitis, a red crescentic papular eruption over face and body. Coughing, with fine râles over the entire chest, persisted. Rash lasted 5 or 6 days. Since onset patient has been hoarse and at present (Feb. 4) cannot speak above a whisper. About Jan. 30 patient developed a pain in both axillæ with marked difficulty in breathing. Râles were heard over both lungs. Inspiration lengthened and so labored as to bring in accessory muscles. Friction rub in left axilla. The percussion note later became dull or flat in the left axilla and back and the friction rub disappeared. Patient growing more and more cyanotic, conscious, and very nervous. Needle inserted at lower angle of left scapula but only blood obtained. Sputum abundant, greyish white, tenacious. Patient died on Feb. 7, 9.50 p.m., 20 days after the onset of measles. Cultures from sputum and material obtained from lung puncture showed *Streptococcus hæmolyticus.* Blood culture taken Feb. 7 negative. Autopsy Feb. 8, 9 a.m.

Anatomical Diagnosis: Clinical history of measles. Bilateral interstitial bronchopneumonia. Fibrinopurulent pleuritis (left). Early serofibrinous pericarditis.

Left pleural cavity.—Contains about 1,500 cc. of greenish brown turbid fluid. The surfaces are covered with a fibrinous exudate, but as there are numerous adhesions posteriorly most of the fluid is held in the anterior portion of the thorax. *Right pleural cavity.*—There is no excess of fluid and the surfaces are smooth anteriorly, but over the posterior part of the cavity and over the diaphragm the lung is adherent by a thin hemorrhagic fibrinous exudate. *Pericardial cavity.*—Contains about 40 cc. of slightly turbid fluid. The pericardial surfaces are slightly injected and there are a few shreds of fibrin. *Left lung.*—The lung feels flabby

and soft but contains some firmer nodules. The upper lobe is largely air-containing while the lower is heavy, dense, and collapsed. On section the upper lobe shows very distinct interlobular septa, and in the upper posterior portion there are a few small peribronchial consolidations surrounded by grey spongy tissue. Several of these areas are embedded in the deep red tissue of each lobule. In the lower part of the lobe the consolidated portions are so numerous as to form a confluent network. Each yellowish branching nodule is bordered with red and these are separated by greyish tissue. In the lower lobe the mesial and posterior parts are thickly studded with greyish yellow areas which in places grow large and become confluent. In the outer or axillary portion of the lobe these are fewer and of smaller size. The septa are still conspicuous but the bronchi are not. The lung is covered especially over the lower part with a thick fibrinous exudate. *Right lung.*—The lung is voluminous and almost everywhere air-containing. There is a thin fibrinous exudate over the lower lobe and lower part of the upper. The bronchi are deeply reddened. The upper lobe is largely air-containing. There are a few small branched peribronchial consolidations and a large firm one 1 cm. in diameter. In the lower lobe there is no conspicuous thickening of the bronchi, but in the lowermost part the bronchi are widened and full of exudate and surrounded by feathery homogeneous, greyish red areas of consolidation. From their homogeneous uniform appearance these seem to be areas in which the alveoli are filled with exudate. There are some large opaque yellow patches and many confluent grey smooth areas. *Larynx.*—Slightly reddened and covered with mucus. No ulceration visible.

Microscopic Examination.—The tissue of the left lung shows great thickening of all the framework of the organ. The interlobular septa are wide, contain a good deal of fibrin in the form of a network, but in most places this has disappeared and the broad septum is made up of loose connective tissue with many fibroblasts. The bronchi have lost their epithelium, contain leucocytes, desquamated epithelium, and a few streptococci (Fig. 31). An effective stain reveals influenza bacilli in great numbers in bronchi and alveoli. Elastic tissue stain shows readily the original outlines, and it is clear that there is a thick layer densely infiltrated with mononuclear cells which has formed just beneath the epithelium, lifting it up. The remaining muscular and connective tissue portion of the wall is densely infiltrated with mononuclear cells and some leucocytes and is much thickened (Fig. 32). Viewed with a low power any one lobule appears denser around the central bronchus and near the surrounding interlobular septa than in the intervening zone. This is largely due to the fact that in the neighborhood of the bronchus and at the periphery near the septum the alveolar walls are greatly thickened. The epithelium is in general desquamated, but the underlying structureless membrane which can be most distinctly seen is lifted away from the capillaries which hold to the middle of the alveolar wall by a great mass of mononuclear wandering cells and newly formed connective tissue. Thus in each alveolar wall the capillaries are covered on each side by a layer of these cells

bounded by the membrane of the wall. In the midzone of the lobule the alveolar walls are thinner. All this infiltration and new connective tissue formation forms another instance of the reason for speaking of this condition as interstitial bronchopneumonia.

The alveoli contain many desquamated epithelial cells, rather dense fibrin, and a few mononuclear wandering cells. There are few if any streptococci to be seen. But in places there are small groups of alveoli densely filled with leucocytes among which there are great numbers of streptococci. This coexistence of what may be called lobular pneumonia with the interstitial bronchopneumonia is noteworthy. The interlobular septa are composed of a network of fibroblasts (Fig. 33). The lymphatics are wide and contain a mass of cells which are practically all mononuclear. Some are as large as alveolar epithelial cells. There is often also a network of fibrin which is beginning to undergo organization. A few streptococci are found there.

In other areas of the left lung and in the right lung the inflammatory process beginning about the bronchi is associated with much edema and hemorrhage into the alveoli. The left lung shows the most extreme interstitial changes yet seen. There are quite large areas which are completely airless, the alveoli being filled with fluid and desquamated cells and blood (Fig. 34), the alveolar walls, vessels walls, and interlobular septa greatly widened by infiltration with mononuclear cells. The lymphatics are filled with mononuclears and fibrin out to the pleural exudate. The bronchi are enormously thickened and overvascularized. Usually the epithelium is lost and the thick wall densely infiltrated with mononuclears. In some places the contents of the bronchi appear to be replaced by a mass of newly formed vascular tissue.

The lobulated fat which hangs into the pleural cavity from the surface of the pericardium is covered with exudate and most of the lobules are glued together. Streptococci are abundant on the surface and extend into the ends of the open crevices but are not found in the fibrin which closes the crevices or in the tissues.

Cultures from blood, pericardial fluid, pleural fluid, and left lung reveal *Streptococcus hæmolyticus.*

Case 30.—F. E. H., age 23 yrs. Was in hospital for tonsillitis Dec. 24–29, 1917. No rash at this time. Since then has been having chills every night. On Jan. 3 developed pain in the left side of the chest and entered the hospital, Jan. 6, 1918, with signs of dulness, tubular breathing, and crepitant râles over the left lower chest. 1,000 cc. of turbid straw-colored fluid were aspirated on Jan. 21, and on Jan. 23 the left pleural cavity was drained by resection of the 7th and 8th ribs. Leucocytes 35,000. Temperature 99–104° F., pulse 90–160, respiration 20–40. Died Feb. 7, at 6 p.m. Autopsy Feb 8.

Anatomical Diagnosis: Interstitial bronchopneumonia and lobular pneumonia with abscess formation and empyema (left side). Lobular pneumonia (right lung).

Left pleural cavity.—Obliterated by fresh adhesions in the anterior portion, but posteriorly there is a cavity open to the air through an incision which interrupts

the 7th and 8th ribs in the left anterior axillary line. This cavity contains about 400 cc. of an extremely foul greenish brown turbid fluid. The surfaces are covered where they form the wall of the cavity with a thick greenish exudate. *Right pleural cavity.*—Contains no excess of fluid and the surfaces are smooth and glistening. *Left lung.*—The lung is partly collapsed, its posterior part covered with greenish exudate. The upper lobe contains a few small consolidated areas. The lower lobe is closely studded with similar small consolidated patches which have become liquefied centrally. The intervening lung substance is collapsed and edematous. *Right lung.*—In general the lung is air-containing, but in the lower lobe there are one or two firm nodules. One of these stands out above the surrounding lung surface and the pleura over it is dull and covered with fibrinous exudate. On section this patch is opaque and yellow, but it is still possible to discern in it the bronchi filled with exudate. In other parts of the lung there are small abscess-like foci surrounded by hemorrhage.

There are evident general signs of postmortem decomposition. The skin of the abdomen is discolored and green and the gastric mucosa and retroperitoneal tissues contain large gas blebs.

Microscopic Examination.—Sections through the least affected part of the left lung show the greatly thickened pleura which is replaced by a dense granulation tissue. The bronchi are in places filled with an exudate of leucocytes and mononuclears. The adjacent alveoli show slight infiltration of the walls; the epithelial cells are desquamated and fill the lumen. Most striking is the presence of whole colonies of bacteria in the blood vessels and capillaries and sometimes in the alveoli and bronchi. Since these are present in enormous numbers in the capillaries of the liver, spleen, kidneys, and adrenals, with little or no reaction about them, it seems probable that they have become so numerous through postmortem growth. In other areas of the lung there are large patches of necrosis in which all structure is lost and merged into a granular material loaded with micrococci and masses of minute Gram-negative bacilli which may be influenza bacilli. About these there is a dense pneumonic consolidation with edema and hemorrhage in the distant margin. Many of the alveoli show a curious columnar form of epithelium which makes them look like minute bronchioles.

No cultures were made.

Case 35.—C. E. P., age 26 yrs. Entered hospital Jan. 13, 1918, complaining of pain in left chest, chills, and fever. No history of sore throat or rash. Does not remember having had measles. Dulness with tubular breathing over the left base at the back. Leucocytes 20,800. Temperature 101–105° F., pulse 120–160, respiration 30–60. Jan. 26, evidences of fluid at the left base with new signs of consolidation in upper left and lower right lobes. On Jan. 29 aspiration of the right side gave 200 cc. of cloudy reddish brown fluid. Feb. 1, severe pain in left chest. Feb. 5, rib resected on left side and drainage established after repeated aspirations during preceding 2 days. Feb. 9, patient complains of severe pains in abdomen which is greatly distended, rigid, and very tender. No special localization of tenderness. Died Feb. 10, 1918, at 10 p.m. Autopsy Feb. 11, 1918.

Anatomical Diagnosis: Interstitial bronchopneumonia and lobular pneumonia with empyema (left). Acute pericarditis (beginning). Acute generalized peritonitis. Acute nephritis.

Upon opening the abdominal cavity there is an escape of turbid yellow fluid with flakes of fibrin. The surfaces of the peritoneum are somewhat injected on the left side but are everywhere smooth. No origin of this infection could be found in the abdominal organs. *Pericardium.*—The pericardial sac contains 50 cc. of slightly turbid greenish yellow fluid. The vessels on the inner surface of the parietal pericardium are slightly injected. *Left pleural cavity.*—There is an incision in the anterior axillary line over the 7th rib and a portion of this rib has been resected allowing fluid to escape through a rubber drainage tube. Between the collapsed lower lobe of the lung and the parietal pleura there is a cavity which contains about 400 cc. of a bloody purulent fluid. The upper lobe is adherent over its whole surface excepting a small area posteriorly where it forms part of the wall of the empyema cavity. The remaining pleural lining where it forms the wall of this cavity is covered with a fibrinopurulent exudate. *Right pleural cavity.*—Obliterated by very fresh light fibrous adhesions which are easily broken through but which bind the lung to the costal pleura and diaphragm. *Left lung.*—The pleura is much thickened and the lobes are bound together by a fibrous layer 4 mm. in thickness. The lobes are heavy and airless except at the anterior margin of the upper lobe. On section the upper lobe is dark red and rather edematous, but there are no areas of consolidation. The lower lobe is also edematous on section and reddish grey in color. The interlobular septa are prominent and in each lobule there are five or six opaque yellow areas of consolidation many of which show a central cavity or lumen. The bronchi in general are thick with reddened and edematous mucosa. The surrounding tissue is dense and yellowish. The bronchial glands are enlarged and soft. *Right lung.*—The surface is roughened and shows subpleural hemorrhages and over the inferior border of the lower lobe a thick fibrinous exudate. All the lobes are readily insufflated, although the lower was collapsed and heavy. In the upper and lower lobes and to a much less extent in the middle there are found a few small greyish translucent areas which appear to be due to thickening of the bronchioles. The bronchi are reddened. The lymph glands at the hilum are swollen and soft. *Kidneys.*—Left kidney measures 12 by 5 by 4 cm. The capsule strips readily, leaving a smooth, pale greyish, opaque surface upon which numerous small hemorrhages are to be seen. On section the cortex measures 7 mm. in width. It appears swollen and opaque. The striations are somewhat obscured by numerous small hemorrhages in the cortex. The glomeruli are visible as small greyish dots. The pyramids are dark brownish red with very distinct striations. Pelvis is normal. The right kidney is in all respects similar.

Cultures from the blood, pericardial fluid, pleural fluid, and left lung show *Streptococcus hæmolyticus* in pure culture.

Microscopic Examination.—The right lung in its lower lobe shows only rather diffuse changes which consist in the filling up of the alveoli with fluid and blood.

The walls are not especially altered, but in the capillaries there are surprising numbers of megalocaryocytes.

Rather large bronchi shown in this section are loosely filled with leucocytes and debris of epithelium. The bronchial wall is not markedly thickened, but it is striking that in many places where the epithelium is desquamated there is a distinct adherent layer of fibrin on the wall like a diphtheritic membrane.

The left lung, covered with a thick vascular layer of granulation tissue surrounded by fibrin, is atelectatic, and the bronchi contain bacteria and pus. There are no other remarkable alterations in this part of the lung. But in the lower lobe the changes are advanced. The pleura is as just described. The interlobular septa are wide and dense and contain lymphatics plugged with clots made up of fibrin, leucocytes, and bacteria. The bronchi are dilated, the walls greatly thickened by mononuclear infiltration, the epithelium is desquamated, and the lumen filled with this and a mixture of fluid and leucocytes with bacteria. Influenza bacilli are present in numbers among the streptococci. From the region of the bronchi the alveolar walls are thickened by infiltration with mononuclear cells and a great many leucocytes, but at a little distance this thickening disappears. The whole tissue is compact and solid because each alveolus while partly collapsed contains desquamated epithelium, fluid, and blood. There are not many mononuclear cells in the alveoli, but even in outlying places they persist in the walls of the small blood vessels and adjacent alveoli.

There are many patches of lobular consolidation in which the alveoli are tightly packed with leucocytes, which in places are entirely disintegrated and appear as a dust of nuclear fragments. They are often surrounded by wide zones of hemorrhage. These are areas of lobular pneumonia rich in bacteria, but in contrast there are often found minute bronchioles which are filled with leucocytes and whose walls are greatly widened by infiltration of mononuclears and rendered so indefinite that their outlines cannot easily be recognized either within or without.

The kidney shows very little change in the glomeruli. There is occasionally some coagulated fluid in the capsule. Epithelium of the tubules much degenerated and partly desquamated. The tubules are in places filled with blood and leucocytes. There are a few leucocytes in the interstitial tissue.

Case 58.—M. F. M., age 25 yrs. History negative. Present illness began on Jan. 10, 1918, with a severe cold accompanied by sore throat, headache, and fever. Began to have pain in his left side on the day of admission to the hospital, Jan. 13. Dulness was found over both lower lobes but there were no râles and breath sounds were faint. Temperature ranged from 101–104.8° F., pulse 120–130, and respiration 28–48 until Jan. 28, when temperature fell to normal. There was marked delirium on Jan. 18. Pus was aspirated from the right chest on Jan. 27, and the next day the 7th rib was resected and the right pleura drained. The temperature remained rather high, 100–102°, and the patient was occasionally delirious until his death on Mar. 8, 1918. Autopsy Mar. 8, 1918.

Anatomical Diagnosis: *Old interstitial bronchopneumonia with empyema (right). Abscess of lung. Acute peritonitis.*

Left pleural cavity.—Contains no fluid but there are light fibrinous adhesions on the back of each lobe. The lower lobe is adherent to the diaphragm and there are slight fibrinous adhesions on the anterior margin of both lobes. *Right pleural cavity.*—In the right anterior axillary line there is a large operative wound over the 6th rib. The margins are covered with granulation tissue and a large piece of the underlying rib has been resected. The lung can be seen to be collapsed. The pleural surfaces are thickened and reddened and covered with a soft fibrinopurulent exudate which overlies a layer of granulation tissue. The cavity contains about 300 cc. of very foul pus. *Left lung.*—The whole lung can be inflated artificially and on section is found to be air-containing everywhere with the exception of a few areas in the lower posterior portion of the upper lobe and a few in the lower lobe. These are grouped together, two and three being found in each lobule. They have a central lumen which is filled with a yellow purulent fluid, and are surrounded by a hemorrhagic zone. The bronchi contain a sticky mucoid material, and the mucosa is hemorrhagic. The interlobular septa are not thickened. Bronchial glands only slightly enlarged. *Right lung.*—Completely collapsed and pressed against the vertebral column. It is densely adherent to the diaphragm by fibrous adhesions. Over the anterior surface of the upper lobe is a large necrotic area, irregular in form and measuring 8 by 6 cm. which is covered by dirty, foul smelling, greenish yellow exudate. On section this mass replaces about half the upper lobe. Its central part is softened, very foul, and yellowish green in color, and this condition radiates out into the surrounding lung substance. The rest of the upper lobe is airless, dark grey, and rather granular in appearance. There are numerous thickened edematous interlobular septa, and in the lobules so outlined the branches of the small bronchi filled with yellow exudate are prominent. One such group in the posterior part of the lobe is surrounded by a hemorrhagic zone. The lower lobe is also heavy, airless, and flabby. In the posterior part there are several lobules which are pale grey and quite airless, in which there are peribronchial nodules. These lobules are sharply outlined by the interlobular septa. *Pericardium.*—Contains 30 cc. of turbid fluid with floating shreds of fibrin. The pericardial surfaces are, however, still glossy. Heart is normal.

Culture from the blood gave a Gram-positive streptococcus, but this was overgrown by putrefactive bacilli.

Microscopic Examination.—The pleura over the right lung is extremely thick and dense with radially placed blood vessels and an overlying layer of fibrin on the surface of which are great quantities of bacteria.

Most of the sections show wide and rather dense interlobular septa running into the lung substance. Most of the fibrin and fluid in these are absorbed and only remnants of dense red-staining fibrin remain. The lymphatics are

hard to find, but where they can be outlined they are distended with a mass of new connective tissue infiltrated with cells. Evidently the thrombi with abundant leucocytes and bacteria have in this case been organized in the same way as the contents of the alveoli and replaced by connective tissue. The septa themselves are composed of rather dense fibrous tissue with many wandering cells.

The bronchi retain their epithelium and are filled with leucocytes in most cases, but their walls are greatly thickened and have the appearance of a layer of granulation tissue with abundant wide blood vessels running radially. They are densely infiltrated with wandering mononuclear cells. The alveolar walls are similarly thickened. Over large areas they are quite collapsed. In others they contain dense fibrin which is often in an advanced stage of organization. Most of them contain fluid and abundant desquamated epithelial cells. There are areas too in which these changes are not developed but in which the bronchi and alveolar walls remain thin and the alveoli are filled with fluid and with polymorphonuclear leucocytes.

In the districts in which the alveoli and bronchi are most thickened there are large irregular abscesses which send off long prolongations and are marked out by a dense wall of fibrin with fragmented nuclei. Within these walls the whole substance of the lung has been broken down, shreds of elastic tissue remain, but the rest is seen in the form of a necrotic debris with great numbers of bacteria. It is not possible to maintain in this case that the formation of such an abscess occurs only in an area of lobular pneumonia; on the other hand the areas of leucocytic exudate show none of the abscesses.

One receives the impression that this is a protracted case of interstitial bronchopneumonia lengthened in its course by the persistence of the empyema and that in some senses an advance toward healing has occurred, especially in the organization of the exudate in alveoli and lymphatics. But the occurrence of large abscesses has interfered with the completion of this process. The whole arrangement of the lymphatics must be greatly altered by such a process, and if recovery had occurred new lymphatics must have been required.

Case 176.—A. G., age 24 yrs. Began on Mar. 25, 1918, with measles. On Apr. 6 complained of pain in the right side, and physical examination on Apr. 10 resulted in the diagnosis of lobar pneumonia involving the right lower and middle lobes. On Apr. 11 empyema was recognized on the right side and an operation was performed with resection of the 9th rib and drainage of the pleural cavity. Died May 9, 1918, at 6 a.m. The clinical diagnosis at the time of death was lobar pneumonia, the right lower lobe resolving. Bronchopneumonia (left); bilateral empyema. Acute pericarditis and myocarditis. Culture from the blood on Apr. 28 was sterile. On Apr. 11 culture from the pleural exudate gave *Streptococcus hæmolyticus*. Autopsy May 9, 1918, at 11 a.m.

Anatomical Diagnosis: Clinical history of measles. Lobular pneumonia (right) with old empyema. Fresh fibrinopurulent pleuritis (left). Subacute purulent pericarditis with adhesions. Acute serofibrinous peritonitis. Phlegmonous infiltration of neck.

Left pleural cavity.—Contains 500 cc. of thick turbid, slightly blood-stained brownish fluid. The costal pleura is covered with yellow fibrin which overlies a velvety red pleural membrane. The lung is plastered against the pericardium and is adherent along the vertebral column to its apex. Otherwise it is everywhere free, but the fibrin is especially thick between the lung and diaphragm. *Right pleural cavity.*—In the right back 3 cm. below the angle of the scapula there is a wound about 7 cm. long rising in an oblique direction along the line of the 9th rib. The ends of the rib project through the granulating wound. The pleural cavity is free from adhesions anteriorly from apex to diaphragm, back to the midaxillary line where it is obliterated above the 6th rib by adhesions, and below that level opens out into a large cavity which extends back to the vertebral column. This space is lined with granulation tissue and fibrin and into it the wound in the back opens. *Pericardial sac.*—Greatly thickened. The anterior wall is fully 6 mm. in thickness and is lined with a layer of translucent tissue about 4 mm. thick which contains opacities. The cavity is partially obliterated, but the remaining space contains about 40 cc. of thick creamy pus which is pale greenish yellow in color and contains thick clumps of yellow fibrinous material. *Peritoneal surfaces.*—Have lost their gloss to some extent and there is some turbid fluid with flakes of fibrin in various dependent parts. *Left lung.*—Almost entirely collapsed and blue and flabby. The whole lung can be inflated and on section presents a normal texture without consolidation and with practically normal bronchi. There is a small part of the lower lobe posteriorly which fails to become inflated. *Right lung.*—The surface is changed in appearance by the alterations of the pleura already described. The bronchial glands are enlarged and opaque grey in color. The upper lobe contains air throughout; it is normal in texture and there are no areas of consolidation. The middle lobe is partly atelectatic but nowhere consolidated. The lower lobe contains air in its upper part, but the lower part is collapsed. In this collapsed part there is a group of small areas of consolidation which are grey on a greyish red background, more or less confluent and irregular in outline. They seem not distinctly peribronchial, but to consist of alveoli filled with exudate. In the more posterior part of the lobe there are even more distinct grey areas of consolidation in which plugs of exudate can be seen in each alveolus. The bronchi and blood vessels are not thickened, but the interlobular septa are rather prominent. *Tonsils, larynx, and pharynx.*—Fairly normal. There is a multilocular abscess in the intermuscular spaces of the left side of the neck extending up as far as the mastoid with which it has no apparent connection and down behind the clavicle to the pleura with which it does not communicate. The right shoulder joint is in-

tact, but the abscess extends between the scapula and the vertebral ends of the upper ribs for a long distance.

Cultures from both lungs, left pleura, pericardium, and from the abscess in the neck gave *Streptococcus hæmolyticus*. Culture from the heart's blood was sterile.

Microscopic Examination.—The substance of the lower lobe of the right lung presents the only remarkable change. The pleura is greatly thickened and converted into a rather dense granulation tissue with overlying fibrin. The interlobular septa are extraordinarily wide and rather dense. They appear to represent old changes. The lymphatics which run in these are distended with cells which are partly leucocytes, partly mononuclear cells, and this material is loaded with Gram-positive cocci which are far more numerous here than elsewhere. They are usually in pairs and only rarely in longer chains. The bronchi are slightly thickened and their walls moderately infiltrated with cells which are in part polymorphonuclear leucocytes. They contain a purulent exudate which is full of streptococci. No influenza bacilli are found. The alveolar walls are slightly thickened, in many places not at all. They are infiltrated in places with leucocytes, but near the blood vessels they may be filled with mononuclear cells. On the basis of this rather slight interstitial change there is a distinct intra-alveolar exudate of red corpuscles, leucocytes in great numbers, and fibrin. It constitutes a definite lobular pneumonia. The bacteria are present among the polymorphonuclear leucocytes, but not in great numbers and not more distinctly in chains than elsewhere. In the margin or tip of the lower lobe there is a peculiar change. The interstitial tissue is greatly increased and infiltrated with leucocytes and fibrin. The alveoli appear as rather widely separated spaces in this tissue and either have no lining or are lined with thin scale-like epithelium. The bronchioles with their columnar epithelium similarly appear isolated in the dense tissue.

Sections of the connective tissue and muscle about the abscess of the neck show great numbers of streptococci in necrotic tissue and in the crevices of a diffuse granulation tissue.

Case 181.—E. J., age 26 yrs. Began Mar. 24, 1918, with bronchitis. Onset rather sudden with chills, fever, headache, weakness, and general malaise. Scattered râles heard over lungs. On Mar. 31 subcrepitant râles and bronchial breathing over the left lower lobe posteriorly. On Apr. 1 a small area of consolidation in the right lower lobe in the axillary line. On Apr. 16 no definite signs over the lungs. Aspiration of right axilla negative. Apr. 19, suppurative otitis. Crepitant râles and slightly diminished resonance over whole right side anteriorly. Apr. 21, impaired breathing over right lower lobe. Apr. 26, 200 cc. of limpid greenish yellow fluid aspirated from right upper chest. This fluid contained *Streptococcus hæmolyticus* as shown by culture. Flatness over this region next day. May 5, aspirated 300 cc. from right chest. Culture from pleural fluid on May 10 gave *Streptococcus hæmolyticus*. Died May 10, 1918, at 2.15 p.m. Autopsy May 11, 1918, at 10 a.m.

Anatomical Diagnosis: Interstitial bronchopneumonia (bilateral) with abscess formation and empyema (right). Lobular pneumonia (left).

Left pleural cavity.—Contains no fluid. Surfaces smooth. *Right pleural cavity.*—Contains 400 cc. of thick greenish mixture of fibrin and pus which will hardly pour. The right lung is plastered against the pericardial sac. The apical part of the lung is adherent along the 3rd rib laterally, but otherwise the pleural surfaces are held apart. They are covered with a thick yellowish shaggy layer of fibrin. *Left lung.*—The lung is voluminous with smooth, glistening surfaces, but some small nodules can be felt in its substance. The upper lobe is easily inflated and on section is normal in texture. The lower lobe is also easily distended, but posteriorly and below there are some small greyish yellow nodular consolidations. *Right lung.*—The organ is collapsed, pasty, and heavy, and one may palpate nodular consolidations in its substance. On section there is found a cavity about 3 cm. in diameter in the substance of the upper lobe (Fig. 35). This excavation is full of purulent material and is in open communication with a large bronchus whose walls it has abruptly interrupted. There is no communication with the pleural space. The lung tissue surrounding this cavity is irregularly consolidated. The interlobular septa are conspicuous. The lower lobe shows the bronchi widely dilated to the periphery and filled with purulent material. About these there are areas of consolidation which become confluent so that practically the whole posterior part of the lower lobe is airless, the smooth firm areas being separated in places by only a narrow line of air-containing tissue. *Pharynx and larynx.*—The pharynx is not especially reddened. The larynx including epiglottis and vocal cords is pale, smooth, and normal throughout. The mucosa of the trachea is pale.

Cultures made at autopsy show *Streptococcus hæmolyticus* in the heart's blood, both lungs, and right pleura.

Microscopic Examination.—The left lung shows a thin smooth pleura. The interlobular septa are not thickened and the lymphatics are inconspicuous. There is a widespread filling of the bronchioles with purulent exudate. The walls are moderately thickened and hyperemic and infiltrated with mononuclear cells. This alteration is relatively slight, however, and the corresponding changes in the adjacent alveolar walls are also very slight. Still there are areas about many of these bronchi in which the alveoli are filled with thick fluid, with blood, and desquamated epithelial cells. Most of the bronchi are surrounded, however, by small groups of alveoli which contain a dense exudate of leucocytes with delicate network of fibrin and very little blood. There are many streptococci among these leucocytes, and numerous influenza bacilli.

The right lung shows a thick pleura covered with granulation tissue and fibrin. The interlobular septa and indeed all the connective tissue structures throughout the lung are enormously thickened and rendered dense by a new growth of tissue.

The bronchi are greatly distended and filled with a solid mass of leucocytes. Their walls still show in most places the layer of epithelium, but some of them

are completely denuded. In general the bronchial walls are greatly thickened and converted into a vascular granulation tissue which is densely infiltrated with mononuclear cells. The alveoli are practically all collapsed, their walls greatly thickened and infiltrated, but there is not much beyond a few alveolar epithelial cells in their cavities. The lymphatics are nowhere conspicuous, and many of them have probably been obliterated.

This case exhibits, therefore, an old interstitial bronchopneumonia with great dilatation of the bronchi and induration of the framework of the lung, with empyema causing a collapse, and necrosis and cavity formation in the upper lobe. All this affects the right lung while the left lung is studded with patches of lobular pneumonia in a tissue in which there are traces of the interstitial process.

Case 194.—J. J., age 25 yrs. Negro. Had measles on May 3, 1918. On admission, May 9, râles at both bases. Lobar pneumonia of right lower lobe recognized May 10, 1918. May 13, dulness of right lower lobe with râles; hoarseness. On May 16 fluid was suspected in the right chest and peritonitis was also diagnosed. Right lower lobe very dull; breath sounds distant. Sputum on May 13 was yellow, mucopurulent, and contained Gram-positive cocci which proved to be *Staphylococcus aureus* and *Streptococcus hæmolyticus*. Influenza bacilli were also there. Died May 16, 1918, at 1 p.m. Autopsy May 16, 1918, 2 hours after death.

Anatomical Diagnosis: Early interstitial bronchopneumonia (left), with lobular pneumonia. Empyema with collapse of lung (right). Acute fibrinopurulent peritonitis. Acute splenic tumor with hemorrhagic infarctions. Ulcerative laryngitis.

Peritoneum.—Contains a yellow fluid with flakes of fibrin which is plastered on the abdominal organs. The pelvis contains a purulent fluid. *Left pleural cavity.*—Contains no excess of fluid, but the surfaces are roughened by a fresh fibrinous exudate. *Right pleural cavity.*—This side contains a great deal (2.5 liters) of turbid fluid much of which is imprisoned in a space between the lung, diaphragm, and pericardial sac. The fluid is brownish and turbid with a thick sediment. *Left lung.*—The lung is voluminous (Fig. 36). The surfaces are smooth except at the posterior part of the lower lobe where the pleura is deep purplish and covers an area which is firm and nodular. The upper lobe is air-containing throughout and normal in texture. The bronchi are not altered. The lower lobe is thickly studded with small greyish nodules which correspond with the terminations of the bronchi and are surrounded by bright red hemorrhagic areas. In the lower posterior part of the lobe there are confluent hemorrhages within which there are several dry, opaque, dull red patches which stand up a little above the surface. The bronchi are widened a little and contain a bloody, frothy, grey exudate. Their walls are deeply congested. The bronchial glands are greatly enlarged, edematous, and grey. *Right lung.*—The right lung is collapsed into a wrinkled soft mass. The lobes are somewhat adherent, and on pulling them apart small cavities in the fibrin, containing green pus, are torn open. The lung can be artificially inflated and then on section the whole lung

is found to be air-containing. The cut surface is smooth and satiny. The bronchi are reddened and contain only frothy fluid. The bronchial glands are large. *Pharynx and larynx.*—Tonsils not enlarged. Epiglottis is pale. The vocal cords are distinctly ulcerated along their edges, but the rest of the larynx seems normal. *Spleen.*—Enlarged, measuring 16.5 by 12.5 by 5 cm. It is irregular in consistency and on section there are dark red, dry looking areas which are firmer than the rest and extend deep into the spleen. It is impossible to make out any plugs in the vessels; in fact liquid blood can be squeezed from the vessels in the centers of these areas. The Malpighian bodies are pretty well seen throughout the cut surface.

Cultures made at autopsy showed *Streptococcus hæmolyticus* in the heart's blood, right and left lung, right pleura, and peritoneum. The streptococci were mixed with many other organisms in the smear from the ulcer of the vocal cord. The right lung gave also *Staphylococcus aureus.*

Microscopic Examination.—The diaphragm shows an exudate of fibrin and leucocytes on both sides. That on the pleural surface is dense and compact while that on the peritoneal side is very loose. The absorbent lymphatics in the peritoneal surface are packed with leucocytes and such dense thrombi can be tracked into the larger lymphatics which extend to the pleural surface. It seems probable that the infection is transmitted from pleura to peritoneum by way of the lymphatics against the ordinary course of their stream which becomes possible when they are thus obstructed by a thrombus in which the bacteria are growing. It is analogous to the condition in the lung which leads to empyema.

In the left lung most of the tissue is properly air-containing, but there are scattered bronchi which contain purulent or bloody exudate whose walls are thickened and infiltrated. They are surrounded by a group of alveoli whose walls are similarly infiltrated, while their cavities are filled with leucocytes or desquamated epithelial cells. They together with the adjacent alveoli contain a great quantity of blood. Some of these patches are overwhelmingly filled with blood so that it is difficult to see anything else, while others have the alveoli filled entirely with polymorphonuclear leucocytes. The latter places are loaded with streptococci which are much more numerous there than in the more intensely hemorrhagic patches. There are also some rather large Gram-positive bacilli in the affected parts of the tissue and these are found in numbers in the hemorrhagic areas. The dull red dry patch in the lower part of the lobe is found on section to be in large part necrotic. The nuclei of the alveolar walls no longer stain, but the walls are yet traceable through the solid mass of blood. The capillaries can be seen to be much distended. The bronchi are widened and thickened by infiltration and contain streptococci, although there are not many organisms in the hemorrhagic tissue. The blood vessels contain dense clots, but they have not definitely the architecture of thrombi. All the alveoli in this neighborhood contain some leucocytes, but there are regions in which their cavities are closely packed with leucocytes among which streptococci are found.

The right lung shows practically no alteration of the tissue. The bronchi are thin walled and not infiltrated. The pleura is, however, thickened by the formation of a granulation tissue and the section shows one of the interlobar encapsulated pockets which is lined with a thickened pleura and fibrin in the same way. The immediately adjacent tissue is still collapsed and perhaps somewhat indurated.

Case 205.—H. W., age 29 yrs. Negro. Began on May 4, 1918, with measles. Later was transferred to pneumonia ward with signs of bronchopneumonia involving both lungs on May 7, 1918. Sputum contained *Streptococcus hæmolyticus* and influenza bacillus. Blood culture on May 8 was sterile. On May 15 otitis media developed in both ears and the patient became very deaf. Died May 20, 1918, at 5.50 p.m. Autopsy May 21, 1918.

Anatomical Diagnosis: Interstitial bronchopneumonia and lobular pneumonia (bilateral). Empyema (right). Bilateral symmetrical rupture of rectus abdominis. Suppurative otitis media (bilateral).

On incision through the anterior abdominal wall a cavity is found in the rectus abdominis at the junction of the lower and middle third of the muscle. This is due to a rupture of the muscle which leaves a space 4 cm. in diameter filled with a bloody fluid. There is a similar hemorrhagic cavity in the opposite muscle at exactly the same level (Fig. 37). On section the ends of the muscle are deeply infiltrated with blood and are dark red and opaque. The lower fragment is distinctly yellow. The hemorrhages bulge into the peritoneal cavity and fluctuate, but there is no excess of fluid in that cavity nor any hemorrhage, and the peritoneal surface of the bulging masses is smooth. *Left pleural cavity.*—Contains no excess of fluid. The surfaces are smooth. *Right pleural cavity.*—The cavity contains 400 cc. of turbid brownish fluid in which float flakes of fibrin. The surface of the lung is gelatinous and covered thickly with slimy patches of fibrin. There are a few small hemorrhages. *Left lung.*—The lung is voluminous and appears to contain some air everywhere. It is readily inflated artificially. On section the upper lobe is found to contain numerous small nodular areas of grey consolidation not especially surrounded by hemorrhage but apparently surrounding the terminal parts of the bronchi. They measure 2 to 6 mm. in diameter and become more numerous in the posterior part of the lobe. They are nowhere confluent. In the lower lobe the same condition exists and the nodules are extremely numerous in the posterior part of the lobe (Fig. 38). *Right lung.*—The lung is heavy and pasty and dark reddish purple in color. The bronchial glands at the hilum are very much enlarged. The pleural surface is roughened by fibrin. The anterior portions of the upper and middle lobes are air-containing. The posterior portions and the lower lobe are collapsed. On section the whole lung is thickly studded with grey peribronchial nodules becoming more abundant in the posterior parts. The interlobular septa are prominent, marking out the lobules, and each lobule contains several nodules. There is in the lower lobe a large wedge-shaped area running back to the posterior border in which the nodules are not

surrounded by air-containing tissue but are broad and confluent forming a greyish red area in which more opaque yellow patches are visible (Fig. 39). The bronchi are dilated and their mucosa is reddened. *Pharynx and larynx.*—The posterior nares and pharynx are reddened. The tonsils are normal. The vocal cords are rather deeply ulcerated throughout most of their length. The mucosa of the trachea is reddened. *Middle ear.*—On exposing the cavities both middle ears are found to be filled with pus.

Cultures at autopsy showed *Streptococcus hæmolyticus* in the heart's blood, both lungs, and right pleura, also in the right middle ear, but the bloody fluid from the ruptured rectus abdominis gave no growth.

Microscopic Examination.—The conditions found throughout the two lungs are about the same.

The pleura is thick on the right side and covered with rather homogeneous fibrin. The interlobular septa are as a rule not very conspicuous, but some of them contain large lymphatics distended with a mass of leucocytes which are usually almost necrotic and disintegrated into a poorly staining debris.

The bronchi are filled with a similar mass of granular and fragmented leucocytes containing streptococci and influenza bacilli. The walls are greatly thickened, hyperemic, and densely infiltrated with mononuclear cells. In most places the epithelium has been destroyed and a necrotic layer forms the lining. The surrounding tissue is edematous, but the nearby alveoli are filled with desquamated epithelial cells, mononuclear wandering cells, blood, and leucocytes. In places the leucocytes predominate and produce patches of what would be recognized as a lobular exudative pneumonia. Here, too, the leucocytes are much disintegrated. But in most places this exudative type is not found and the lesion is essentially that so often described as interstitial bronchopneumonia. The thickening of the alveolar walls is relatively slight, but the lining epithelium tends to be cubical and is evidently in proliferation.

The rectus abdominis muscle shows a mass of blood clot in contact with the ruptured end where necrotic hyaline muscle tissue alone is found. All through the muscle, however, in diminishing degree as one passes away from the point of the rupture there are extreme alterations which consist in the conversion of the muscle fibers into hyaline material. This looks like an old process. Each clump is surrounded by a mass of nuclei which are probably sarcolemma nuclei which have been concentrated. In places these look like wandering cells, but they are fairly well limited to the surrounding sheath of each hyaline clump. A separate and more detailed study of these muscular changes must be made.

This group of cases is not sharply distinguished from the preceding, since many of those showed a few foci of lobular pneumonia, but it is separated because it is desired to show that this combination is possible in an advanced degree. It may possibly represent a stage in the whole process at which the lung which is the seat of a lesion in the

production of which the tissues have evinced a marked power of resistance finally fails so that the organisms invade more readily. But not much stress can be laid upon this suggestion since these lesions seem to develop side by side in some cases of brief duration.

Dr. Allen Krause has suggested that in a person already tuberculous the sudden appearance of a tuberculous pneumonia is probably due to hypersensitization of the individual by the old tuberculosis, so that the introduction of bacteria into a fresh bronchus results in pneumonic infiltration in a way that could not happen in a normal non-sensitized person. It seems possible that this suggestion might be transferred to the case of this combined form of streptococcal pneumonia. We have observed the anatomical difference between the lesions and especially the type of distribution of bacteria in the two forms and have found that in a lung in which in general the streptococci are limited to bronchi and lymphatics there suddenly appear patches in which the alveoli are filled with bacteria and with leucocytes which tend to act toward them as phagocytes. We have spoken of this as a final failure of resistance—possibly the failure of resistance has through the action of the poison of the original infection become an actual welcome to the invaders.

In Cases 181, 205, and 29 there were influenza bacilli in the bronchial exudate. These must be looked upon as possible participants in the production of the interstitial changes. Indeed, except for the occurrence of advanced lesions of this type in cases in which the streptococcus is present alone (Nos. 34, 41, 178, and 184), it would be difficult to insist that the influenza bacillus is not regularly the cause of the interstitial changes.

In its gross appearance such a lung resembles closely those just described. Nevertheless one may recognize here and there on the cut surface irregularly outlined areas which are solid, dull and opaque, and rather dry looking, grey or greyish red, and generally accompanied by a wide zone of hemorrhage. Such areas can be seen in the lungs of Cases 194, 184, 178, and others.

On microscopic examination these prove to be areas in which the interstitial changes described before which lead to the thickening of the alveolar walls are absent. Thickened bronchi and widened interlobular septa may pass nearby, but in these areas the alveoli are thin

walled and widely distended or packed with an exudate which is composed chiefly of polymorphonuclear leucocytes in a delicate network of fibrin. Blood corpuscles are present in small numbers and in far greater numbers in the adjoining or marginal alveoli. The most interesting feature is found in the distribution of the streptococci which are present in great numbers all through the exudate, usually in pairs or short chains or even singly. They lie everywhere among the leucocytes, often within some of the cells which have acted as phagocytes, but usually free. It is noteworthy that in most of these cases the leucocytes forming the exudate in the alveoli show signs of disintegration. In places their nuclei stain indefinitely or are fragmented and the outlines of the cells have become extremely indistinct. In some cases, as in No. 194, there are areas of necrosis involving the alveolar walls and surrounded by hemorrhage.

Other areas of lobular consolidation containing the streptococci in numbers are surrounded by zones of edema in which the alveoli contain only fluid in which float a few chains of streptococci.

These cases show also peculiarly well the lesions of the interstitial bronchopneumonia, sometimes very fresh as in Cases 178 and 184, sometimes old as in Cases 29, 58, and 181. In the last of these, No. 181, there is extensive bronchiectasis in the lower lobe and a cavity in communication with a bronchus in the upper lobe of one lung, while the opposite lung is studded with foci of lobular pneumonia together with the fresher stages of the interstitial change in the bronchi.

Such lobular lesions appear, however, in their most destructive form in the third group of cases in which they are not combined with the interstitial changes.

3. Lobular Pneumonia.

Case 20.—J. C., age 22 yrs. Entered hospital Jan. 28, 1918, complaining of headache, rash, and pain in the eyes. Symptoms of 8 hours duration. Very faint papular rash on chest, arms, and face. Conjunctivæ injected, pharynx red, Koplik's spots present. No dulness, but fine moist râles throughout both lungs. Temperature 101–106° F., pulse 100–140, respiration 20–50. Died Feb. 4. Autopsy 2 hours later.

Anatomical Diagnosis: Confluent lobular pneumonia with abscess formation. Hemorrhagic serofibrinous pleuritis. Hemorrhagic lobular pneumonia (left lung).

Left pleural cavity.—Contains no excess of fluid and the surfaces are smooth and glistening. *Right pleural cavity.*—Contains about 1,500 cc. of turbid greenish fluid with some floating fibrin. The surface of the right lung is red and dull looking, and this appearance seen also on the parietal pleura is due to intense injection of the blood vessels and minute hemorrhages. There is very little deposit of fibrin. The lung is much collapsed but floats upon the surface of the fluid. *Left lung.*—Very voluminous with smooth surface but mottled posteriorly with dark red platelets. It is somewhat collapsed. The anterior portion is air-containing, the posterior portion thickly studded with slightly elevated dry hemorrhagic patches from 2 to 5 mm. in diameter. In these areas there is no very definite consolidation, there is no yellow opacity nor any solid nodule, nor can distinct alveolar plugs of exudate be seen. Bronchi are not definitely seen in the centers. *Right lung (Fig. 40).*—Adherent to a slight degree. It is almost entirely collapsed. In the posterior part of the lower lobe there is a large solid mass about 8 cm. in diameter, which is seen through the pleura to be purplish black in color. There are a few small rounded or branched opaque yellow areas which shine through. On section the lung is very deep red throughout, but the firm area in the lower lobe is almost black and a quantity of turbid bloody fluid exudes from it. In the upper lobe which is fairly easily insufflated there are many small irregular patches of grey consolidation in which each alveolus contains a plug of exudate. These are dull brownish grey, dry, and hemorrhagic. In the lower lobe there are many confluent areas of this sort often showing central bronchioles. They are greyish red and the intervening lung is hemorrhagic and solid. Each blood vessel is sheathed in a great wide mantle of yellowish white suggesting distension of the adventitial lymphatics with purulent exudate. Toward the lower margin such beaded yellow strands run out in the interlobular septa to the pleura where they spread out as yellow networks immediately under the surface. Some are quite large and in the depth of the lung show softened centers like abscesses. There is no fibrinous exudate on the surface. Bronchial glands slightly enlarged with some pigmentation.

Microscopic Examination.—The left lung shows early hemorrhagic patches. In these the central bronchiole and the adjacent alveoli contain streptococci in long chains and in great numbers. There is a fresh exudate of leucocytes with abundant red corpuscles but little fibrin. This intensely hemorrhagic exudate with few leucocytes and little fibrin is characteristic of all the patches.

The right lung shows much edema and a leucocytic exudate in the alveoli. The lymphatics are distended with exudate and here and elsewhere there are myriads of streptococci. In places there are actual abscesses into which the alveolar walls project and end abruptly. These abscesses are loaded with streptococci. The bronchial and blood vessel walls are infiltrated with leucocytes and some mononuclear cells. The lower lobe of the right lung shows large

areas in which the alveolar walls are necrotic and their cavities filled with necrotic material which is loaded with streptococci in long chains. All the surrounding alveoli are packed with red corpuscles with rather few leucocytes and little fibrin. The bronchi in the neighborhood are also full of leucocytes and bacteria, their walls are infiltrated with mononuclears and leucocytes, and markedly thickened. The lymphatics are distended with exudate. Streptococci are present everywhere in pure culture and are in long chains of 20 to 30 elements. They have about them a pink-staining material which is ragged and irregular in outline, like adhering albuminous material. Where there is much fibrin there are no organisms; on the contrary they are especially numerous in the necrotic areas.

Cultures from right and left lung show *Streptococcus hæmolyticus*.

The impression gained from this case is that the individual offered no resistance to the virulent infection, so that while in the left lung there are patches of lobular pneumonia in its early stages, the right shows extensive areas of necrosis with hemorrhage and little reaction.

Case 26.—D. C. H., age 21 yrs. Began Jan. 20, 1918, with photophobia, sore throat, fever, and headache. Entered hospital Jan. 25 with conjunctivitis, reddened throat, Koplik's spots, and red papular rash over entire body. Jan. 30, developed cough and profuse expectoration; râles over entire chest. Temperature 98–104° F., pulse 70–150, respiration 15–50. On Feb. 4 and 5 marked dulness over lower left chest. Flatness over left back on Feb. 6. Abundant râles everywhere in both lungs. Died Feb. 7, 5.30 a.m. Cultures from sputum showed *Streptococcus hæmolyticus* in almost pure state.

Summary of Clinical History.—(Dr. R. Cole.) The signs were those of diffuse pulmonary involvement, especially at the left base, and suggested consolidation rather than fluid. Breath sounds over this area were loud and tubular. Whispered voice sounds well transmitted and the tactile fremitus well felt. The percussion note over this area was very dull, practically flat. The presence of fluid was suspected, although the signs were not definite. Autopsy Feb. 7, 10.45 a.m.

Anatomical Diagnosis: Confluent lobular pneumonia. Serofibrinous pleuritis. Atelectasis of lung. Pericardial ecchymoses.

Left pleural cavity.—Obliterated anteriorly by fresh fibrinous adhesions, but in the posterior part it contains 1,200 cc. of turbid greenish fluid with shreds of fibrin. The pleural surfaces are covered with a thick shaggy exudate of fibrin. *Right pleural cavity.*—Contains no excess of fluid, but the surfaces have lost their gloss and are roughened by a very thin exudate of fibrin in patches. *Left lung* (*Fig. 41*).—There is a thick pleural exudate of fibrin, the underlying pleura being slightly thickened. The lung is flabby and airless except in the anterior margin of the lobes, but on artificial insufflation only the superficial portion of the lower lobe remains collapsed. There are some patches of spongy grey tissue alternating with the generally red lung substance. No areas of actual consolidation are visible. The bronchi seem relatively little changed, but

many of the blood vessels are sheathed in thick yellowish white mantles which shine through the overlying tissue and appear to be due to an infiltration of their adventitia or the distension of the lymphatics in their walls. Bronchial glands are slightly enlarged. *Right lung.*—Very voluminous and mottled with alternating emphysematous and collapsed areas. In the upper lobe there is an area of homogeneous consolidation with alveoli filled with exudate. In the more posterior part of this lobe there are several small grey foci about 1 mm. in diameter which project slightly. So too in the middle lobe there are several areas of consolidation involving two or three lobules. Elsewhere and throughout the lower lobe there is no consolidation. *Pericardium.*—There are many minute hemorrhages in the epicardium and in the parietal pericardium. The pericardial sac contains about 50 cc. of fluid which is not turbid but contains floating shreds of fibrin. Pericardial surfaces are glistening.

Microscopic Examination.—Section through the right lung including the pleura and the margin of one of the sharply outlined areas of consolidation shows that the pleura is covered with fibrin which is thickly sprinkled with streptococci. The interlobular septa are very wide and edematous and enclose a network of fibrin, but this is especially true of the deeper portions and the adventitia of the larger vessels. The bronchi are distinctly but slightly thickened and infiltrated with mononuclear cells. They contain polymorphonuclear leucocytes. The alveolar walls are not thickened or infiltrated. In some areas the alveoli contain coagulated fluid with desquamated epithelial cells. In other rather sharply outlined patches they contain packed leucocytes. All these alveoli are found to contain great numbers of streptococci in pairs or short twisted chains. No other bacteria are found. There is practically no fibrin. The streptococci are very numerous in the substance of the pleura and in the lymphatics there, and can be traced through to the fibrinous exudate.

The uniform consolidation of certain whole lobules is much like that in lobar pneumonia. Polymorphonuclear leucocytes are densely crowded in the alveoli, but there is little fibrin and few red corpuscles. The alveolar capillaries have a hyaline appearance as though the corpuscles had fused.

Sections of the left lung show the very thick layer of granulation tissue covered by a thick layer of fibrin which represents the lining of the empyema cavity. From this, greatly widened interlobular septa run into the lung and in them or nearby there are enormous lymphatics distended with a disintegrated fibrinopurulent material loaded with streptococci.

The bronchial walls are not really much altered in this lung. Some of them are slightly thickened and contain leucocytes and debris. There is a little infiltration of the alveolar walls about blood vessels and bronchi and there are areas of collapse with hemorrhage and desquamation of epithelium. But the most striking feature is the colossal distension of the lymphatics and it is around them that the infiltration and thickening of the alveolar walls are greatest.

Cultures from the lung showed *Streptococcus hæmolyticus* in both cases.

Case 55.—O. F. D., age 22 yrs. Had measles at age of 7. On Dec. 27, 1917, developed measles and was in the hospital for 2 weeks. Went on duty Jan. 9, 1918, but was very weak. On Jan. 11 was brought to the hospital again with a stitch in his left side and dyspnea. After 9 days was able to walk about, but on Feb. 8 had a chill with severe pain in his left side, vomiting, and cough. Dulness over entire left side with flatness behind and below the middle of the scapula. Tubular breathing at the left apex becoming distant and suppressed at the base. Jaundice and cyanosis. Aspiration of thorax on Feb. 15, but no fluid was obtained. Flatness over whole left side with distant tubular breathing. On right side resonance somewhat impaired behind but good anteriorly; breath sounds bronchovesicular with few râles. On Feb. 16, 640 cc. of slightly turbid straw-colored fluid were withdrawn from the left chest and the patient was sent for operation which was performed on Feb. 18 with resection of a rib. Temperature became normal and drainage was good, but from about Feb. 26 to Mar. 7 when the patient died the drainage had decreased, there were signs of septic poisoning, and the temperature was irregular. Cultures from the circulating blood on Feb. 11 and 15 were negative. The sputum contained *Streptococcus hæmolyticus* and *B. influenzæ*. Fluid aspirated from the chest on Feb. 11 and 16 showed *Streptococcus hæmolyticus* alone. Autopsy Mar. 7, 1918.

Anatomical Diagnosis: Clinical history of measles. Lobular pneumonia with multiple abscess formation. Empyema (left). Seropurulent pleuritis (right). Infected infarcts of spleen.

Left pleural cavity.—In the line of the scapula on the left side there is a wound 12 cm. long running obliquely along the course of the rib from which a portion has been removed. The cavity is obliterated along the anterior margin of the lung and over its lower portion by old adhesions. The upper part of the pleural cavity is lined by thick yellowish fibrinopurulent exudate. Practically all the fluid exudate has escaped, but there is a pocket containing about 100 cc. of thick greenish pus between the diaphragm, the lower mesial surface of the lung, and the pericardium. This communicates with a space between the two lobes. *Right pleural cavity.*—Contains about 5 cc. of creamy purulent fluid which is spread over the back of the lung and to a less extent anteriorly where the pleura is still shining. The costal and diaphragmatic pleuræ are injected and have lost their gloss in the posterior part of the thorax. *Left lung (Fig. 42).*—The upper lobe is firm except in its anterior lower part which is collapsed. On section it is found that the whole posterior part from the apex down is dense, greyish yellow and moist, but rather thickly studded with patches of opaque pale greenish yellow. At the apex there is one such mass about 2 cm. in diameter and in the lower part there is a great group of them reaching up to the pleura and only partly separated from each other. These patches have softened and partly liquefied foul smelling central portions and hemorrhagic margins. The more anterior part of the lobe shows thickened interlobular septa and numerous smaller nodular consolidations. The lower lobe is

more flabby and of darker reddish grey color. The interlobular septa are also rather conspicuous and in the lobules there are to be found numerous projecting nodules. There are also several large yellow abscess-like masses. The bronchial glands are large, soft, and grey. *Right lung.*—The lung is very voluminous (Fig. 43) and the upper lobe easily inflated with air. On section the upper and middle lobes and the anterior portion of the lower lobe are air-containing. The posterior portion of the lower lobe is dark purplish, airless, and fairly firm. There project from its surface a number of opaque firm yellow areas some of which are 3 cm. in diameter. They are partly hidden by the reddened pleura, but in places show through as opaque yellow patches. A similar mass projects from the posterior part of the middle lobe. On section the lower lobe is collapsed and studded throughout, even in the air-containing part, with yellow opaque nodules, the smaller of which seem to have a central lumen. The large ones are quite like those in the upper lobe. *Spleen.*—Measures 19 by 11 by 5.5 cm. It is quite firm, especially in certain greyish projecting portions which are irregular in outline and surrounded by a red border. On section much of the spleen is greyish in color with distinctly visible trabeculæ and Malpighian bodies. The splenic pulp is swollen, shining, and velvety. In contrast to this there are irregular patches with ragged outline extending deep into the substance of the organ and bordered by a broad margin of hemorrhage. These patches are dry and opaque with a dull greyish red color.

Cultures from the heart's blood showed *Streptococcus hæmolyticus*, and similar Gram-positive cocci were found in abundance in films from the spleen and pericardial and pleural fluids, but all autopsy material was grossly contaminated with a Gram-negative spreading bacillus with putrefactive odor.

Microscopic Examination.—The greatly thickened pleura over the left lung is dense and fibrous and covered with fibrin. The interlobular septa are not especially conspicuous on section. The bronchi although filled with purulent exudate are scarcely thickened or infiltrated. The exudate contains streptococci and Gram-negative bacilli which appear to be influenza bacilli. The alveolar walls are nowhere especially thickened nor do they show any extensive desquamation of epithelium. The alveoli are filled with fluid and leucocytes. There are certain areas in each section which show the especial filling of the alveoli with leucocytes and in these there are whole patches of the central alveoli in which walls and exudate are completely necrotic. In these alveoli streptococci are extraordinarily abundant. They are present in short chains, in tangled masses, or engulfed singly by leucocytes.

Throughout both lungs the changes appear to be the same. They are definitely areas of lobular pneumonia with large numbers of streptococci causing necrosis and liquefaction, and surrounded by an edematous lung tissue in which the changes characteristic of the interstitial bronchopneumonia do not appear. But there are some areas especially near the thickened pleura where the interlobular septa are wider and infiltrated, and the bronchi and blood vessels and

even the alveolar walls share in this infiltration. The alveoli in these areas are mostly collapsed, but some are distended with leucocytes and great quantities of streptococci. Most striking is the fact that the lymphatics are enormously distended in many places and filled with a disintegrated mass of cells and bacteria. It is evidently from these that some of the large necroses begin, although in the collapsed lung around them there are numerous foci in which whole colonies of bacteria are surrounded by necrotic tissue.

The spleen shows irregular areas of necrosis edged with hemorrhage and studded throughout with veritable colonies of streptococci. The artery supplying one such area is plugged with a softened thrombus which contains the same great masses of organisms. The other organs show no such gross evidence of infection, although there is cloudy swelling of the liver and kidneys.

Case 56.—F. E., age 40 yrs. Had scarlet fever and measles in early life. For 6 weeks before entrance to hospital had pain in right side whenever he caught cold. On Feb. 7, 1918, had a chill, pain in side, and a temperature of 102° F. Entered the hospital Feb. 8, 1918. There was found dulness over the right lower lobe with distant bronchial breathing. Breathing over left side accentuated. Tenderness over abdomen with rigidity of muscles. Temperature 98° F. Leucocytes 24,400. On Feb. 26 the right chest was aspirated and the pleural fluid contained *Streptococcus hæmolyticus*. Temperature from 100–103° F. for the first 10 days. On Feb. 19 it fell abruptly to normal and later fluctuated from 98 to 101° until Feb. 26. Respiration 40, pulse 100–128. On Feb. 26 the 7th rib was resected under local anesthesia and the right pleural cavity drained. Died Mar. 7, 1918. Autopsy Mar. 8, 1918, 10 a.m.

Anatomical Diagnosis: Confluent lobular pneumonia with empyema and extension through diaphragm. Pericarditis with effusion. Axillary cellulitis.

Left pleural cavity.—Free from adhesions. Contains a small amount of fluid, but the surfaces are smooth and glistening although slightly hyperemic posteriorly. *Right pleural cavity.*—Partly obliterated by very dense fibrous adhesions which enclose a pocket filled with greenish yellow purulent fluid. There is an incision over the 8th rib in the right lateral scapular line which allows the escape of pleural fluid through a rubber drainage tube. The tissue about this wound is very edematous and the margins are necrotic. *Pericardium.*—Contains 100 cc. of yellow purulent fluid with floating shreds of fibrin. The surfaces are covered with a thick fibrinopurulent exudate. Endocardium normal. *Left lung.*—Surface is smooth and lung is normally air-containing throughout. *Right lung.*—The pleura is 3 mm. thick and very dense. It is covered with a layer of fibrin in places. The upper lobe is air-containing. The lower lobe is dense and uniformly grey and consolidated with a few scattered flecks of more hemorrhagic appearance. There is no thickening of the septa or walls of the bronchi.

Microscopic Examination.—The left lung is normal. The right is in part edematous with a scattered exudate of polymorphonuclears. The lower lobe, however, shows a compact exudate of these leucocytes filling the alveoli. Septa,

bronchial walls, and alveolar walls are delicate and not infiltrated with mononuclear cells.

No cultures were recorded.

The right lung at its base is adherent to the diaphragm and between them there is a collection of fibrinopurulent exudate. This is seen to extend through the diaphragm so that the dome of the liver is also covered with a localized fibrinopurulent exudate.

Case 187.—E. S., age 23 yrs. Had German measles on May 2, 1918. On May 6 moist râles throughout both chests, with bronchial breathing in right upper lobe. On May 12 dulness over left upper lobe with fine crepitant râles and high pitched expiration. Friction rub in right axilla. Bronchopneumonia of both lungs on May 8. Sputum on May 8 was purulent, homogeneous, slightly blood-tinged, with a few Gram-positive diplococci. Cultures show predominant staphylococcus, few colonies of hemolytic streptococcus. Blood culture was negative May 7, 1918. Died May 13, 1918, at 8.40 p.m. Autopsy May 14, 1918, 14 hours after death.

Anatomical Diagnosis: Confluent lobular pneumonia (both upper lobes). Disseminated lobular pneumonia with slight interstitial changes. Rupture of rectus abdominis muscle.

The sheath of the rectus abdominis muscle bulges into the peritoneal cavity on each side at a point just below the umbilicus. On incision it is found that the muscles are torn across and that the ends are retracted leaving a space filled with blood clot and bloody fluid. This rupture is symmetrically placed on the two sides. The ruptured muscle is contracted into a thick belly on each side and there are opaque greyish yellow discolorations seen in the substance of the broken ends. The peritoneal cavity contains no excess of fluid and the surfaces are smooth and glistening. *Left pleural cavity.*—The cavity is partly obliterated above by old fibrous adhesions and there are similar adhesions between the base of the lung and the diaphragm. The free portion of the pleural cavity contains about 20 cc. of clear fluid and the surfaces are smooth. *Right pleural cavity.*—Contains very little fluid. The surfaces are smooth except over the upper lobe where there is a thin fibrinous exudate. *Left lung (Fig. 44).*—The lung is voluminous and in part covered with shreds of old adhesions. The upper lobe is air-containing anteriorly, but firm posteriorly. On section there is found a large area of complete consolidation which is pinkish grey in color and fairly smooth although plugs of exudate can be seen projecting from the alveoli. The bronchi in this area are wide with a dull grey lining, and contain a grey purulent exudate. Scattered through the area of consolidation there are irregular patches which are still more prominent and of a lighter yellowish color and more opaque than the rest. These are softened and even partly liquefied in places. In the anterior air-containing portion there are some nodular consolidations about the branches of the bronchi. The lower lobe is in general air-containing but is rather firm posteriorly. Throughout it there are scattered

small peribronchial consolidations such as are seen in the anterior part of the upper lobe. These are more numerous and larger in the posterior part of the lobe. They are not accompanied by any marked hemorrhage. The bronchial glands are much enlarged and are dark greyish red. *Right lung.*—The lung is large and in general seems to be air-containing. It is found, however, that there is in the posterior middle portion of the upper lobe an area of consolidation about 4 cm. in diameter which on section is greyish pink and smooth. Part of the area is yellowish and opaque and appears to be beginning to soften. The anterior part of the lobe is air-containing. The middle lobe is air-containing except for some of the bronchioles which are thickened and filled with exudate and in places surrounded by nodular areas of consolidation. In the lower lobe of this lung there are many bronchioles whose lining epithelium is entirely lost and the surface of the exposed tissue necrotic. These bronchi have greatly thickened walls with extreme hyperemia and infiltration with mononuclear cells. The adjacent alveoli are generally collapsed, their walls infiltrated with mononuclear cells, and their cavities with blood, fluid, and epithelial cells. *Pharynx and larynx.*—The tonsils are not enlarged. The pharynx is rather pale. The larynx is only slightly reddened and there are no ulcers on the vocal cords or epiglottis. The trachea is slightly reddened. The cervical lymph glands are edematous and greyish red.

Cultures at autopsy showed *Streptococcus hæmolyticus* in the heart's blood, right and left lungs, and in the bloody fluid between the torn ends of the rectus abdominis muscles. Smears from these localities showed these organisms alone.

Microscopic Examination.—The lung shows remarkable changes. The pleura is perhaps somewhat thickened over the left lung, but there is no exudate or granulation tissue formation. The interlobular septa are wide and edematous, and contain wide lymphatics which are not thrombosed or at most contain a strand of fibrin. They contain abundant streptococci. The area of consolidation in the upper lobe shows no bronchi conspicuous for their thickening, although there is a definite mononuclear infiltration of the walls in some cases. The alveolar walls are not infiltrated or thickened. The alveoli are densely packed with polymorphonuclear leucocytes with little fibrin and scarcely any blood (Fig. 45). These leucocytes are fairly loaded with micrococci and there are great quantities of these organisms free between them. It appears as though the leucocytes were inadequate to engulf all of them.

The alveolar walls are noticeably pale and flattened or thinned out in places. With Weigert's fibrin stain it suddenly becomes evident that the capillaries in many of the alveolar walls are completely obstructed by fibrinous coagula which are not quite homogeneous but fill the whole network of capillaries, at times in such a way as to demonstrate this network as though by a purple injection mass (Fig. 46). Evidently the obstruction to circulation is great and such areas are widely necrotic, there being no nuclei of the alveolar wall left intact enough to stain. Doubtless these are the opaque yellowish patches observed in

the consolidated area in the gross inspection. This consolidation is very dense and extends over a large area in the manner of a lobar or confluent lobular pneumonia.

In the portion of the lung which is not the seat of a uniform consolidation the bronchi are more definitely thickened by the great hyperemia and new tissue formation which is so often seen. But there is no characteristic surrounding zone of thickening of the alveolar walls with desquamation of the epithelial cells, hemorrhagic organization of the exudate, etc. Instead there are minute patches of lobular consolidation in every respect resembling the large patch in the upper lobe. In the outlying area where there is a great deal of edema this fluid is loaded with bacteria. In places it contains numerous vacuoles which vary greatly in size but are peculiarly surrounded by bacteria which appear to float on the surface of the vacuole. These cavities may be air bubbles from the mixing movement of the fluid and the bacteria may swim on their surface in order to be in contact with air, or else their position may be merely an effect of the surface tension of the fluid. The same phenomenon was observed with pneumococci in Case 31.

There is, therefore, an extraordinarily intense infection with *Streptococcus hæmolyticus* which produces a confluent lobular pneumonia resembling a lobar pneumonia in places, with only traces of its usual interstitial action. The right lung is similar. Careful search failed to reveal any influenza bacilli.

Microscopically the rectus muscle shows extensive reduction of muscle fibers to hyaline formless clumps. Where the rupture has occurred there is, of course, much hemorrhage and the separation of fragments of completely necrotic muscle tissue which had already shown the hyaline change in the substance of each fiber. Streptococci are present in quantities in the necrotic ends. The hyaline clumps are found within the sarcolemma sheaths quite far back. They are invaded by wandering phagocytic mononuclear cells which can be distinguished from the shoals of sarcolemma nuclei by their more chromatin-rich nucleus. The sarcolemma nuclei are pale with one deeply stained nucleolus.

Case 192.—J. R. B., age 23 yrs. No history of measles or other predisposing disease. Began suddenly on May 5, 1918, with a chill and pain in the chest. The diagnosis of lobar pneumonia involving the left lower lobe was made on May 11. Blood culture on May 14 was negative, but the sputum contained *Staphylococcus aureus* and influenza bacilli. Died May 14, 1918. Autopsy May 15, 1918, 15 hours after death.

Anatomical Diagnosis: Hemorrhagic bronchopneumonia (bilateral). Ulcerative laryngitis.

Left pleural cavity.—Contains only about 5 cc. of clear fluid. The pleural surfaces are smooth but flecked with hemorrhage posteriorly. *Right pleural cavity.*—The cavity contains a little clear fluid. There are a few easily torn adhesions over the apex of the lung. The pleural surfaces are smooth but the lower lobe of the lung is deep blue and covered with areas of hemorrhage.

Left lung (*Fig. 47*).—The upper lobe is found to be air-containing throughout, with the exception of very minute foci about the terminal bronchioles which stand out as greyish opaque points. The lower lobe receives a little air in the anterior part. The remainder is deep red and rather nodular looking although the nodules do not stand out very distinctly. They appear rather as greyish centers of reddened hemorrhagic areas. *Right lung* (*Fig. 48*).—The lung is much more voluminous than the left. The upper lobe is firm in its apical portion but otherwise air-containing. The firmness is due to the presence of scarred and pigmented areas at the apex and a little lower on the posterior side. In the lower portion of the lobe posteriorly there are several branching nodular consolidations which surround the ends of the bronchi. The middle and lower lobes contain a little air anteriorly but are consolidated posteriorly, the consolidation being produced by greyish nodules surrounded by deep red confluent hemorrhages. The bronchial lymph nodes are large and greyish red. *Pharynx and larynx.*—The pharynx and base of the tongue are deeply reddened and the lateral walls of the pharynx are covered with an opaque yellow mucoid layer. There is similar congestion of the larynx and trachea, but this does not extend into the esophagus. There are slight erosions of the edges of the epiglottis and a shallow ulceration in the wall of the larynx at the attachment of the vocal cords, but the cords themselves are not ulcerated.

Cultures at autopsy gave *Streptococcus hæmolyticus* from the heart's blood and lungs.

Microscopic Examination.—The lungs show a fairly uniform process on both sides which is different from any previously described.

The pleura is densely infiltrated with blood. All crevices and the lymphatics are distended with blood. The interlobular septa are not conspicuous, and where they are found they are in places edematous and infiltrated with mononuclear cells and blood. The lymphatics are not prominent but often contain blood and leucocytes. The bronchi are filled with polymorphonuclear leucocytes and blood cells. Their walls have usually lost their epithelium and are very hyperemic and edematous but not really thickened or infiltrated with cells. The adjacent alveoli are usually filled with leucocytes. Their walls are not thickened although in places there are leucocytes in their substance. Further from the bronchi the alveoli contain fewer leucocytes and are more and more filled with blood. Indeed, except for the peribronchial filling of the alveoli with leucocytes the whole lung is nearly solidly filled with red corpuscles with which a few desquamated epithelial cells and leucocytes are mingled. The whole area is one vast hemorrhage. As a rule, few or no bacteria can be found but there are some patches in which streptococci are present in great numbers, sometimes scattered in single chains, sometimes in dense clumps or tangles of chains. Since influenza bacilli were found in the sputum and since the lesion in this lung is so totally unlike that seen in other cases of streptococcus pneumonia the idea suggests itself that it may be due to the influenza bacillus, and search in sections properly stained shows the presence of enormous numbers of minute Gram-

negative organisms which may be influenza bacilli, although they often occur in short chains.

Section of the rectus abdominis (Fig. 49) shows the most extensive hyaline degeneration of the muscle fibers which are reduced to formless clumps of red-staining material still enclosed in the sarcolemma sheath. There are still some intact fibers among the altered ones. The nuclei of the sarcolemma sheaths show no alteration and there is no inflammatory reaction.

Case 195.—G. M., age 23 yrs. Negro. Began with measles on May 3, 1918, and developed pneumonia which was thought to be a lobar consolidation of the right lower lobe on May 10, 1918. Died May 16. Autopsy May 17, 1918, 11 hours after death.

Anatomical Diagnosis: Clinical history of measles. Disseminated lobular pneumonia. Empyema (left).

Left pleural cavity.—Contains 450 cc. of yellowish fluid with flakes of fibrin. The surfaces are covered with a yellowish fibrinous exudate but there are no adhesions. *Right pleural cavity.*—Contains about 50 cc. of a slightly cloudy fluid. There are on the pleural surface numerous small discrete roughened brownish patches. *Left lung.*—The upper lobe is air-containing throughout. In the lower lobe there are numerous nodular masses of consolidated tissue which measure 2 by 6 mm. in diameter and surround the bronchioles. These become more numerous in the posterior part of the lobe and are often confluent. *Right lung.*—There are nodular consolidations scattered throughout all the lobes, becoming more numerous and close set as one passes towards the posterior part of the lung. In the upper lobe they are fairly discrete but occupy a large proportion of the lung substance posteriorly. In the middle lobe there is also a larger area of consolidation, a patch 2 cm. in diameter which is firm and grey at the periphery but rather more rose-colored in the center. In the lower lobe the nodules are very numerous especially in the posterior part. The mucosa of the bronchi and trachea is hemorrhagic and deep red.

No cultures were made at autopsy.

Microscopic Examination.—The pleura is found to be hyperemic and slightly thickened but still covered by its lining layer of cells. There is a thick layer of fibrin overlying it but there is no sign of organization. The interlobular septa are everywhere wide and edematous. The lymphatics are also wide, and while some of them may be traced along in the septa filled with fluid only, most of them are distended with a compact mass of disintegrated leucocytes, blood, and fibrin with bacteria. Everywhere in the walls of bronchi and blood vessels, in the interlobular septa, and in the pleura the lymphatics are very wide and conspicuous.

The lung in general is edematous, the alveoli are filled with what appears to be a rather viscid fluid. There are focal areas of consolidation which were recognized in the gross and can be seen as such by the unaided eye in the stained section. It is difficult to outline these as they shade off into the adjacent tissue in which there is only edema with desquamated epithelial cells. But it is clear that

there are numerous patches of completely consolidated lung tissue in which every alveolus is filled with polymorphonuclear leucocytes. In and especially about these there is much hemorrhage and then further out the alveoli are found to contain only fibrin with fluid and mononuclear cells which are probably desquamated epithelium. The bronchi are not at all conspicuous. They contain leucocytes and bacteria. The walls are hyperemic but not infiltrated with cells, nor are the alveolar walls thickened or infiltrated at any point. The most prominent feature in these areas is constituted by the great thrombosed lymphatics. In places and perhaps especially in these lymphatics the leucocytes are necrotic and disintegrated. In the middle lobe of the right lung the area of uniform infiltration with polymorphonuclears is much greater. There are hyaline thrombi in the capillaries of the alveolar wall and much necrosis of the exudate and of the walls. The bronchi are but little altered. The consolidation even here is patchy with alternation in the types of exudate.

In these cases the pleural effusion is quite like that in the preceding groups and it is somewhat surprising to find that a man may survive for 55 days with this lesion extensively developed in association with an old empyema. The gross appearance of the lungs is usually different from that found in interstitial bronchopneumonia, since these areas of consolidation are no longer nodular, hard, and prominent, nor especially situated about the branches of the bronchi. Instead, they are very rough, grey, and slightly elevated, often confluent in quite large patches where they resemble closely in their texture the consolidation of pneumococcal lobar pneumonia. But in many cases they are intensely hemorrhagic and in the central parts dull and opaque. As an example of the first type Case 187 may serve, in which a large area of homogeneous consolidation with granular exudate projecting from the alveoli occupies part of the upper lobe, while smaller areas of the same sort are scattered through the lower lobe. In Cases 20 and 192 the areas of consolidation are large and hemorrhagic.

In all these the participation of the lymphatics is extremely striking. Great beaded canals distended with opaque yellow pus so as to become very conspicuous accompany the blood vessels and bronchi or run in the line of the interlobular septa to the pleural surface. These stand out especially in Cases 20 and 26 and can be readily traced to their connection with the network in the pleura which is similarly prominent and distended with pus.

In Case 55 extensive areas of necrosis occur in which the lung substance is converted into a soft yellow opaque material. These areas look like abscesses as they project under the pleura and possibly they should be so called, but they are really pretty firm opaque necrotic patches of consolidated lung swarming with streptococci but still composed of coagulated tissue and not of pus. There is no real distinction except perhaps in the lack of an intense leucocytic invasion to reduce this necrotic material quickly to a liquid state. In other cases it has been seen that such areas may be discharged through a bronchus the walls of which are interrupted on entrance into the necrotic patch. This leaves a cavity which may or may not communicate with the pleural cavity. In none of our cases had this actually occurred, but it seems that this is the explanation of the formation of the pleurobronchial fistulæ which are encountered by many surgeons in treating the late empyema cases.

Microscopically the lesions just mentioned are the outcome of the filling of alveoli with streptococci and an exudate of leucocytes and fibrin. The streptococci are extremely abundant throughout this exudate. In Case 187 in which the consolidation is almost lobar in appearance the capillaries of the alveolar walls are widely thrombosed with hyaline strands of fibrin which completely occlude them. The exudate and even the tissue of the lung becomes necrotic under these conditions.

In the more hemorrhagic consolidation such as is seen in Case 20, great stretches of lung substance simply become necrotic and filled with blood without any adequate infiltration of leucocytes. In such places the streptococci in long chains form a tangled matted growth as though they were growing in the most favorable culture medium. In the outlying parts of the lung about these places there are alveoli filled with leucocytes and fibrin but the destructive process seems to have been too intense and rapid to allow the institution of a proper reaction. The lymphatics distended with leucocytes, fibrin, and myriads of streptococci form enormous objects in the microscopic field.

The lesion then in all these cases is produced by the streptococcus; it is the simplest inflammatory reaction to the invasion of great numbers of streptococci and often even this reaction fails, so that with

great extravasation of blood the whole invaded area becomes necrotic and a good soil for unlimited multiplication of the organisms. It represents the most passive attitude of the body in which resistance is at its lowest.

The Changes in Other Parts of the Respiratory Tract in Streptococcal Pneumonia.

No distinction is practicable between the groups of cases just considered in so far as the lesions of the rest of the respiratory tract are concerned. The changes in the lung proper have been described and the forms of pleurisy will be analyzed later. There remain the bronchial glands, the larger bronchi and trachea, the larynx, and the upper air passages.

The bronchial lymph glands are always somewhat enlarged although not so greatly as in some other affections of the lungs. They are soft, edematous, and greyish red except when deeply pigmented. I have encountered no abscesses in these glands. The cervical and peritracheal glands are often similarly affected. Microscopically they show in each case a considerable increase in the cells of the lymph cords and islands, but it is in the sinuses that the change is most marked. These are very wide and are packed with cells, chiefly large and small mononuclear wandering cells which have probably been swept into these sinuses from the lymphatics of the lungs since they are of the type seen there. They are to some extent phagocytic, loading themselves with the debris of other cells. There is no evidence that they are derived from the endothelium of the sinuses which is intact. Among these there are quantities of streptococci often single or in pairs, often in tangled masses.

The large bronchi and trachea are deeply reddened, covered with purulent exudate, and occasionally with a pseudomembrane which is generally limited to the bronchi. Streptococci are found abundantly strewn along the surface of the mucosa.

In the acuter cases and especially in those in which the disease is associated with measles there is aphonia with corresponding changes in the larynx. These changes, which are found in Cases 165, 178, 184, 192, 194, 180, and others, consist in an intense reddening of

the mucosa often with some edema. Most striking, however, is the ulceration which commonly affects the vocal cords and causes a deep loss of substance along their whole edges. Microscopically it is found that the epithelium and underlying elastic tissue is necrotic or has been swept away completely leaving the base of the ulcer thickly strewn with streptococci. Streptococci are found in crevices of the neighboring tissue and in folds of the mucosa nearby. Similar ulcerations occur on the epiglottis, on the arytenoepiglottic folds, in the pyriform sinuses, and elsewhere, in the walls of the pharynx and larynx. In Case 165 there was a marked swelling of the arytenoepiglottic folds and of the epiglottis with only a shallow superficial ulceration, but all the swollen tissue was packed with streptococci and a diffuse inflammatory exudate. Most of the other cases, however, showed no especial alteration in the larynx. The walls of the pharynx are generally deeply congested and in a few instances there was a superficial ulceration of the uvula and of the pillars of the fauces. The tonsils are not much enlarged or altered in appearance, and although streptococci can be found in clumps in the depths of the crypts there is no especial reaction of an inflammatory character about them. We were, of course, concerned with the idea that the tonsils might harbor the streptococci and in this way play an important part in the development of the disease, but it is not even certain that the clumps of streptococci which often have a radial marginal arrangement are of the same character as those which produce the pneumonia. At any rate the impression received was that the tonsils are passive in this process. The hemolytic streptococcus from outside seems to sweep past them through the pharynx, the larynx, and trachea into the bronchi. At most they fail in their function as guards, and this may be said too of the lingual and other adenoid tissue which becomes slightly swollen.

The condition of infection of the accessory sinuses which communicate with the nasal cavity and of the nasal mucosa itself is unknown to me as there was no opportunity to investigate them. It seems, however, that they may be the first to become infected and they should be studied. It is evident that inflammation follows the extension of infection up the Eustachian tube to the middle ear, for otitis media is by no means uncommon as a complication (Cases 205, 21, 181).

Lesions in Other Organs.

The channel of infection of the pericardium is not clearly decided. It seems probable that infection must take place by extension from the pleura although this is difficult to demonstrate, and it is puzzling to find so many cases of intense pleural infection without pericarditis.

In the whole series of 60 cases there were ten in which there was a definite pericarditis. Of these, two, Nos. 19 and 186, were associated with lobar pneumonia caused by the pneumococcus; two others, Nos. 36 and 46, occurred in cases in which the pneumococcus and streptococcus were both present, and the remaining six were in cases of streptococcus infection, although three of these at least, Cases 56, 57, and 176, were associated with very old empyema in which the bacterial flora was no longer uncontaminated. There are no sharply distinctive features in the streptococcus pericarditis, although there seems to be a tendency to great thickening of the pericardial tissues and the formation of obliterating adhesions. In one, Case 203, the pericardial sac was enormously enlarged and thickened and contained at autopsy 1,000 cc. of thick pus, although it had been aspirated by the surgeon some days before. The others presented a thick turbid purulent fluid with shaggy fibrinous exudate on the pericardial surfaces. There were several other cases in which minute hemorrhages and a slightly cloudy and somewhat increased fluid attracted attention to the pericardium, but in these the pericardial surfaces were still glossy.

Endocarditis was present in one case, No. 45, of lobar pneumonia, and the pneumococcus was isolated from the vegetations. One case, No. 24, showed a lobular pneumonia with some of the features of an interstitial bronchopneumonia in which there was acute endocarditis, but the body was partly decomposed, and although streptococci were present in smears the exact nature of the case is not clear. In none of the more definite instances of streptococcal pneumonia was there endocarditis.

The spleen in the cases of streptococcal pneumonia was sometimes slightly enlarged and occasionally rather soft. On the whole, however, it showed no definite change from normal, and microscopic examination failed to reveal any marked alteration of any part of its

structure. In one case only, No. 55, which was a case of lobular pneumonia with large areas of necrosis or abscess formation and an empyema of 55 days standing, were there infarct-like infected areas scattered through the substance. These on microscopic examination showed the presence of whole colonies of streptococci and Gram-negative bacilli lying in the middle of necrotic and disintegrated areas.

The liver in most instances showed a moderate cloudy swelling, but otherwise no departure from the normal. In one case only, No. 16, were there fresh midzonal necroses throughout the organ.

In general the kidneys were normal in appearance except for a slight cloudiness of the cortex which appeared in microscopic section as a slight swelling of the epithelial cells of the convoluted tubules. But in four cases, Nos. 35, 36, 171, and 188, there was an acute nephritis with petechial hemorrhages and swelling and some opacity of the cortex. Microscopically these cases showed glomerular lesions characterized by hyaline thrombosis of the capillaries with hemorrhage and exudation of leucocytes into the Bowman's capsules and tubules and the accumulation of leucocytes and wandering cells in the interstices of the tissue. Epithelial degeneration was present in only moderate degree. But of these four cases two, Nos. 36 and 188, were essentially pneumococcus infections and were really cases of lobar pneumonia. Acute nephritis therefore occurred in only two of the cases of streptococcal infection and cannot be regarded as a characteristic accompaniment of this infection but rather as an accidental occurrence.

The peritoneal cavity was infected, however, in several cases, so that acute peritonitis seemed to be a not infrequent accompaniment of the streptococcal pneumonia.

In this series five cases in all showed an acute peritonitis and of these one, No. 51, was a case of pneumococcal pneumonia with pneumococci in the peritoneal exudate. In the others, Nos. 35, 165, 176, and 194, the peritoneal exudate contained the streptococci. They were all rather old cases of streptococcal pneumonia with empyema. No origin could be found for the peritoneal infection in the abdominal organs, and it may be that extension of the infection occurred through the lymphatics of the diaphragm. Indeed it seemed possible to trace this directly in Case 194.

In Case 56 there was a gross extension of the infection through the diaphragm so that an abscess-like accumulation of pus on the pleural surface communicated freely with a similar enclosed pocket on the upper surface of the liver.

The testes show in nearly all these cases an extraordinary change which is especially striking in the streptococcal infections, although occurring sometimes in the pneumococcal infection and failing to appear in some of the streptococcal ones. It appears to consist in a cessation of spermatogenesis which has probably come about through a stoppage of mitosis at an early stage. In most of the cases of streptococcal infection spermatozoa are not to be found in the tubules of the testis, although a few may persist in the seminal vesicles embedded in the viscous fluid which is found there. Not only are the spermatozoa absent, but in many cases one looks in vain for spermatids or spermatocytes. The spermatogonia are always present, and the Sertoli cells become very conspicuous, but with only these types of cells left the tubule is reduced to an extremely simple structure.

The interstitial tissue is less altered although frequently greatly increased in bulk. Leydig's cells are generally unchanged. It is possible that older changes, such as the complete conversion of the tubules into hyaline strands, and even the great thickening of the interstitial tissue may be the remains of some earlier injury such as may have resulted from mumps. But the cessation of spermatogenesis is so constant that it must be ascribed to the present disease. Among the cases of pneumonia caused by the pneumococcus two or three showed normal tubules, but the rest exhibited various stages in the same process leading to the interruption of formation of spermatozoa.

This matter has been discussed by Cordes, who found this condition after many acute infections. Details of the present material need not be given here.

Bone marrow taken from the femur in a great number of these cases showed uniformly an increase in the cell content, depending especially upon an increase in the myelocytes. It was not different from that observed in many other acute infections accompanied by leucocytosis.

In Cases 187 and 205 there was found a symmetrical rupture of the two sides of the rectus abdominis in its lower third. The separation of these torn ends was accompanied by the production of a considerable hematoma such as is often seen in the same position in typhoid fever—the so called Zenker's degeneration of the muscle. Study of these and other rectus abdominis muscles shows that there is a most extensive hyaline degeneration of the fibers which are broken into irregular masses of glassy material with no trace of the former striations. These become surrounded by the concentrated nuclei of the sarcolemma sheath and new cellular connective tissue springs up between them. Before long such weakened muscles tear with coughing or some other strain and the hemorrhage occurs. In Case 187 the streptococcus was found in the bloody fluid, but in the other there were no bacteria. In Case 192 there was no such rupture, but although the rectus muscle looked normal it showed microscopically a very extensive degeneration of its fibers (Fig. 49). Muscle taken from the corresponding point in several other cases failed, however, to show any degeneration. It seems probable that this is not the direct effect of infection, but that it is caused by some toxic process after which bacteria may lodge on the necrotic material.

In another case, No. 45, in which the pneumococcus was found in the pneumonic lesion there were symmetrically placed abscesses in the same position occupying most of the substance of the lower third of the rectus abdominis on each side. In these the pneumococcus was found. Several other cases of this kind were observed at Fort Worth, Texas.

The lodgement of streptococci in other parts of the body, such as the bones, joints, and muscles, appears not to be very common.

In Case 176 in which there was an old empyema there was found an extensive abscess among the muscles of the neck reaching upward toward the left ear and downward past the dome of the pleura into the muscles between the scapula and the vertebral column. How the infection reached this region is not clear. The pleural cavity was not in communication with the abscess, and the shoulder joint was normal although surrounded. It seemed possible that it might have been due to extension from the pleura, but this was not proven. In no other case was there any such area of infection away from the res-

piratory organs themselves. Nevertheless I have heard from various surgeons of the occurrence of abscesses in the muscles and subcutaneous tissues in different localities. Although joint infections have been described we met with none in these cases.

The question of the existence of a streptococcal septicemia is much discussed and there are differences of opinion on the point. We have made in all about 100 blood cultures[5] from the circulating blood taken from the arm vein at various times before death with the usual technique of adding the blood to sterile broth, etc., but none of these cultures gave a positive result except when they were taken just before death. Even then there were very few positive results and the contrast between this organism and the pneumococcus is made more striking by the fact that in the cases in which lobar pneumonia is found combined with interstitial bronchopneumonia the pneumococcus has been isolated from the circulating blood, but not the streptococcus. Of course after death the heart's blood gives invariably a culture of the streptococcus. It seems that the conditions produced by the streptococcus are once more comparable with those produced by the tubercle bacillus, because in chronic phthisis we do not find the tubercle bacilli circulating in the blood as must be the case in generalized miliary tuberculosis; nevertheless scattered tubercles in all the organs attest the fact that at least a few tubercle bacilli are able to enter the blood stream. So with the hemolytic streptococcus. Its distribution is chiefly local in the respiratory tract, but enough streptococci may from time to time enter the blood stream to give rise to an occasional abscess.

4. Lobar Pneumonia.

Case 18.—J. P. W., age 30 yrs. Previous history negative. Developed cold and hoarseness Jan. 14, 1918. Entered hospital Jan. 26, with nausea and vomiting, chill, fever, and cough. Pain in back and right shoulder. Dulness, prolonged expiration, increased vocal fremitus, and crepitant râles over lower left back. Leucocytes 19,000. Temperature 104–101° F., pulse 100–150, respiration 26–50. Developed signs of consolidation at right base Feb. 1 and died Feb. 3. Autopsy Feb. 3.

[5] These cultures were made by the Commission in Texas, and at Camp Dodge by Captain Sellards and Lieutenant Toomey.

Anatomical Diagnosis: Lobar pneumonia (left lung) with fibrinous pleuritis.

Left pleural cavity.—Obliterated by fresh fibrinous adhesions anteriorly, but in the posterior part there are 200 cc. of turbid fluid. The lung is covered with an edematous layer of fibrin measuring 2 cm. in thickness in places. *Right pleural cavity.*—Contains no fluid, surfaces glistening. *Left lung.*—The upper lobe is air-containing anteriorly, but in its posterior portion is completely and uniformly consolidated. In the anterior portion there is also a patchy consolidation with a few masses of yellowish fibrinous material embedded in the substance of the lung. In other places the walls of the vessels and bronchi are edematous. In the lower lobe the consolidation is uniform and of a greyish red color. It is distinctly produced by the filling of the alveoli with exudate. *Right lung.*—With the exception of the posterior portions of the upper and lower lobes which are atelectatic and a small area of consolidation in the upper lobe, the lung is air-containing. The bronchi are normal in appearance.

Microscopic Examination.—The left lung shows a loose thick layer of fibrin upon its surface. The pleura itself is slightly thickened by hyperemia, edema, infiltration of leucocytes, and some new formation of connective tissue cells. The layer of cells lining the pleural cavity is still visible, however, and no organization of the overlying fibrin has occurred. Numerous pneumococci can be seen scattered through the layer of fibrin and usually enclosed in phagocytic leucocytes. The same condition is found in the interlobular space where the surfaces are bound together by fibrin, but there organization appears to have begun.

The bronchi contain an exudate of leucocytes and red corpuscles. The alveoli are uniformly filled with an exudate of red corpuscles, leucocytes, and fibrin. Pneumococci are seen scattered diffusely in the exudate, both in the bronchi and alveoli. It is clear that the fibrin is more conspicuous in the alveoli adjoining the interlobular septa, but organisms are not obviously more abundant in the more central parts adjacent to the bronchi. The alveolar walls are distinctly infiltrated with leucocytes and occasional mononuclear cells. So too are the bronchial walls and walls of blood vessels, as well as the interlobular septa. This is not enough to make them prominent, however, and in general all these structures are but slightly thickened. The lymphatics in the bronchial walls, adventitia of blood vessels, interlobular septa, and pleura are greatly distended with a network of fibrin entangling red corpuscles and leucocytes. In these pneumococci are found. Some of these lymphatics are enormous and readily visible to the naked eye as yellow beaded strands in the consolidated lung.

The bronchial lymph glands are extremely hyperemic and the afferent lymph sinuses are greatly distended with red corpuscles and large phagocytic mononuclear cells. Pneumococci are abundant there, but there are few in the remainder of the gland.

Cultures showed Pneumococcus Type IV from the heart's blood and both lungs.

Case 19.—B. N., age 27 yrs. Previous history negative. Taken sick suddenly Jan. 29, 1918, with vomiting and pain in the right hypochondrium. Entered hospital Jan. 30, and on Jan. 31 complained of acute pain in right chest. Dulness over upper lobe of right lung. Leucocytes 18,800. Temperature 101–103° F., falling to 99° before death. Pulse 90–130. Died Feb. 3. Autopsy Feb. 4.

Anatomical Diagnosis: Lobar pneumonia (right upper lobe) with fibrinopurulent pleurisy. Fibrinopurulent pericarditis with abundant effusion.

Left pleural cavity.—Contains a little brown fluid. Surfaces are covered over the lower lobe by a thin fibrinous exudate. The lung is adherent at the apex posteriorly. *Right pleural cavity.*—The anterior portion of the lung is glued to the parietal pleura and to the pericardial sac. Between the pericardium and the mesial surface of the lung there is an encapsulated cavity containing about 100 cc. of fibrinopurulent exudate. The posterior part of the pleural cavity is filled with similar exudate which bathes the lower lobe. Its surface is covered with a thick layer of fibrinous exudate. The upper lobe is adherent by fresh fibrinous adhesions to the costal pleura. *Left lung.*—Air-containing throughout. The bronchial glands are soft and pigmented but not enlarged. Bronchi are pale and contain sticky mucus. *Right lung.*—The upper lobe is uniformly consolidated, the cut surface showing a greyish red exudate which fills all the alveoli. The interlobular septa are prominent, the bronchi distended with opaque yellow exudate. The middle and lower lobes are almost entirely collapsed except in their anterior margins. There is no consolidation. *Pericardium.*—The pericardial sac contains 550 cc. of a thick greenish turbid fluid with floating shreds of fibrin. The surfaces are thickly covered with yellowish fibrinous exudate.

Microscopic Examination.—The consolidated part of the right lung shows a thin pleura with a covering of fibrin which is not organized; the lining cells of the pleura are still visible. The interlobular septa are widened and edematous, and a network of fibrin extends throughout their length. Numerous pneumococci are found scattered through the fibrinous exudate on the pleura and many are enclosed in phagocytes. The bronchi contain a purulent exudate. The walls are slightly thickened and infiltrated with mononuclear cells. The alveolar walls are in general thin but some are infiltrated with leucocytes, and in the neighborhood of the large vessels, broad interlobular septa, and pleura there is a thickening of the alveolar walls by mononuclear infiltration.

In the alveoli the exudate, composed of red corpuscles, leucocytes, and fibrin, is loaded with pneumococci which are uniformly scattered. Some of them are in phagocytes. Even the alveolar walls are occasionally invaded by them. The lymphatics are everywhere greatly distended with a clotted exudate of leucocytes and mononuclears together with large quantities of pneumococci.

There is a fresh pericarditis. The lining layer of cells is still complete and the fibrinous exudate is alternately compact and loose.

Cultures from the lung show Pneumococcus Type II.

Case 25.—F. G. W., age 24 yrs. Previous history negative. Measles and mumps at 6 years. On Jan. 30, 1918, had a chill followed by fever and pain in right side. Entered hospital Feb. 1, expectorating rusty sputum. Dulness and tubular breathing over both sides posteriorly. Extreme cyanosis. Leucocytes 19,800. Temperature 99–103° F., pulse 110–140, respiration 25–35. Died Feb. 6. On account of the coarse bubbling râles it was suggested that the pneumonia was in the stage of resolution. Cultures from sputum and circulating blood gave Pneumococcus Type II. Autopsy Feb. 6.

Anatomical Diagnosis: Lobar pneumonia (bilateral). Fibrinous pleuritis.

Left pleural cavity.—Contains no excess of fluid. There are old adhesions over the posterior portion of the lung. *Right pleural cavity.*—Surfaces are glued together by fibrin and there is no fluid. *Left lung.*—The upper lobe is soft and cushiony and, although much pigmented, is air-containing throughout except for small areas of consolidation in the lowermost portion. The lower lobe shows extensive though somewhat patchy consolidation in which the individual alveoli are seen to contain plugs of exudate. *Right lung.*—The anterior part of the upper lobe is air-containing. The posterior part of the upper lobe, the whole of the middle lobe, and all of the lower lobe except the lowermost margin are consolidated. This consolidated tissue on section is smooth and grey and uniform in appearance; the alveoli are not easily made out to contain individual plugs.

Microscopic Examination.—The right lung shows an intraalveolar consolidation which stops sharply at the limit of the lobe. The interlobar cleft is filled with fibrin entangling a few leucocytes. The pleural cells are well preserved and on the pleural surface covered with a thin layer of fibrin which is not organized. The bronchi show no modification of their walls except a subepithelial accumulation of polymorphonuclear leucocytes. The lumen of each bronchus is filled with leucocytes. The alveolar walls are distinctly thickened (Fig. 50) through the accumulation of polymorphonuclear leucocytes between the capillaries and within the substance of the alveolar wall in such a way as to lift up from the capillaries into rounded eminences what seems to be a very thin structureless membrane upon which the alveolar epithelium lies. The thickening is thus very uneven and the alveolar surface of one of the walls presents a series of mammillations. In general the epithelial cells are greatly swollen and most of them are desquamated. The alveoli contain a loosely attached and rather shrunken network of fibrin with granular looking leucocytes and very numerous large round mononuclear cells which are active phagocytes and are stuffed with fragments of leucocytes. Pneumococci have been found by Weigert's stain in small numbers. There is much pigment in the lung, and interlobular septa as well as vessel and bronchial walls are loaded with it. Other portions of the lung where there is no consolidation are normal except for this.

Cultures from the lung showed Pneumococcus Type II.

Case 33.—D. K., age 21 yrs. Began about Jan. 5 with a cold and chilly feeling after exposure to rain. Entered hospital Jan. 9, 1918, with fever, headache,

cough, and a macular eruption which was diagnosed measles. Jan. 11, pain in both ears. Drums incised and pus discharged. Jan. 20, much cough with râles over whole chest. Feb. 1, dulness in both lower lobes. Feb. 5, leucocytes 8,600. Temperature very irregular, varying daily from 97–103° F., pulse 80–110. On Feb. 7 rash had disappeared, throat not reddened. Dulness merging into flatness over left lower lobe with tubular breathing in that area. Elsewhere indefinite. Thoracentesis on the left side below the angle of the scapula gave 60 cc. of bloody fluid which contained Gram-positive insoluble cocci apparently streptococci. The sputum contained similar cocci and influenza bacillus. Blood culture on this day gave Pneumococcus Type IV. Feb. 8, patient very ill; temperature 104°. Lungs resonant anteriorly with large râles. Died Feb. 10, at 4 a.m. Autopsy Feb. 10, 10 a.m.

Anatomical Diagnosis: Bilateral lobar pneumonia.

Left pleural cavity.—Contains 800 cc. of greenish yellow fluid with shreds of fibrin. The pleural surfaces are shaggy and covered with a fine honey-combed layer of fibrinous exudate. *Right pleural cavity.*—Contains no excess of fluid; there are some fresh adhesions over the posterior surface of the lung which are easily broken through. There are also interlobar adhesions which are rather lax. *Left lung.*—The upper lobe is in general air-containing, although in its lower part there are a few yellowish opaque patches surrounded by hyperemic zones. The lower lobe is quite uniformly consolidated, the alveolar exudate projecting as minute granules which give the cut surface a reddish grey color. The septa are not conspicuous. The bronchi are somewhat reddened, the bronchial glands enlarged. *Right lung.*—The anterior portions of all the lobes are distended with air. The upper lobe is air-containing except in its lower portion where there is a patch of uniform consolidation. There are pretty dense interlobar adhesions. The middle lobe contains only a few small foci of consolidation which are grey and prominent. The lower lobe shows a rather peculiar distribution of the consolidation. There is a wedge-shaped area extending upward and backward from the hilum and about 3 cm. in width at its base at the pleura. There is also a large irregular area measuring about 10 by 5 cm. which extends through most of the lower and posterior part of the lobe. These are greyish red and uniformly consolidated. Between these and below the lower one there are air-containing portions of the lung. The bronchi are only slightly reddened and not thickened or prominent. The interlobular septa are rather conspicuous. The lymph glands at the hilum are large and soft. Other organs show no especial alteration.

The blood post mortem gave *Streptococcus hæmolyticus* and the influenza bacillus. Cultures from both lungs gave *Streptococcus hæmolyticus* alone.

Microscopic Examination.—The consolidated tissue from the left lower lobe shows a typical lobar pneumonia. The pleura is covered with a thin layer of fibrin with numerous leucocytes and innumerable cocci in pairs. The pleural membrane itself is hyperemic but not especially thickened or infiltrated and there is no

trace of organization of the overlying fibrin. The interlobar spaces present the same appearance. The bronchi contain a purulent exudate with enormous numbers of cocci in pairs. There are also great numbers of influenza bacilli. There is a slight infiltration of their walls with leucocytes and a few mononuclear cells, but this is relatively inconspicuous. The alveolar walls are normal in thickness and are nowhere infiltrated with cells. The capillaries seem to be on the whole rather empty and compressed. The alveoli are closely packed with leucocytes. Those nearest the atria and bronchioles are especially full of these leucocytes, while in the peripheral parts of the lobule fibrin occupies a part of the space. The leucocytes are disintegrating and although in most places the nuclei are well preserved the cell outline is ragged or indistinct. Red corpuscles are scarcely seen. The leucocytes have acted as phagocytes and many of them appear as rounded packets of micrococci. The bacteria are numerous especially in the alveoli which are centrally placed and free of fibrin. These are rather elongated cocci in pairs arranged stiffly and suggesting pneumococci rather than streptococci. Their distribution is that of pneumococci also. The interlobar septa are rather wide and are infiltrated with fluid and fibrin. The blood vessels and lymphatics which run in these septa contain leucocytes and fibrin with many organisms. The bronchial glands show a great collection of large phagocytic cells in their sinuses which are much widened to accommodate them.

Other portions of the lung aside from the consolidated area show, especially in the lower lobe of the right side, a great deal of edema. The bronchi are in most places filled with leucocytes and there is a slight infiltration of their walls. In the alveoli which contain fluid there are great numbers of cocci. These are commonly collected about minute rounded spaces so that they lie in the fluid on the surface of these bubble-like spaces. Such spaces are no larger than a leucocyte and often form a network in the coagulated fluid contents of the alveolus. In most places the same stiff arrangement of the cocci in pairs is seen, but in some alveoli there are bacteria of different form. There are minute round cocci arranged in long wavy or twisted chains. These are evidently streptococci and distinguishable by their morphology even in the tissue. They are not abundant and the pneumococci seem well preserved so that it is remarkable that streptococci alone were recovered in cultures from the lung. Other organs show no especial alteration.

Case 36.—J. W., age 29 yrs. No history of measles. Entered hospital Jan. 19, 1918, complaining of dizziness and headache, pain in left side of chest, cough, and expectoration of blood-streaked sputum. Throat negative. Signs of consolidation in lower lobes of both lungs. Blood culture negative. Leucocytes 40,800. Urine shows faint trace of albumin, otherwise negative. Temperature 102–105° F., gradually falling to 98° at time of death. Pulse about 100, respiration 30–40. Sputum showed Pneumococcus Type I. Was given antipneumococcus serum Jan. 19. Feb. 1, feet became edematous. Insomnia on account of

dyspnea. Urine shows albumin, pus cells, blood, and granular casts. Died Feb. 12, 1918. Autopsy Feb. 12, 1918.

Anatomical Diagnosis: Lobar pneumonia with encapsulated empyema (left). Serofibrinous pleuritis (right). Subacute pericarditis. Acute nephritis.

Left pleural cavity.—Contains a considerable quantity of thick greenish yellow pus which is encapsulated in several distinct and non-communicating pockets. The largest of these pockets containing about 300 cc. of pus lies between the anterior border of the lower lobe and the pericardium. The other pockets are between the lower lobe and the lateral chest wall. Posterior to the upper lobe there is another encapsulated empyema cavity containing 250 cc. of pus. Elsewhere the pleural cavity is obliterated by dense fibrous adhesions. *Right pleural cavity.*—Contains about 500 cc. of blood-stained fluid. The lung is collapsed and adherent over the posterior surface by fibrinous exudate. *Pericardium.*—The pericardial sac is obliterated by fresh fibrous adhesions except for two small pockets which contain blood-stained fluid. The heart shows no other abnormality. *Left lung.*—The pleura is thick and yellowish with abscess-like spaces in the substance. In places it is lifted up from the lung by accumulations of fluid. Both lobes of the lung are flabby and airless. In the upper lobe there is a small moderately firm but rather spongy area in the posterior part near the hilum. In general the substance of the lobe is reddish grey in color and in the posterior part there is a grey patch of loose consolidation. There are no small areas of focal consolidation. The cut surface of the lower lobe is also greyish red, but there are a few hemorrhagic areas which measure 2 to 4 mm. in diameter and project above the surrounding lung tissue. The bronchi are very hyperemic, and the bronchial glands are very soft. *Right lung.*—The pleura is thickened and covered with a thin fibrinous exudate which, however, appears as a viscid, bloody fluid between the lung and the diaphragm. The lobes are all easily distended with air. On section the cut surface is greyish red in color and there are no areas of consolidation. Bronchial mucosa is reddened. Bronchial glands are not enlarged. *Kidneys.*—Right kidney measures 15 by 8 by 4.5 cm. The capsule strips off readily leaving a smooth greyish purple surface on which can be seen numerous small hemorrhages. On section the cortex measures 8 mm. in width, is dark greyish red and opaque, and is studded with numerous small hemorrhages. Glomeruli are visible as small dots. The mucosa of the pelvis is injected. The left kidney is quite similar.

Cultures from the pleural fluid gave Pneumococcus Type I and *Streptococcus hæmolyticus*. Those from the left lung gave the streptococcus alone.

Microscopic Examination.—The left lung shows in the consolidated areas a rather lax filling of the alveoli with leucocytes together with a ragged network of fibrin. There are enormous numbers of organisms, most of which lie free among the leucocytes. They are lanceolate diplococci and seem to possess a definite capsule. There is some infiltration of the bronchial and vessel walls and even of the alveolar walls, but it is chiefly with polymorphonuclear leucocytes, there being relatively few mononuclear cells. There is no marked thickening of the

bronchial walls or infiltration of the interlobular septa. There is no organization of the intraalveolar exudate. Even in distant and relatively unaffected parts of the lung there is some infiltration of the alveolar walls with leucocytes. The pericardium shows a thick layer of fresh granulation tissue binding together the two layers. This is much infiltrated with leucocytes.

The kidney shows extensive changes in the glomeruli, tubules, and interstices. The glomeruli are large, their capillaries packed with nucleated cells, many of which are leucocytes. In the capsule of Bowman there are in some cases hyaline masses and strands which stain pink with eosin. In places the capillaries of the glomerular tuft are adherent to the parietal wall of the capsule. The epithelium of the tubules shows rather advanced degenerative changes. The tubules are in many places filled with blood and polymorphonuclear leucocytes. So too the interstitial tissue between the tubules of the cortex is in many places greatly widened and infiltrated with leucocytes.

Case 40.—B. M. G., age 28 yrs. No history of measles. Caught cold on Jan. 29, 1918, and had a chill followed by fever and vomiting. Felt very much nauseated for several hours. Pain in the right side of chest. Entered the hospital Jan. 30, with dulness and diminished breath sounds in the right chest behind. Left side apparently normal. Sputum bloody with Pneumococci Type IV. Leucocytes 30,000. On Feb. 8 temperature fell to normal, but the next day it rose again, and from that time to death showed great variations. Patient very ill and unconscious. Stiffness of neck and arms. Death Feb. 13, 1918. Autopsy Feb. 14, 1918.

Anatomical Diagnosis: Lobar pneumonia with fibrinous pleuritis.

Left pleural cavity.—Contains 150 cc. of blood-stained fluid. There are old fibrous adhesions over the whole lung posteriorly and between the lobes. *Right pleural cavity.*—Entirely obliterated by light fibrinous adhesions which are easily torn through. There is no fluid. *Left lung.*—Air-containing throughout, but a few bronchi in the posterior portion of the upper lobe contain plugs of exudate. Their walls are thick and greyish. *Right lung.*—The pleural surface is dull and covered with a thin fibrinous exudate. On section the lung is found to be uniformly consolidated throughout and grey in color except for a few lobules in the central portion of the lower lobe which are red and loosely consolidated. The alveoli are everywhere filled with plugs of exudate which project above the cut surface giving it a roughened appearance. The interlobular septa are rather conspicuous in the lower lobe.

Microscopic Examination.—The left lung shows no alteration except the bronchial changes in the upper lobe which prove to be tuberculous. Sections through the consolidated right lung show a perfectly uniform filling of the alveoli with masses of exudate composed of leucocytes and fibrin. The fibrin has become compact; the leucocytes are disintegrated. There are also desquamated epithelial cells and some large phagocytes, which contain cell fragments. There are many cocci in short chains which are presumably pneumococci although no cultures

were made and some of them look like streptococci. The walls of the alveoli are not thickened and the finer structure appears unchanged. The pleura is thickened and vascularized and is covered with a thin layer of fibrin. In it there are lymphatics which contain masses of leucocytes and large phagocytes. The interlobular septa are wide and dense.

Bronchi and blood vessels show in many cases a definite mononuclear infiltration of the walls. Nevertheless in most of the smaller vessels the infiltration is largely in the adventitial lymphatics and is composed of polymorphonuclears. Near the pleura the exudate in many alveoli has undergone organization.

Case 45.—J. K. S., age 19 yrs. Measles when a child. No eruption lately. Onset Jan. 17, 1918, with a chill, cough, and expectoration of tenacious, blood-streaked sputum. Fever and weakness. Entered the hospital Jan. 18, 1918, with painful dyspnea and dulness over lower lobes of both lungs posteriorly. Leucocytes 30,000. Temperature 101–105° F., pulse 100–150, respiration about 50–60. Sputum showed Pneumococcus Type III (?). On Jan. 25 he apparently had a fall of temperature by lysis but were still very sick, coughing up purulent material. There was still dulness posteriorly over both lungs with diffuse crepitant râles. Aspiration negative on both sides. Steadily improved for the next week, but on Feb. 1 there were still some dulness and the same crepitant râles. Sputum now showed *Streptococcus hæmolyticus*. Feb. 12, lungs fairly clear throughout. There are a few spots of dulness with crepitant râles, but the breath sounds are mostly vesicular. There was a sudden rise in temperature to 106° followed by a fall to 97° on the 14th, when he lapsed into coma and died with symptoms of extreme dyspnea. Death Feb. 18, 1918, 10 a.m. Autopsy Feb. 18, 1918, 11 a.m.

Anatomical Diagnosis: Indurative and organizing pneumonia with abscesses and pleural adhesions. Acute aortic endocarditis. Bilateral abscesses of rectus abdominis. Acute splenic tumor. Duodenal ulcer.

Right and left pleural cavities.—The cavities contain no fluid. The surfaces are bound together everywhere by organized adhesions which are thin, delicate, and veil-like. *Heart.*—Pericardium is normal. The heart is not enlarged, contains only postmortem clot. The endocardium is smooth throughout except over the aortic valve. The right coronary and posterior leaflets are occupied by large reddish yellow masses which in each case bulge in rounded forms both into the sinus and into the ventricle penetrating the leaflet. The right coronary orifice is not involved and the coronary vessels are normal throughout. The other valves are delicate and competent. The heart muscle is greyish red and uniform in appearance. *Left lung.*—The lung is small but very cushiony throughout as though everywhere air-containing. The bronchi exude a thick purulent fluid. On section the tissue is yellowish brown in color and in general air-containing, but through the lower lobe there is a network of greyish yellow strands which are irregular in outline and firmer than the surrounding tissue. In places these are rather translucent, in other places much more opaque than the adjacent tissue. The upper

lobe is more uniformly air-containing, but it too shows a few firm patches like those in the lower lobe. These are not specially related to the bronchi which are practically normal in appearance. *Right lung.*—This lung is in general air-containing, but there are scattered through the whole organ such strands of condensed tissue as form a network in the left lung. This particular appearance is more distinct after the lung has been hardened when there appear normal spongy portions in the rather small meshes of the close network of denser tissue. This denser tissue has not the appearance of a pneumonic consolidation but suggests the possibility of organization and contraction of an old pneumonic exudate. The upper lobe contains in addition a small group of abscesses each measuring 3 to 5 mm. in diameter and filled with yellow pus. In the anterior part of the lower lobe the tissue is entirely solid, dense, and grey. There are two small abscesses in this area. *Stomach and duodenum.*—Just below the pylorus there is an ulcer about 1 cm. in diameter in the mucosa of the duodenum. The margins are not indurated; the pancreas is not adherent to the base of the ulcer. *Rectus abdominis muscle.*—There is an abscess measuring 1 by 4 cm. in the substance of each rectus muscle about the junction of middle and lower thirds. These abscesses are exactly symmetrical in position. They contain a thick, sticky green pus and are lined by a yellowish wall which is stained brown in its deeper portions.

Cultures at autopsy gave the following results: Right lung, *B. influenzæ*, *Staphylococcus aureus* (hemolytic), *Streptococcus hæmolyticus*, and no pneumococcus. Heart valve and abscess in rectus muscle, Pneumococcus Type I.

Microscopic Examination.—The lungs show practically the same changes. The pleura is slightly thickened and vascular with some infiltration of wandering cells. There are on the surface remains of dense fibrin and groups of the original lining cells of the pleura.

The interlobular septa are not especially thickened. The bronchi show practically no changes in their walls although most of them are filled with leucocytes. The epithelium is in general intact and the connective tissue and muscular layers of the wall are compact and show very few wandering cells.

On the other hand, the alveolar walls in most places are extraordinarily thickened, not by infiltration with mononuclear cells but by a new formation of connective tissue. There are, it is true, some mononuclear wandering cells in the substance of these walls and many of them are very large and loaded with yellow pigment. The epithelium is in general complete but much thickened so as to be almost cubical in many places. The alveoli are usually empty but there are places in which they still contain leucocytes and other more extensive places in which they are filled by an organized tissue. This organization of old exudate is not very widespread, however. Such changes in the lung are not uniformly distributed, but alternate with areas in which the alveoli are overdistended with air but are otherwise normal. The exudate both in the bronchi and alveoli contains pneumococci, very abundant influenza bacilli, and occasionally a coarse streptothrix.

Blood vessels and lymphatics are inconspicuous.

In certain sections of the lung there are found large abscesses with old compact masses of fragmented leucocytes forming the center within a dense wall of granulation tissue.

Case 46.—F. W. S., age 23 yrs. Had measles 10 years ago according to his own account. Had no doctor. Began Feb. 5 with headache, conjunctivitis, coryza, sore throat, and malaise. On Feb. 6 chills and fever with red papular eruption on chest and face next day. Admitted to hospital Feb. 7. On Feb. 10 had a chill, vomiting, and headache. Temperature 104° F. Feb. 14, signs appeared in lungs for the first time. There was a period of normal temperature between the measles and the pneumonia. Feb. 15, uncomfortable, breathless with a grunt and cyanosis. Dulness over left back and axilla, breath sounds tubular over tip of lower lobe. Bronchophony and whispered pectoriloquy here. Tactile fremitus diminished. Died Feb. 18, 11 a.m.

Sputum on Feb. 15 shows Pneumococcus Type I, also *Streptococcus hæmolyticus*. Blood culture on that day gave Pneumococcus Type I. On Feb. 16 cultures of fluid aspirated from the chest gave Pneumococcus Type I and *Streptococcus hæmolyticus*. Thought to have lobar pneumonia with empyema and secondary streptococcus infection. Autopsy Feb. 18, 1 p.m.

Anatomical Diagnosis: Pneumonia with abscess formation and empyema. Fibrinopurulent pericarditis.

Left pleural cavity.—Contains an enormous amount of fluid which is olive-green in color, turbid with great flakes of fibrin floating up from the injected pleural surface. *Right pleural cavity.*—Contains no fluid; the pleural surfaces are smooth and glistening. *Pericardium.*—Contains 300 cc. of turbid fluid with floating shreds of fibrin. The walls are thickly studded with small hemorrhages and covered with a loose fibrinous exudate. *Left lung.*——Completely collapsed and flattened against the mediastinal tissues; is flabby and soft, except in the upper part of the lower lobe where there are several firm masses, one of which is necrotic and covered by yellow necrotic pleura. On section it is found that there is an abscess about 12 mm. in diameter in the upper posterior part of the lower lobe. About it is a clearly outlined zone of uniform greyish consolidation. The rest of the lower lobe is collapsed. In the upper lobe the interlobular septa are prominent but there is no consolidation. Bronchi contain purulent fluid but the walls are not thickened nor are the bronchi dilated towards the pleura. *Right lung.*—Air-containing throughout and normal in appearance. The adrenals are greatly swollen and have lost the distinctness of their zonal marking.

Microscopic Examination.—The pleura over the left lung is thickened by the formation of granulation tissue which is overlaid by a thin but dense layer of fibrin. The interlobular septa are not very conspicuous, although slightly thickened and infiltrated with fibrin and cells. The tissue under the pleura is consolidated, each alveolus being packed with dense fibrin which contains but few cells. These are mostly red corpuscles, desquamated epithelium which is deeply pigmented,

and leucocytes. The alveolar walls are greatly thickened by infiltration with various sorts of cells, chiefly mononuclears which act as phagocytes. This dense consolidation extends for a considerable depth. Even where the lung becomes insufflated it appears that the air is only forced into partly consolidated, partly collapsed tissue. The bronchi contain a purulent exudate, but their walls are not much altered from normal, and very slightly infiltrated.

The lymphatics in the bronchial and vessel walls are distended with leucocytes, fibrin, and bacteria. There is a fresh pericarditis with hemorrhages under the pericardial lining cells and a little fibrinopurulent exudate.

Cultures from pleural fluid, pericardial fluid, both lungs, and blood gave *Streptococcus hæmolyticus*. No pneumococcus was found in material from these five sources.

Case 51.—J. L. A., age 35 yrs. Had a cold for several days and was admitted to the hospital Feb. 15, 1918, with chill, fever, and vomiting. Dulness over right lower lobe with crackling râles. No tubular breathing. Faint pleural rub near the right nipple. On Feb. 17 there was a crisis and the temperature sank to normal from 103°. Patient remained in good condition until Feb. 24 when he had a chill followed by severe pain in the right side. There were dulness and diminution of breath sound in this region. Sputum contained pneumococcus. On Feb. 27 the tenacious bloody sputum contained Pneumococcus Type II, with influenza bacilli. Mar. 1, patient was very sick, with abdominal distension. Tubular breathing and râles on right side. Blood culture gave Pneumococcus Type II. Sputum gave the same organism. Aspiration of thorax was negative on Mar. 2 and 3. Patient cyanotic; râles over entire chest. Tubular breathing over right lower lobe only. Died Mar. 4, 1918, at 2.15 a.m. Autopsy Mar. 4, 1918.

Anatomical Diagnosis: Lobar pneumonia (right lower lobe) with anemic infarctions. Fibrinopurulent pleuritis. Acute peritonitis. Diphtheritic colitis.

Left pleural cavity.—Contains a few cc. of turbid fluid. The surfaces are fairly smooth except on the posterior portion of both lobes where the lung is collapsed and there are numerous hemorrhages on the surface. *Right pleural cavity.*—Obliterated by fresh fibrinous exudate which is especially thick over the upper part of the lung where it contains some fluid. There is no free fluid but it is held in the meshes of the fibrin. The surface of the diaphragm is deeply injected. *Pericardium.*—The pericardium contains about 100 cc. of slightly turbid fluid. There are a few punctate hemorrhages on the heart but the surfaces are smooth and glistening. *Peritoneum.*—The hepatic flexure of the colon is adherent to the liver, and in this region the peritoneum has lost its gloss and there is a collection of purulent fluid. The appendix and pelvic organs are bathed in purulent fluid. There is less fluid on the left side and the peritoneal surfaces are glossy. There is no obvious source for this infection. The mucosa of the intestines is normal throughout except for a few areas of diphtheritic exudate in the region of the ileocecal valve, which stand above the surrounding mucosa and are out-

lined by hemorrhage. *Left lung.*—The lung feels soft throughout although there is some collapse in its posterior part. It was readily insufflated artificially and on section the tissue is normal in appearance throughout. There is no thickening of the bronchi. *Right lung.*—The organ is voluminous and heavy. The upper lobe is soft and collapsed and so is the middle lobe except in the anterior part where it is air-containing. The lower lobe is distended with exudate and is solid. The bronchial glands are enlarged and the bronchi contain a purulent exudate. The upper and middle lobes are insufflated readily and normal in structure. The lower lobe on section shows a uniform consolidation in which the alveoli are filled with an exudate of dark reddish grey color. There is no thickening of the bronchial walls and no focal character to the consolidation. There is a firm grey area at the lower margin and the blood vessel passing to this area is thrombosed. There are several patches just beneath the pleura in the more posterior part of the lobe, which correspond sharply with the outlines of lobules and in which the consolidated tissue is paler and mottled. Over one of these the thick yellow fibrinous exudate is thinned out so that the opacity of the area shows through. All such patches come up to the surface of the lung and are pale grey, sometimes with reddish central portions or small areas of softening. The blood vessels supplying these areas appear to be thrombosed. The interlobular septa are not widened, but there are some beaded distended lymphatics in the lower part of the consolidated lobe. These are rendered conspicuous by their opaque yellow contents.

Cultures at autopsy from the lung showed Pneumococcus Type II atypical with *B. influenzæ*; peritoneal and pericardial fluids contained Pneumococcus Type II atypical in pure culture. The blood gave Pneumococcus Type II atypical with a Gram-negative colon-like bacillus.

Microscopic Examination.—The consolidated right lung shows the typical lesions of lobar pneumonia. The pleural exudate is of fibrin not organized. The pleura is not thickened and the original layer of pleural lining cells is still distinguishable. The interlobular septa are wide, infiltrated with fluid and a network of fibrin. There are many polymorphonuclear leucocytes and some mononuclear cells in the meshes of the fibrin. The lymphatics in these septa are enormously distended and plugged completely with clotted masses of leucocytes, blood, and mononuclear cells among which rather numerous pneumococci can be seen. The lymphatics in the pleura and in the adventitia of blood vessels and of bronchi are also distended with the same material, but they are not such huge beaded channels as those related to the septa.

The bronchi contain leucocytes and fibrin with pneumococci and influenza bacilli, but their walls are not thickened or markedly infiltrated nor is their epithelium destroyed. The alveoli are uniformly filled with a network of fibrin with leucocytes, red corpuscles, and great numbers of pneumococci. Their walls are not thickened or infiltrated, although occasional leucocytes are found there. There are several blood vessels which are completely thrombosed and the areas of lung tissue ordinarily supplied by them are, with their contained exudate,

completely necrotic. These represent anemic infarctions in the consolidated lung. The bronchial glands are enlarged and contain in their sinuses phagocytic cells and pneumococci.

Case 186.—W. F., age 29 yrs. Began with cough, general malaise, and pain in chest, and was admitted to the hospital on May 2, 1918. Bubbling râles were found in both lungs. On May 8 there was evidence of meningitis, and 50 cc. of spinal fluid were aspirated, 45 cc. of antimeningococcus serum being injected. On May 11 there were signs of consolidation in the left lower lobe. On May 12 patient was irrational and cyanotic. 50 cc. of fluid were aspirated from the left chest. Sputum contained Pneumococcus Type I and influenza bacillus on May 11. Died May 12, 1918. Autopsy 20 hours after death.

Anatomical Diagnosis: Lobar pneumonia (left lung) with fibrinopurulent pleurisy. Acute serofibrinous pericarditis.

Left pleural cavity.—The cavity is practically obliterated by a great mass of greenish yellow fibrin which is thick and shaggy and in the interstices of which there is a large quantity of turbid greenish fluid. This accumulation is chiefly between the lung and the pericardial sac. The lung is bound to the costal pleura by fresh light fibrinous adhesions. There are about 160 cc. of fluid in the space between the lung and the pericardial sac, but the rest of the pleura contains relatively little fluid. The surfaces, where free, are covered with greenish fibrin in a thin layer. *Right pleural cavity.*—Contains no fluid. The surfaces are smooth and glistening. *Pericardial cavity.*—Contains 50 cc. of turbid fluid with shreds of fibrin. The pericardial lining membrane is congested, its surface dull, and covered with a thin exudate of fibrin. *Mediastinal tissue.*—Infiltrated with yellow purulent exudate. At the region of the lower end of the thymus there is an abscess-like accumulation of pus. *Left lung.*—The lung is large and heavy with its lobes glued together by fibrin which extends over the surfaces as described. The upper lobe is air-containing in its anterior and upper part, but in the region of the hilum and near the cleft between the lobes there are greyish translucent branching areas of consolidation. The bronchi are thickened and reddened, but it is not clear that these consolidations are definitely peribronchial. In the lower lobe there are two definite areas of consolidation between which the lung is collapsed and contains only indefinite nodular foci of consolidation. One of these larger areas occupies the upper posterior portion, the other the anterior lower part. They are reddish grey and uniform, showing a granular surface from which a plug of exudate projects from each alveolus. The bronchial glands are large, soft, and edematous, and contain some old yellowish nodules. *Right lung.*—Everywhere air-containing except for a few small patches of greyish red consolidation in the lower part of the upper lobe. *Pharynx and larynx.*—Pharynx, epiglottis, and larynx slightly congested. There are no ulcerations in the vocal cords or elsewhere in the larynx. The trachea is slightly reddened.

Cultures from the heart's blood, left lung, and pericardium gave Pneumococcus Type I. A culture from the left pleura showed *Streptococcus hæmolyticus.*

Microscopic Examination.—The left lung shows a thick layer of fibrin on the pleural surface with abundant Gram-positive cocci in short stiff chains scattered throughout. Many of these are in phagocytic cells. The pleura itself overlaid with a dense exudate of fibrin is edematous, slightly thickened, and spread open into meshes and remarkably hyperemic. It appears that there is the beginning of organization of the overlying exudate, although the proliferation of connective tissue cells has barely begun. The pleural lining cells are almost all gone; a few can still be seen. The interlobular septa are quite inconspicuous. The lymphatics in the pleura are filled with fibrin and cells with few bacteria. They are not easily found in the substance of the lung. The bronchi are filled with purulent exudate; their walls are slightly infiltrated with mononuclear cells. The alveolar walls are nowhere thickened or infiltrated. Their cavities are filled with an exudate of leucocytes, red corpuscles, and fibrin. There are numerous Gram-positive diplococci in places in the alveolar exudate, but almost all of them are enclosed in leucocytes and are apparently partly disintegrated. They, like those seen in the superficial layers of the pleural exudate, look like pneumococci. In addition to these there are in the bronchial exudate great numbers of influenza bacilli. In another section from the left lung there is the same condition of the pleura, but the alveoli are filled not with a fresh exudate of leucocytes but either with fluid or with a dense exudate of fibrin in which are entangled red corpuscles and a few mononuclear cells and leucocytes. These plugs of fibrin are outlined in many cases by a single layer of flat epithelial cells which have grown over them from the alveolar wall. The alveolar walls are thickened by an infiltration with leucocytes. In places the epithelium is greatly proliferated and several mitotic figures can be seen in these cells in a single alveolus. They grow until the alveolus is half filled with a mass of epithelium. In this region the walls of the vessels are somewhat infiltrated with mononuclear cells, but those of the bronchi are not much thickened. Enormous numbers of bacteria are found on the surface of the pleural fibrin, but none in the alveolar cavities.

This is a peculiar condition since certain parts of the consolidated tissue show the alveoli almost but not quite filled with a compact fibrillated mass clothed in a layer of epithelial cells in which the cells are indistinct and in which no bacteria are found, while other areas are filled with exudate containing bacteria. The proliferation of the epithelium recalls the epithelial giant cells described by Hecht in the lungs of children.

Case 188.—D. W., age 21 yrs. No history of measles. Began gradually about May 3, 1918, with a cough and pain in chest. Drilled for 2 days when pain became more severe. Admitted to hospital May 7 when he had a few crepitant râles in the left lower lobe. On May 11 there were tubular breathing, crepitant and moist râles in the right upper lobe, and few râles in the left lower lobe. On May 13 it was evident that there was consolidation of the right upper and middle lobes with many râles. Diagnosis of lobar pneumonia, left lower, and right upper and middle lobes. Died May 14, 1918, 1.05 a.m. Autopsy May 14, 1918.

Anatomical Diagnosis: Lobar pneumonia involving whole right lung (fresh). Organizing lobar pneumonia (left lower lobe). Fibrinous pleuritis. Acute nephritis.

Left pleural cavity.—There is a fibrinous exudate over the whole lower lobe which binds it to the costal pleura. This extends between the lobes and a short way on the upper lobe; the remaining pleura over the upper lobe is smooth and without adhesions and contains no excess of fluid. *Right pleural cavity.*—The whole cavity is obliterated by a fresh fibrinous exudate which glues the surfaces together. There are a few old adhesions about the apex of the lung. There is no accumulation of fluid. *Left lung.*—The upper lobe is uniformly air-containing and of normal texture. The lower lobe is nearly solid but there are small spongy patches distributed throughout. These alternate with greyish red irregular areas of solid lung which show a rough surface with projecting alveolar plugs. The bronchi are lined by an opaque ragged layer. In several places but especially near the hilum there are large branching opaque yellow lines which look like obstructed lymphatics. *Right lung (Fig. 51).*—Large and heavy and consolidated except in the anterior margin of the middle and lower lobes. It is covered with a thin fibrinous exudate more abundant between the lobes which are glued together. The bronchial glands are very large, pigmented, and flecked with pale grey opacities. The upper lobe on section shows a few small scattered patches of spongy air-containing lung; these patches amount to only a few alveoli in each case. They are separated by rather mottled greyish red areas of consolidation which are flecked in places with hemorrhages. These areas are practically confluent and continuous throughout. The bronchi contain a grey exudate and in places their lining walls are opaque and yellowish red. The middle lobe is more uniformly consolidated, paler than the upper, and with more definite alveolar plugs. It too is flecked with hemorrhages. The lower lobe like the middle is uniformly solid and no spongy areas are seen. It is paler than the upper lobe and does not contain so many hemorrhages.

Microscopic Examination.—The right lung shows in its consolidated part a pleura covered with dense fibrin. On the outer surface the covering cells are largely destroyed but there is very little evidence of organization. In the interlobar space, however, the lining pleural cells are well preserved in most places. Nevertheless, definite organization of the exudate is going on. The interlobular septa are not conspicuous and lymphatics are scarcely to be found in the sections. The bronchi contain a purulent exudate. Their walls are not thickened or infiltrated. The alveolar walls are not thickened. The alveoli contain a rather uniform dense exudate of polymorphonuclear leucocytes, red blood corpuscles, and fibrin. Blood is very abundant in places. In other areas edema predominates. The exudate both in the bronchi and alveoli is loaded with bacteria. The Gram-positive cocci are usually free and are morphologically identical with pneumococci. There are great numbers of minute Gram-negative bacilli, most of which are contained in leucocytes, in the protoplasm of which they are closely packed. These appear to be influenza bacilli.

The left lung presents a different appearance and it is difficult to decide how this should be interpreted. The consolidation is patchy, with areas which contain air. The pleura is thickened by a layerof granulation tissue over which there is fibrin. The interlobular septa are not prominent. The bronchi are filled with a purulent exudate; their walls are slightly spread apart and contain a few wandering cells with leucocytes and mononuclear cells. Some of the bronchi show a distinct overdistension of the blood vessels, but the changes are in general slight. The alveolar walls are not thickened or infiltrated with mononuclear cells. The alveoli are not filled with an exudate of polymorphonuclear leucocytes as in the right lung, but contain fluid, red blood corpuscles, desquamated epithelial cells, and dense masses of fibrin containing few cells but overgrown and almost completely covered by epithelium. Such masses are partly replaced by new connective tissue. There are some areas in which the alveoli contain leucocytes, but throughout most of the lung the condition is as described. Possibly it represents a much later stage of the lobar pneumonia caused by the pneumococcus than that seen in the right lung, but it is also possible that these changes may depend upon the influenza bacillus.

The kidney shows a general cloudiness of the cells of the epithelium of consolidated tubules, although their free borders are well preserved. There are several glomeruli in each section in which the capillaries are plugged with hyaline thrombi. In the capsules of all the glomeruli there is a mass of bubble-like coagula and in those which have the thrombosed capillaries there are a few leucocytes. The tissue surrounding these glomeruli is infiltrated with red corpuscles and leucocytes. Some of the tubules contain casts and a few polymorphonuclear leucocytes.

There is little that requires comment in these cases. Most of them were from the Texas epidemic, which is perhaps to be accounted for from the fact that those studies were made in February and March, while the Iowa epidemic was studied in May.

The cases of lobar pneumonia are described here not because they are extraordinary in any way, but chiefly to show the proportion which they bear to the others and to emphasize the contrast between the anatomical lesions produced by the different organisms.

The distribution of these organisms has already been mentioned. It was Ribbert's idea that in lobar pneumonia one might recognize a lobular arrangement of the exudate with most compact fibrin in the alveoli adjoining the interlobular septa, while the greater number of leucocytes and more especially of pneumococci was to be found in the central portions of the lobule and in the bronchus. This is true to some extent, although the pneumococci are far more uniformly dis-

tributed throughout the alveoli and through the whole thickness of the pleural exudate than are streptococci. The latter organisms keep to the bronchial contents and the surfaces of the pleural exudate in interstitial bronchopneumonia and are scattered more like pneumococci in the lobular form. But both pneumococci and streptococci quickly gain the lymphatics and distend them with the resulting exudate which clots. In lobar pneumonia as in the streptococcal form these lymphatics become very prominent in their course from the pleura as beaded yellow channels.

In several cases in which there was definite lobar pneumonia and in which blood cultures during life showed the presence of pneumococci (Case 33), or when sputum and pleural fluid contained them (Case 36), or sputum, blood, and pleural fluid (Cases 45 and 46), the cultures from lungs and other sources at autopsy failed to show them and *Streptococcus hæmolyticus* grew instead. It appears from repeated experiences of this kind that the pneumococcus must quickly die out or be overgrown by the streptococcus, or one may find it, as in Cases 186 and 188, in the process of being overgrown.

Curious changes occur in the exudate itself if the first stages of the disease are survived. In Case 25, which was of only 8 days duration, the pneumonia was thought to be in a stage of resolution. This seems questionable, but at any rate few pneumococci could be found in sections, although the fibrin still stained well and they were isolated in culture. But in this lung the infiltration of the alveolar walls with polymorphonuclear leucocytes and the upheaval of the epithelial cells are remarkable. Of a different character are the changes in Case 45 in which the pneumonia has left the alveolar walls thickened with fibrous tissue in certain strand-like areas, and the alveoli themselves filled with organized exudate in the form of fibrous bands. The presence of abundant influenza bacilli must be remembered.

Organization is advanced in one of the lungs of Case 188, and in Case 186 there are alveoli partly filled with dense fibrin from which bacteria have disappeared and nuclei faded. In Case 186 there are in places striking evidences of the proliferation of the epithelium which forms great protoplasmic masses only faintly divided into cells and studded in places with mitotic figures.

One of the most striking lesions, which may be common enough in any great series, is shown in Case 51 in which the cultures show throughout Pneumococcus Type II. In this uniformly consolidated lung there are many thrombosed blood vessels and as many anemic infarctions which extend to the pleura. They are actual infarctions because the circulation of the lung is embarrassed, and anemic because the lung has become firm like the kidney and there is no longer a chance for blood to ooze into the dead area from adjacent regions.

No unusual changes were found in the other organs in connection with this form of pneumonia, although there were pericarditis, endocarditis, peritonitis, and in one case abscesses of the rectus abdominis.

5. Lobar Pneumonia Combined with Interstitial Bronchopneumonia.

Case 21.—A. A. McL., age 22 yrs. Entered hospital Jan. 7, 1918, with fever, cough, and sore throat. Conjunctivæ injected, no rash, throat clear. Jan. 8, throat very red, marked conjunctivitis, but no rash. Jan. 10 and 11, cough with much expectoration, nausea, and vomiting. Chill and epistaxis. Had acute bronchitis since Jan. 1, otitis media Jan. 25. Jan. 26, there were dulness over the upper right lobe and râles over the entire chest. Very ill until Feb. 4 when he died. Temperature 100–104° F., pulse 100–120, respiration 24–30. Much delirium and vomiting. Leucocytes 25,600. Autopsy Feb. 5, 1918.

Anatomical Diagnosis: Bilateral lobar pneumonia. Bilateral interstitial bronchopneumonia. Fibrinopurulent pleuritis.

Left pleural cavity.—Free from fluid. Surfaces dulled by thin fibrinous exudate with minute hemorrhages. *Right pleural cavity.*—Contains a little viscid yellow fluid. *Left lung* (*Fig. 52*).—There is an area of consolidation which occupies the posterior part of the upper lobe. The lower lobe is partly collapsed, partly air-containing, the surface greatly injected and flecked with hemorrhages and covered with a fibrinous exudate. On section the upper lobe with the exception of a small part of the mesial surface is uniformly consolidated. The lower lobe shows on section numerous greyish white minute areas of consolidation distributed in groups of two or three, several being found in each lobule. These correspond with the terminal bronchioles. *Right lung.*—The upper lobe contains a large area of uniform consolidation in which each lobule is sharply outlined and shows each alveolus filled with exudate. Throughout the lower part of the lung there is atelectasis. In this area each interlobular septum is quite distinct and there are numerous minute areas of consolidation in each lobule. These correspond in position with the terminal bronchioles. The same condition is distinctly visible in the lower part of the upper lobe and may be traced into the area of lobar consolidation. The nodules are numerous throughout the remainder of the lung.

Microscopic Examination.—The lungs are practically alike. In the sections which pass through the area of lobar pneumonia the pleura is not thickened. The overlying fibrin is not organized and the pleural lining cells are still visible. This is true over the portions of the lung occupied by the interstitial bronchopneumonia, but the pleura is distinctly more vascular and the fibrinous exudate thicker. In the area of lobar consolidation the bronchi contain an exudate of leucocytes; their walls are somewhat infiltrated with mononuclear cells. The adjacent and also distant alveoli are uniformly filled with the characteristic exudate of pneumococcus pneumonia. The walls are not definitely thickened or infiltrated. It is not really possible to recognize areas of interstitial bronchopneumonia embedded in the area of lobar pneumonia, although at the margin where the two conditions join one another it is true they overlap somewhat. The alveolar exudate contains many organisms, probably pneumococci, which are in pairs or short stiff chains scattered evenly throughout. Many of these are enclosed in phagocytes. No organization of this exudate has occurred. The interlobular septa are wide and edematous with a loose network of fibrin and many leucocytes and mononuclear cells. There are a few bacteria and often these appear to be streptococci in long flexible chains. The lymphatics injected from the pleura with Berlin blue run in these septa and are often plugged with thrombi rich in leucocytes. There are no great numbers of bacteria to be seen there. The blood vessels have walls somewhat thickened by an infiltration of mononuclear cells.

As one passes from the area of lobar pneumonia the whole character of the pulmonary alteration changes. The bronchi become conspicuous from the greatly increased thickness of their walls. They are still filled with leucocytes and debris of epithelial cells with streptococci, but the walls are very hyperemic and greatly thickened by the infiltration of mononuclear cells. This extends to the walls of the neighboring alveoli. Such alveoli are filled no longer with a delicate network of fibrin supporting uniformly distributed polymorphonuclear leucocytes, but are found to contain dense plugs of pink-staining fibrin surrounded by mononuclear wandering cells and desquamated epithelium. Streptococci are rarely found there. But organization has occurred everywhere and has advanced so that there are whole patches of the lung in each alveolus of which the exudate is replaced by vascular connective tissue which has retracted and has been covered by alveolar epithelium. The same is true in the bronchi although the connective tissue lies uncovered there in the midst of the exudate. Most of the lung is atelectatic, but the parts intervening between the peribronchial nodules can be blown up with air.

Pneumococcus Type IV and *Streptococcus hæmolyticus* were recovered from the lungs and from the heart's blood.

Case 23.—F. L. G., age 18 yrs. Taken sick Jan. 15 with cough and pain in left chest and fever. Entered hospital Jan. 19, 1918. Dulness over left lower lobe with tubular breathing and râles. Aspirated Jan. 31, and pus removed from left pleura. Resection of rib Feb. 1. Died Feb. 5. Autopsy Feb 5.

Anatomical Diagnosis: Interstitial bronchopneumonia with empyema (left lung). Lobar pneumonia (right lung).

Left pleural cavity.—Over the 6th left rib in the anterior axillary line is an operation wound 7 cm. long from which projects a rubber tube. A piece of rib has been removed. The pleural cavity is entirely obliterated over the anterior half by light fibrinous adhesions. The posterior part of the pleura forms a cavity which extends to the vertebral column and contains a small quantity of purulent material. The mediastinal tissues are very edematous. *Right pleural cavity.*—Contains a small amount of fluid. The surfaces are covered with a thin fibrinous exudate. *Left lung.*—The lung is collapsed and adherent to the diaphragm where it encloses a pocket of 100 cc. of greenish yellow pus. The surface of the lung is covered with a yellow fibrinous exudate which binds the lobes together. In the posterior portions of both lobes, which are much collapsed, there are numerous greyish red foci in the centers of which bronchi are seen filled with purulent exudate. Other reddened areas 2 mm. in diameter seem not to be related to the bronchi. In the upper and posterior part of the lower lobe there is a grey area of consolidation in which each alveolus contains a plug of exudate. *Right lung.*—The lower lobe is covered with a thin fibrinous exudate while the surface of the upper lobe is smooth. The upper lobe is air-containing throughout, and there are no foci of consolidation. The lower lobe except for the anterior margin is uniformly consolidated. It is grey, firm, and airless and from each alveolus a plug of exudate projects. The lymph glands are moist and swollen.

Microscopic Examination.—The left lung presents the typical appearance seen in interstitial bronchopneumonia. The pleura is greatly thickened and appears as a layer of granulation tissue with overlying dense fibrin. Much of the lung substance is collapsed. The bronchi are conspicuous because they are filled with leucocytes and desquamated columnar epithelium. There are many influenza bacilli among these cells. The walls are greatly thickened and hyperemic and densely infiltrated with lymphocytes, plasma cells, and mononuclear wandering cells of other forms. The adjacent alveolar walls are similarly thickened in the neighborhood of bronchi, vessels, and interlobular septa. Their epithelium is partly desquamated and they contain these cells as well as the mononuclear wandering cells. Where fibrin is found in the alveoli it is not in a delicate network but in dense masses. Organization is well advanced and dense strands of vascularized tissue are found in the bronchi and in the alveoli. In the alveoli hemorrhage is not a prominent contributor to the exudate. There are some red corpuscles but far more of a formless coagulated fluid. The interlobular septa are greatly widened, and where lymphatics are seen they are packed with mononuclear cells and leucocytes.

Sections through the consolidated portions of the lower lobe of the right lung show a thin pleura with an overlying layer of fibrin showing no indication of organization. The bronchi contain an exudate of leucocytes; the epithelium is in-

tact or retracted in a ring from the walls. There is no organization of the exudate. The walls of the bronchi are very slightly infiltrated with leucocytes and so too are many of the alveolar walls. It is striking that in this lung the polymorphonuclear leucocytes invade the alveolar walls, while in the opposite lung the mononuclear cells do so. The alveolar exudate is composed of leucocytes and fibrin. The latter is rather contracted and dense. Many of the alveoli contain fluid. Bacteria which are Gram-positive lanceolate diplococci of considerable elongation are numerous and uniformly scattered throughout the exudate. The influenza bacilli are also present. The interlobular septa are inconspicuous.

Bacteriological cultures show *Streptococcus hæmolyticus* in both blood and lung. Nevertheless it seems clear that the bacteria which have caused the lobar pneumonia in the right lung are pneumococci, both from the anatomical character of the lesion and the morphology of the organisms themselves together with their peculiar distribution.

Case 31.—J. D. W., age 22 yrs. Began Jan. 14, 1918, with headache, sore throat, coryza, and conjunctivitis. Rash appeared on Jan. 18 when he entered the hospital. Difficulty in breathing developed shortly afterward and temperature rose to 102–104° F. Pain in left axilla. Crepitant râles throughout chest. Examination on Feb. 6. Temperature fell to normal on Jan. 29 but rose again suddenly on Feb. 2 and remained above 102° until death. Pulse and respiration changed in parallel way. Dulness over left lung passing into flatness over lower lobe. Tubular breathing with râles over lower lobe. Loud friction rub in left axilla. Right thorax resonant with coarse râles. Cyanosis and slight jaundice. Attempt at aspiration of left pleura resulted in withdrawal of bloody fluid from lung. This contained Pneumococcus Type IV. It was thought that bronchopneumonia followed the attack of measles with acute onset of lobar pneumonia on Feb. 3. Died Feb. 8, 8.30 a.m. Autopsy Feb. 8.

Anatomical Diagnosis: Clinical history of measles. Interstitial bronchopneumonia. Lobar pneumonia (left) with fibrinopurulent pleuritis.

Left pleural cavity.—Contains a considerable quantity of brownish green turbid fluid; the lung is bound by light fibrous adhesions to the diaphragm and pericardial sac. Posterior portion of upper lobe and whole lower lobe are covered with a thick fibrinous exudate and so also is the parietal pleura. *Right pleural cavity.*—There is no excess of fluid and the pleural surfaces are everywhere smooth and glistening. *Left lung* (*Fig. 53*).—The lobes are glued together by yellow fibrinous exudate. The upper lobe is collapsed but not consolidated. The interlobular septa are very distinct. The bronchi are thickened and grey with yellowish white opaque contents. The lower lobe is completely and uniformly consolidated; the cut surface is grey except for a small area in the center of the lobe which is hemorrhagic. The alveoli are filled with plugs of exudate which stand out above the cut surface giving it a rough granular appearance. The septa are not distinct. The bronchi are filled with a yellow exudate. *Right lung.*—The upper and middle lobes are cushiony, while the posterior portion of the lower lobe is blue and heavy.

There are numerous minute hemorrhages in the pleura about the interlobar clefts. The whole lung is readily insufflated except a small part of the upper lobe. Through all the lobes there are found on section small greyish areas of consolidation about 2 to 3 mm. in diameter frequently surrounded by hemorrhage and containing a central bronchiole. One of these patches in the lower lobe is 1 cm. in diameter.

Microscopic Examination.—The left lung shows a typical lobar pneumonia with uniform densely packed exudate in the alveoli. The bronchi contain a purulent exudate. Their walls are slightly infiltrated with mononuclear cells. The alveolar walls are not thickened; the capillaries appear rather bloodless but contain a few megalocaryocytes. The exudate in the alveoli is almost entirely composed of leucocytes with very few red corpuscles. The leucocytes are ragged and in certain places reduced to fragments of nuclei. In these places the alveolar walls become indistinct and the capillaries appear to contain hyaline thrombi. There is little to suggest the features of the interstitial bronchopneumonia within the area of lobar consolidation.

Very few organisms can be found in the alveolar exudate but two or three were found in one alveolus. The right lung shows small bronchi filled with an exudate of leucocytes and with walls much thickened by the infiltration of these cells and mononuclear cells. The walls of the adjacent alveoli are thickened and infiltrated and they contain leucocytes and desquamated epithelial cells and much pigment. The occurrence of pigmented epithelium suggests the possibility of a local obstruction to the outflow of blood or a local chronic passive congestion. There is also a great deal of free blood in these alveoli. The bronchi contain streptococci in pairs and rather long chains.

Cultures from the blood and right lung showed *Streptococcus hæmolyticus.* Those from the left pleural fluid showed Pneumococcus Type IV and the streptococcus.

Case 50.—L. J. W., age 19 yrs. Never had measles. The patient was vaccinated against typhoid on Jan. 26, 1918, and had a severe reaction. He felt so badly that he was sent to the hospital where after about a week he developed measles, on Jan. 30. Rash lasted 2 days. Then he walked about the ward for a few days when he began to have a pain in his chest and shortness of breath. Coughed and expectorated a great deal and vomited. On Feb. 10 he was found to have a hacking cough but no difficulty in breathing. Did not seem very sick. Dulness over right upper lobe with harsh breath sound. Fine moist râles over both lower lobes behind. On Feb. 15 complained of bad stitch in left side; cough short and grunting. Marked dulness in lower left back with suppression of breath sounds. Feb. 16, 1918, 10 cc. of turbid fluid aspirated from left side. Feb. 18, operation for drainage of left side. Died Mar. 2, 1918. Sputum on Feb. 14 gave *B. influenzæ* and *Streptococcus hæmolyticus.* Blood culture on Feb. 14 negative. Pleural fluid Feb. 16 showed *Streptococcus hæmolyticus.* Autopsy Mar. 3, 1918.

Anatomical Diagnosis: Lobar pneumonia with empyema (left). Interstitial bronchopneumonia (left).

Left pleural cavity.—In the left posterior axillary line there is a wound over the 9th. rib from which protrudes a rubber drainage tube discharging a small amount of foul smelling fluid. The lung is bound on the anterior margin by light fibrinous adhesions which become more dense as the empyema cavity is approached. Between the anterior margin of the lung and the pericardium there is an encapsulated pocket containing 50 cc. of thick greenish yellow pus. The base of the lung is densely adherent to the diaphragm by fibrinous adhesions. The pleura over the anterior part of the lower lobe is covered with a thin fibrinous exudate, while that over the anterior portion of the upper lobe is smooth and glistening. The pleura over the posterior surfaces of the upper and lower lobes is covered by a thick fibrinopurulent exudate, the parietal pleura corresponding with this showing a similar exudate. The empyema cavity contains only a few cc. of pus. *Right pleural cavity.*—There is no excess of fluid, the lung is free from adhesions, and the pleural surfaces are everywhere smooth and glistening. *Left lung.*—Except for the anterior margin of the upper lobe the whole left lung is consolidated and on section both lobes are greyish red in color with a few scattered areas which are more hemorrhagic. There appears to be no thickening of the bronchial walls although the bronchi are filled with purulent material. The mucosa is hemorrhagic. The bronchial lymph glands are slightly enlarged. *Right lung.*—The whole lung is uniformly air-containing except for a slightly firmer patch in the upper lobe which on section is slightly more greyish than the surrounding lung but does not seem definitely consolidated; the alveoli contain no plugs of exudate which project above the surface. There is no thickening of the bronchial walls although they contain a thick creamy pus. *Pericardium.*—Contains 50 cc. of slightly turbid fluid with a few floating strands of fibrin. The surfaces are slightly injected with an occasional petechial hemorrhage but they have not lost their gloss.

Cultures from the pericardial fluid gave *Streptococcus hæmolyticus* in pure culture. Those from the lung, pleural pus, and blood gave also *Streptococcus hæmolyticus* but contaminated with a Gram-negative bacillus.

Microscopic Examination.—The left lung shows a pleura which is converted into a thick layer of granulation tissue surrounded by dense fibrin. The interlobular septa are not conspicuous. The bronchi are scarcely altered. The alveolar walls are of normal thickness, the alveoli filled with leucocytes. There is little evidence of blood or even of any considerable amount of fibrin. In many places the alveolar walls become scarcely visible and a whole area seems to fuse into a mass of leucocytes. In other places the leucocytes in each alveolus are reduced to a dust of fragments. Many Gram-positive cocci are present among the leucocytes in the exudate. These are in very short chains, although there are sometimes as many as ten in a chain. They are quite large and elongated and grow rather stiffly and not in sinuous lines. One has the impression that they may be

pneumococci and not streptococci, although only the latter were cultivated from the lung and pleura. Their distribution and the nature of the lesion suggest this strongly. There are places in the same lung, however, beneath the thickened pleura but in areas not consolidated by the alveolar exudate in which the interlobular septa are thickened and contain thrombosed lymphatics. The alveoli contain fluid and desquamated epithelium and their walls are infiltrated with mononuclears. The bronchi are greatly thickened and infiltrated with mononuclears and show thrombosed lymphatics in their walls. In a word, the whole picture is that of interstitial bronchopneumonia.

The right lung seems normal. This may be a lobar pneumonia caused by the pneumococcus in which a secondary infection has overgrown the first.

Case 18.—W. H., age 27 yrs. Negro. Had German measles beginning on Apr. 28, 1918. No history of measles. Entered hospital May 7, when a diagnosis of lobar pneumonia involving the right lower lobe was made. Sputum was yellow, mucopurulent, and nummular, and was found to contain Pneumococcus Type II atypical, and influenza bacillus. Blood culture on May 8 gave a pure culture of Pneumococcus Type II atypical. There was acute pharyngitis. Died May 11, 1918, 2 a.m. Autopsy May 11, 1918, 10 a.m.

Anatomical Diagnosis: Clinical history of German measles. Lobar pneumonia (right upper and middle lobes). Interstitial bronchopneumonia (right middle and lower and left lower lobes). Serofibrinous pleurisy (right). Ulcerative laryngitis.

Left pleural cavity.—Contains no fluid. The surfaces are smooth and glistening. There are no adhesions although both costal and pulmonary pleura are extensively scarred. *Right pleural cavity.*—The surfaces are slightly glued together by a thin fresh fibrinous exudate which contains about 20 cc. of turbid brownish fluid. The surfaces are dulled over the whole lung. *Left lung.*—The lung is voluminous; the pleural surfaces are smooth. The upper lobe is cushiony and on section is air-containing throughout. In the lower lobe there are some firm patches in the posterior lower margin. Most of the lower lobe is air-containing, but there are some small patches of consolidation surrounded by zones of collapsed lung in the posterior portion. *Right lung (Fig. 54).*—The lung is very large and heavy, the upper and middle lobes except for the apical and anterior marginal portions being firmly consolidated. The lower lobe is largely collapsed and feels nodular throughout. On section the whole lower and posterior parts of the upper and middle lobes are consolidated and greyish red in color, each alveolus containing a plug of greyish exudate. The anterior portions are air-containing in general, but there are small patches of collapse and a number of small nodular peribronchial consolidations which can be traced to some extent into the area of lobar consolidation. In the lower lobe the tissue is air-containing and appears normal except in the lower posterior portion where there is a group of firm greyish nodules surrounded by collapsed lung tissue. The bronchi are reddened and contain a turbid frothy fluid. The bronchial glands are enlarged, soft, and grey. The mucosa of the trachea is deeply reddened. *Organs of the neck.*—The base

of the tongue and the pharynx in general are reddened. The tonsils are much enlarged. There are ulcerations over the back of the uvula and on the sides of the nasopharynx behind the pillars of the fauces. The posterior aspect of the epiglottis is reddened but not ulcerated, but the vocal cords are rather deeply ulcerated on both sides. The mucosa of the larynx is red and there is a ragged dull opaque area on the right side below the vocal cords.

Cultures at autopsy showed *Streptococcus hæmolyticus* in the heart's blood, left lung, and right pleura. Pneumococcus Type II atypical was recovered in culture from both lungs. Gram-positive diplococci were found in smears from the larynx.

Microscopic Examination.—Section of the vocal cord shows a superficial loss of substance with an inflammatory reaction and numerous streptococci on the surface of the necrotic material. There are remnants of coagulated epithelium and many fragmented leucocytes in the surface layer. The ulceration is not very deep, but the streptococci are found in the crevices of the tissue for a considerable distance below the surface.

Sections from the upper lobe of the right lung show a rather thin but dense fibrinous exudate over the pleura. The surface of this is sprinkled with Gram-positive micrococci in pairs and short chains.

The interlobular septa are wide and edematous and infiltrated with fibrin. The lymphatics are very large and are filled with blood, leucocytes, and mononuclear cells and fibrin. Gram-positive cocci are abundant among these cells.

The bronchi are rather delicate and although their walls are slightly infiltrated with mononuclear cells they are not thickened. Their lymphatics are plugged in exactly the same way as those of the septa and blood vessel walls. The alveolar walls are normal in thickness. The cavities are filled with a uniform exudate of polymorphonuclear cells with occasional red corpuscles and a network of fibrin. There are many cocci in pairs evenly distributed and often contained in leucocytes. In the margins of the area of consolidation some of the bronchi are more definitely thickened and infiltrated, and the same condition is found in the walls of some blood vessels. The alveolar exudate remains the same. In the lower lobe the condition is different. The pleural changes are about the same, the interlobular septa wide with lymphatics obstructed by massive thrombi. But the bronchi even to their smallest branches are greatly thickened. They contain massed leucocytes with streptococci and numerous influenza bacilli. The epithelium is in some instances destroyed and gives place to a necrotic lining layer. The walls are like a loose vascular granulation tissue with radially placed blood vessels and dense mononuclear infiltration. The alveolar walls are enormously thickened. New connective tissue has formed in their thickness as in the bronchial walls and they are densely infiltrated. The alveolar cavities are filled with blood in many places especially near the bronchi, but others are filled with fluid. All contain desquamated epithelial cells, some mononuclear cells, and dense plugs of fibrin. In many cases there is evidence of or-

ganization of the exudate, and columns of vascular granulation tissue extend into the bronchioles.

There is in this case a sharply defined lobar pneumonia in one part of the lung and an equally distinct and characteristic interstitial bronchopneumonia in other parts. From the one the pneumococcus was isolated, from the other the streptococcus. The lesions overlap scarcely at all. Influenza bacilli are scattered widely through the lung and are found in the larynx.

Several cases are separated to form this group because the lung shows a typical lobar pneumonia in one lobe and equally typical lesions of interstitial bronchopneumonia scattered through the remaining tissue of the same lung. This is especially striking in Cases 21 and 180 in which the pneumococcus was cultivated from the area of lobar pneumonia and the streptococcus from the bronchopneumonia lesions. Similarly these organisms could be demonstrated in as far as their morphology permits of their recognition, in characteristic distribution in the corresponding lesions. Influenza bacilli accompany the streptococcus in Case 180 but there are none in Case 21.

In several cases, Nos. 33, 36, and 45, in which there were definite lesions of lobar pneumonia in the lungs and in which the pneumococcus had been isolated from the blood during life or was isolated from other lesions at autopsy, it had been overgrown and killed by the streptococcus in the lungs without the development of typical streptococcal lesions there. In one case, No. 25, in which the pneumococcus was cultivated from the area of lobar pneumonia, it was nevertheless difficult to demonstrate many organisms in the sections. The lung was supposed to be in a state of resolution and it seemed probable that most of the organisms had disappeared. These examples tend to show that the pneumococcus is in many instances at least not a very persistent organism and may be supplanted by another such as the streptococcus. It is possible, although I think we have no strong evidence to prove it, that in the cases of the present series in which both organisms are present and alive with characteristic lesions produced by each in the lung, the pneumococcus in producing lobar pneumonia has acted as the forerunner and predisposing agent to infection with the streptococcus.

The lobar pneumonia in these cases is typical and within its area there are practically none of the interstitial changes which belong

to the streptococcus. The pleura over it is thin and shows no granulation tissue formation; the bronchi are filled with exudate but otherwise are scarcely altered. One passes abruptly from this into the rest of the lung where typical interstitial bronchopneumonia prevails. Even the pleura seems to become slightly thickened and hyperemic, and the interstitial changes in the bronchi and framework of the lung stand out clearly. But it is difficult to trace these lesions into the area of lobar pneumonia. It is as though the two processes excluded each other, as though the lobar pneumonia once developed formed a barrier to the invasion of the streptococcus but more especially to its power of stirring the tissues to a special type of reaction. One might say that having completed one maneuver of defense the tissues are unable to carry out a different one at once.

On the whole, one is impressed with the probability that the pneumococcus was the first invader. Whether the pneumococcus could gain a foothold in a lung already the seat of extensive lesions caused by the streptococcus seems questionable.

The following somewhat imperfectly studied case is introduced at this point because it seems important in suggesting the possibility that the combination of lobar pneumonia and interstitial bronchopneumonia may be brought about by the pneumococcus alone. In this instance culture from the sputum made 11 days before death showed the predominance of Pneumococcus Type II, and blood culture made on the same day showed the same type of pneumococcus. Unfortunately no cultures were made at autopsy and *Streptococcus hæmolyticus* was never demonstrated. Even in the tissues the organisms resemble morphologically the pneumococcus rather than the streptococcus. Influenza bacilli are not present in the sections. Nevertheless there are not only extensive lesions of the type of lobar pneumonia but also characteristic interstitial bronchopneumonic lesions. Since the latter changes have been shown to occur in cases of pure infection with *Bacillus influenzæ*, there is no reason to suppose that they could not be produced by the pneumococcus, but if this is accepted as the interpretation of the case, it stands alone in our material.

Case 196.—R. G., age 25 yrs. Admitted May 5. Died May 18, 1918. Onset about May 1 was gradual with slight pain in the chest, cough, and aching

in back and legs. Physical examination on admission revealed dulness over the right lower lobe, with fine râles, and high pitched expiration. On May 8 there was dulness with distant bronchial breathing over the right upper lobe. May 10, delirium. May 11, dulness and bronchial breathing over the left lower lobe. Voice sounds somewhat diminished as though by fluid. Cyanosis. Temperature high in the beginning, 103–105°F.; later 101–103°. During the last 4 days about 104°. Leucocytes 12,000–20,000. Sputum culture on May 7 showed as the predominant organism Pneumococcus Type II. Blood culture on May 7 showed Pneumococcus Type II in considerable numbers. Autopsy May 18, 4 hours after death, by Major Glomset.

Anatomical Diagnosis: Lobar pneumonia (left upper lobe). Bilateral interstitial bronchopneumonia. Acute splenic tumor.

Left pleural cavity.—There is no accumulation of fluid. The surfaces are glued together by fibrin over the upper lobe of the lung but are easily separated. *Right pleural cavity.*—No excess of fluid is present. The surfaces of the lower part of the upper lobe and the middle lobe are covered with fresh fibrinous exudate. *Pericardial cavity.*—Contains 100 cc. of clear straw-colored fluid. The surfaces are smooth. *Left lung.*—The lung is not collapsed. In the upper lobe there is a patch of coarsely granular consolidation which is greyish in color and involves the upper half of the lobe. The lower lobe is studded with small greyish nodules which are related to the bronchioles and surrounded by dark brown peripheral zones. *Right lung.*—The upper lobe contains a number of palpable nodules which on section are branched, grey or greyish yellow, and often surrounded by hemorrhage. There are in the anterior part two distinct areas of consolidation which are granular with hemorrhagic patches. In the lower lobe there are numerous small nodular areas of opaque yellowish grey. These branch and follow the bronchioles and several are seen within a single lobule (Fig. 55).

Microscopic Examination.—The area in the left upper lobe shows the alveoli filled with an exudate of leucocytes among which abundant pneumococci are found. In the lower lobe and elsewhere throughout the lung the lesions are typically those described as interstitial bronchopneumonia.

The pleura is practically unaltered. The interlobular septa are widened with some infiltration of cells but especially by the greatly dilated and thrombosed lymphatics which can be traced into the arterial and bronchial walls. The bronchi are filled with masses of leucocytes among which are Gram-positive diplococci, often separated by a space from the adjacent material and therefore appearing to have a capsule. These are sometimes in short chains of four or six but never in long sinuous chains. Influenza bacilli were carefully searched for, but were not found. The mucosa of the bronchi is greatly swollen and the wall thickened by the formation of a loose, very vascular granulation tissue with abundant mononuclear wandering cells. The adjacent alveoli are filled with dense plugs of fibrin with many red corpuscles and some desquamated epithelial

cells. The fibrin is in many places partly or completely organized and clothed in a single layer of epithelium. Hemorrhage of a fresh character is, however, prominent. The alveolar walls and indeed all the tissues of the lung about the infected bronchi are thickened and infiltrated with mononuclear cells.

In connection with these peribronchial changes there are numerous small patches of consolidated lung tissue in which the alveoli are packed with leucocytes together with phagocytic epithelial cells. In these areas the cocci are scattered in great abundance, although elsewhere they are practically confined to the bronchial contents and lymphatics.

6. Old Empyema.

Case 52.—H. C., age 24 yrs. Entered the hospital Jan. 12, 1918, with fever of sudden onset beginning 3 hours before he was brought to the hospital. Breathing was rapid and he was expectorating a reddish foamy sputum. Dulness over right lower chest behind and breath sounds scarcely audible. On Jan. 15 the breath sounds became tubular over this area, but on Jan. 26 they were again inaudible, although the dulness persisted. Pus was aspirated from the chest and found to contain pneumococci. On Jan. 28 the 8th rib was resected and the thorax drained. The temperature which was irregular and ranged up to 104° F. fell and remained normal until about the middle of February when it again became irregularly elevated. On Feb. 22 the 7th rib on the right side was resected. Smears from the pus discharged showed a Gram-positive diplococcus, but no culture was made. After the second operation the patient's temperature became practically normal and he seemed to be doing well. He died suddenly upon sitting up in bed on Mar. 4. Autopsy Mar. 5, 1918.

Anatomical Diagnosis: Empyema (right) with drainage. Atelectasis of right lung. Embolism of pulmonary artery.

Left pleural cavity.—Contains no excess of fluid; surfaces are smooth and glistening. *Right pleural cavity.*—There is a small partly healed wound in the right axillary line over the 8th rib. In the right midscapular line there is a fresher wound from which blood and pus exude through a rubber tube. On opening the thorax it is found that the mediastinal tissues on the right side are infiltrated with a purulent exudate. There are dense adhesions between the base of the lung and the diaphragm and with the costal pleura over the whole lower and anterior part of the lung. From the apex downward and extending half-way forward there is an unobliterated part of the pleural cavity which is lined with thick red velvety granulation tissue and filled with purulent fluid. It is found that the old operation wound extends through the 8th rib, a part of which has been removed. This wound is incompletely healed internally. The second operation wound involves the same rib with removal of another portion. *Left lung.*—Normal throughout, but in the pulmonary artery there is impacted a folded mass of thrombi which are loose but large enough to

occlude it. These thrombi are nowhere adherent and the wall of the blood vessel is normal. *Right lung.*—The pleura on the upper posterior aspect is covered with granulation tissue as described. The bronchi are slightly reddened. On section the lower lobe posteriorly is completely collapsed, but there is no area of consolidation. The upper and middle lobes are air-containing throughout. The pulmonary artery contains several large thrombus masses one of which is bent upon itself and glued together in that position by a fresh clot. Another is smaller and hollowed out. They are sufficient to occlude the artery, the wall of which is smooth except for one small patch which is slightly roughened.

The iliac veins are normal on both sides and the walls perfectly smooth. The femoral veins are smooth as far as they could be opened and nothing but liquid blood could be pressed up from them. The pelvic veins show no thrombi. The vena cava is smooth throughout. So too the azygos, the jugulars, subclavians, and other veins seem quite smooth and contain no thrombi. The heart is not enlarged and rather flabby and soft. The endocardium is smooth throughout; the valves are delicate and competent. There are no thrombi.

Smears from the lung tissue and pleural fluid showed many Gram-positive diplococci often in short chains, but in cultures these were overgrown by a Gram-negative bacillus with putrefactive odor.

Microscopic Examination.—The right lung shows in part a thick fibrous pleural covering. Where it adjoins the empyema cavity and in the interlobar adhesions there is a vascular granulation tissue filled with mononuclear and plasma cells. There are certain round empty spaces surrounded by giant cells, evidently produced by some foreign body. The lung itself is extensively collapsed and the alveoli are filled with pigmented epithelial cells. This represents a local chronic passive congestion caused by the collapse. Otherwise no especial alteration of the lung substance is to be observed. The left lung is normal. The thrombi in the pulmonary artery show the characteristic architecture with strands of platelets bordered by leucocytes. They are fresh and show no signs of organization.

Case 53.—R. J. O'M., age 23 yrs. History negative. On Feb. 1, 1918, he had a severe chill followed by high fever and a pain in his right side and was admitted to the hospital. Physical examination at this time was negative although the temperature was 102.4° F. and the pain in the side distressing. On Feb. 6 leucocytes were 23,000 (polymorphonuclears 94 per cent). There was some abdominal pain and rigidity. Temperature ranged from 101–104.6° F., respiration 20–40. On Feb. 12, 150 cc. of pus were aspirated from the left chest and a streptococcus was found in smears and cultures. On Feb. 14 the 7th rib was resected under local anesthesia. Temperature remained as before and patient died on Mar. 5, 1918. Autopsy Mar. 6, 1918.

Anatomical Diagnosis: Multiple pulmonary abscesses. Bilateral empyema.

Left pleural cavity.—Partly obliterated by fibrinous adhesions in the upper portion, while in the lower part the lung is retracted from the chest wall and the pleural surfaces are covered with a thick fibrinopurulent exudate. In the axillary

line over the 11th rib there is an incision wound and a portion of the rib has been removed. Very little fluid remains in the cavity. *Right pleural cavity.*—Partly obliterated by adhesions, but in the lower portion there are about 300 cc. of purulent fluid. The lower lobe of the lung is collapsed and the pleural surfaces are covered by a yellow fibrinopurulent exudate. The anterior border of the lung is adherent to the pericardium and beneath it is an encapsulated pocket containing about 50 cc. of turbid fluid. *Left lung.*—The lower lobe is collapsed, but the whole lung can be inflated artificially except the posterior inferior portion of the upper lobe. The upper lobe is air-containing on section except for an area 7 cm. in diameter in the posterior part, which is greyish red and consolidated. It includes several soft yellow areas which project above the cut surface. In the lower lobe there are several yellow areas which are irregular in outline and frequently confluent and surrounded by consolidated lung. These are fairly firm and contrast sharply with others which measure about 0.5 to 1 cm. and are slightly elevated. The latter are filled in the center with a dark greyish fluid which can be readily expressed, leaving a crater-like depression with necrotic sides. They are not surrounded by so much induration as the firmer yellow areas. Bronchial glands are enlarged and softened but contain no foci of caseation. *Right lung.*—The pleura is slightly thickened and covered with a ribbed fibrinous exudate. In the upper lobe the texture is coarse, and the septa are prominent. There is a yellowish grey flecked consolidation in the lower part of the upper lobe and in the middle lobe. This is not uniform but appears to form a sort of network of alternating spongy and grey translucent tissue often mottled with yellow. There are several abscesses measuring 3 to 5 mm. or even more and surrounded by a halo of red. The lower lobe is air-containing but has one abscess about 1 cm. in diameter in its upper portion. The lymph glands are enlarged and soft.

Cultures at autopsy gave the hemolytic streptococcus in blood and pleural and pericardial fluid, but in each case it was overgrown by a Gram-positive bacillus.

Microscopic Examination.—The pleura over the left lung is covered with thick granulation tissue and fibrin. In places the interlobular septa are thickened and contain lymphatics filled with bacteria and leucocytes. In certain areas the lung substance is not much altered except that throughout sharply outlined patches which reach up to the pleura the alveoli are filled with a purulent exudate with abundant bacteria. The neighboring alveoli are flattened and collapsed. In the central portion the bacteria form a cloud and the cells including the walls of the alveoli have become necrotic. In other areas there are no abscesses but there is an advanced organization of exudate in the alveoli. The strands of new connective tissue are covered with epithelial cells. In the center of some of these strands there are spaces lined with epithelium which look almost as though it were attempted to produce new alveoli there.

Case 57.—H. H. H., age 18 yrs. History negative. On Jan. 18, 1918, the patient had a cold followed by weakness and anorexia. Since Jan. 27 has felt worse and there has been pain in the right chest. On Feb. 1 had a definite chill and was admitted to the hospital. Physical examination was negative except for signs of fluid in the right pleural cavity. Temperature 101° F., pulse 98, respiration 23. Leucocytes 23,400. On Feb. 3, 30 cc. of cloudy fluid were aspirated from the right chest, and streptococci were found in smears and culture. This was repeated on Feb. 8, and on Feb. 13 the 7th right rib was resected and drainage established. On Feb. 18 the temperature rose to 102.4° and continued to range between 100° and 104° until death on Mar. 8, 1918. Autopsy Mar. 8, 1918, at 1.30 p.m.

Anatomical Diagnosis: Empyema (right side) with drainage. Atelectasis of right lung. Subacute pericarditis.

Pericardial cavity.—Contains a small amount of fibrinopurulent exudate. The parietal and visceral layers of the pericardium are granular and covered with fibrin and in a few places are bound together by frail adhesions. The surfaces are flecked with hemorrhages. *Left pleural cavity.*—Contains no fluid; the surfaces are smooth and glistening. *Right pleural cavity.*—In the right axillary line there is a wound 10 by 5 cm. with necrotic edges. This extends into the posterior part of the pleural cavity which contains about 400 cc. of dark greenish foul smelling pus. The pleural surfaces are covered with a greenish fibrinopurulent exudate about 5 mm. in thickness. The surfaces are bound together along the anterior margin of the lung. *Left lung.*—The lung is crepitant throughout and is everywhere easily inflated. On section there is no consolidation and the lung is normal in texture. *Right lung.*—The lung is collapsed against the vertebral column and is heavy and airless. There is no consolidation and the bronchi do not seem to be thickened but luminaare somewhat dilated. The bronchial mucosa is pale grey. Bronchial glands slightly enlarged and soft.

Cultures are not recorded from this case.

Microscopic Examination.—The left lung appears to be normal. The right lung is covered with a dense flattened fibrous granulation tissue over which is a thick layer of purulent material. The interlobular septa are very wide and dense like hard old connective tissue. The lymphatics where they are discoverable are embedded in this dense tissue, not enlarged but filled with leucocytes and mononuclear cells.

The bronchi are rather thick walled but have a scarred look as though they had receded from a previous thicker state. They are not densely infiltrated but are commonly full of leucocytes and other cells. The alveolar walls are very thick and are not only infiltrated with mononuclears but show an actual connective tissue thickening. They are usually empty and quite collapsed.

Case 165.—E. B. deL., age 22 yrs. On Apr. 18, 1918, developed German measles which was succeeded on Apr. 24 by mumps. Present illness began

Apr. 27 with a pain in the right chest. Next day the diagnosis of lobar pneumonia with consolidation of the right lower lobe was made and confirmed by radiogram. Empyema developed Apr. 30, and was recognized by aspiration of fluid which contained *Streptococcus hæmolyticus*. Died May 4, 1918, at 5.35 a.m. Autopsy May 4, 1918, 5 hours after death.

Anatomical Diagnosis: Old interstitial bronchopneumonia with empyema (right). Acute fibrinopurulent peritonitis. Phlegmonous laryngitis.

Left pleural cavity.—Contains very little fluid. The surfaces are smooth anteriorly but posteriorly are dark blue and covered with hemorrhagic areas and fibrinous exudate. *Right pleural cavity.*—Contains about a liter of turbid fluid which is of the color of pea soup. There are a few floating shreds of fibrin. The right lung is flattened against the outside of the pericardium and is slightly adherent. The surfaces of the pleura are nodular and roughened and covered, except over patches where the lung has adhered, with yellowish exudate. Between the middle and lower lobes there are two pockets filled with yellow fibrinopurulent material. *Left lung.*—The lung is voluminous but the lower lobe is somewhat collapsed. On section the upper lobe is dry, coarse in texture, rather pale red; and everywhere air-containing. The anterior and upper parts of the lower lobe are quite similar, but the lower and posterior parts are dark red and collapsed with some projecting nodules which have pale grey centers. The bronchi in this lobe are deeply congested. Bronchial glands moderately enlarged. *Right lung.*—Small, pasty, and airless. On section it is almost entirely collapsed, but there is no consolidation except for a few fairly firm projecting nodules in the lowermost part of the lower lobe. *Larynx.*—The epiglottis and aryepiglottic folds are greatly swollen and vary in color from greyish red to opaque yellow. On incision the swollen tissues are found to be infiltrated with a purulent fluid. There are slight superficial ulcerations at the brim of the larynx, but the vocal cords are not altered. The trachea is slightly reddened. There are opaque yellow patches on the wall of the pharynx laterally. Tonsils reddened but not swollen. *Other organs.*—The peritoneum contains a yellow fibrinous exudate which glues together the intestinal loops and is especially abundant over the right lobe of the liver. There are two needle puncture wounds in the right axillary line on a level with the nipple. There are one or two points of hemorrhage in the diaphragm and there is a small opaque yellow point in the liver surrounded by a hemorrhagic area corresponding fairly well in position with the points of hemorrhage in the diaphragm.

Microscopic Examination.—The right lung shows a thick layer of granulation tissue replacing the pleura and covered with fibrin. The lung is completely collapsed but it can be seen that the bronchi and blood vessel walls are moderately infiltrated with mononuclear cells. The alveolar walls are thickened by a cellular infiltration and their cavities filled in part with fibrin and desquamated epithelium. Streptococci are seen in the bronchi associated with large numbers of Gram-positive spore-bearing bacilli.

Section of the arytenoepiglottic fold of the larynx shows superficial ulceration. There is the most intense phlegmonous inflammation of the underlying tissue, part of which is spread wide by the accumulation of fluid, fibrin, and cells. But all this area of edema is necrotic and is found to contain myriads of streptococci which form a dense feltwork in the tissue.

No cultures were recorded.

Case 183.—H. P., age 24 yrs. Began May 2, 1918, with sore throat. Later there was pain in the chest beginning about May 5, and on May 7 the physical signs indicated a lobar consolidation of the right lower lobe. There was dulness to flatness over the right base with bronchophony and bronchial breathing. This was confirmed by the radiogram and the suggestion was made that there might be fluid in that pleural cavity. This was made certain by aspiration on May 10, and on May 12 a bloody fluid was aspirated from the pericardial cavity. The latter fluid gave on culture a mixture of *Streptococcus hæmolyticus* and influenza bacillus. The pleural fluid also gave the same combination. Blood culture made on May 7 was negative. Sputum on that day was tenacious and mucoid with no blood and contained both the hemolytic streptococcus and influenza bacillus. Died May 11, 1918, at 4.30 a.m. Autopsy May 11, 12 hours after death.

Anatomical Diagnosis: Slight pulmonary changes. Bilateral empyema. Acute fibrinopurulent pericarditis.

Left pleural cavity.—Contains about 150 cc. of yellowish turbid fluid. The surfaces are dull and the lung is slightly adherent to the pericardial sac and to the diaphragm. The tissues of the anterior mediastinum are thickened by an accumulation of turbid fluid. *Right pleural cavity.*—Contains 1,400 cc. of turbid fluid with much brown sediment which can be stirred up easily. It has the appearance of thin pea soup. The surface of the pleura is deeply reddened and is covered with a layer of yellow fibrin which is easily removed. There is a thick layer of fibrin between the lung and the right side of the pericardial sac. *Pericardium.*—The pericardial sac is enormously thickened and contains about 300 cc. of turbid yellowish fluid. The surface is covered with fibrin which overlies a translucent reddish granulation tissue in which there are some hemorrhages. *Left lung.*—The lung is heavy and blue, and although the upper lobe is largely air-containing the lower lobe is collapsed and in the posterior portion dark bluish red and pasty. There are patches of hemorrhage under the pleura between the lobes. On section no areas of consolidation are to be found. *Right lung.*—The lung feels flabby and is airless. No areas of consolidation can be felt and upon artificial inflation the whole is distended. On section there are no solid portions except for a small encapsulated tubercle at the apex. The bronchial glands are enlarged and purplish in color and those at the bifurcation of the trachea contain a few caseous tubercles. The tracheal mucosa is deeply reddened.

Cultures at autopsy showed the hemolytic streptococcus in the heart's blood, both lungs, right pleura, pericardium, and mediastinum. The influenza bacillus was found in cultures from the right pleura and pericardium.

Microscopic Examination.—The pericardial surfaces are covered with an exudate of fibrin, but there is no underlying granulation tissue. The epicardium is edematous and infiltrated with cells, but the lining pericardial cells are still visible in most places. The superficial layer of the heart muscle is spread apart by an infiltration of leucocytes and mononuclear cells. The mediastinal fat bordering the pleura is edematous and infiltrated with leucocytes. In places the tissue has disappeared and given place to a mass of disintegrated leucocytes. Here streptococci in chains are found in enormous numbers. So too in the cellular debris which adheres to the surface of the fibrin on the pleural side, but no organisms are found in the denser fibrin or in the tissue where it has not undergone necrosis.

The right lung shows several caseous tubercles in one area and around them the connective tissue structures are dense and thickened. Throughout the rest of the lung, however, there is no definite alteration of interlobular septa, bronchi, or alveoli, except near the surface where there are patches of edema and hemorrhage with desquamation of the alveolar epithelium and fibrinous exudate in the alveoli; even here the bronchi are little changed. The pleura is converted into a thick layer of granulation tissue with overlying fibrin.

In the left lung over which the pleura is scarcely thickened it is similarly difficult to find any definite lesion in the lung. There are, however, patches beneath the pleura in which the alveoli are filled with partially organized exudate which is ensheathed in a layer of epithelium.

This case is one which would offer the greatest support to those who favor the idea of a primary pleurisy. The duration was only 9 days in all and only 6 days after the first pain in the chest was felt.

The question as to the mode of infection of the pleura has been discussed above and the cases of this group are detailed as examples in which it is difficult to determine the mechanism of infection. There are some who argue for the primary and independent infection of the pleura since they find cases such as these in which it is not easy to observe striking changes in the lungs other than the collapse which is caused by pressure. They must then have recourse to the idea that the bacteria are brought to the pleura by the blood stream because there is scarcely any other way in which the pleura could be infected. Since we have so regularly found cultures of the circulating blood sterile, this explanation does not seem acceptable.

It seems, on the contrary, necessary to hold to the idea that infection takes place by way of the trachea and bronchi and extends thence by way of the lymphatics of the lung (especially after they are obstructed by thrombi) to the pleura. The difficulty in explaining this origin of the pleurisy in such cases as have just been given is probably

due to the fact that they are old cases in which the empyema has persisted for a long time during which it is conceivable that the pulmonary changes might have been healed. In Case 52 especially, the man was convalescent except for remains of his empyema, but died of pulmonary embolism. In Case 53 abscesses are present but there are remains of an old pneumonia which show as organized exudate, in Case 57 great thickening of the interlobular septa and alveolar walls, in Case 165 even recognizable remains of a diffuse interstitial bronchopneumonia. Even in Case 183, which was of only 9 days duration and in which the explanation of the pleurisy is especially difficult, there are slight changes in the lungs. But in all the others the tracing of the development of the lesions in the lungs which at first are not accompanied by pleurisy, into their later stages in which the lymphatics become so strikingly involved and pleurisy arises, seems to show clearly the dependence of the pleurisy upon intrapulmonary lesions.

7. Empyema.

The tabulation and analysis of 53 cases of all the types of pneumonia as they occurred shows an extraordinary frequency of pleurisy with fibrinopurulent effusion which is especially due to the activity of the hemolytic streptococcus. The term empyema which is in common use is not sharply limited in its significance, for although it should mean the filling up of the pleural cavity with pus it has been made to do duty in this epidemic for all those forms of pleurisy with extensive effusion in which although the exudate becomes distinctly purulent if the patient survives long enough, it is frequently in the earlier stages a thin watery brownish turbid fluid with a granular sediment and floating shreds of fibrin.

The profusion of this fluid exudate is shown crudely by the statement that although in thirteen of these cases the chest had been evacuated by resection of a rib and drainage, more than 28 liters of fluid were measured out at the autopsies.

In only seven of these cases was a fluid exudate in any considerable quantity found on both sides, and then usually there was a rather small amount only on the less affected side. At the autopsies fluid was found in quantities varying from 10 to 4,000 cc., but it is possible that

this does not represent the extremes. 1,000 to 1,500 cc. were commonly found.

In the most acute cases in which the streptococcus has produced either peribronchial or lobular lesions in the lungs, the pleura is generally empty and its surfaces are smooth and glistening. This was true in practically all those in which death occurred within 8 days of the onset of the disease and also when fresh lesions developed in the lung opposite to that in which an old affection was found. But when the lung had been infected for 10 days or 2 weeks or more, the pleura nearly always contained an exudate. Then the surface was covered with fibrin overlying petechial hemorrhages, either as a rough thin layer or a thicker shaggy or ribbed coat of yellow or yellowish green.

The character of the fluid in these earlier cases is so distinctive that at the risk of repetition it should be described once more. Numerous epithets have been applied to it—it is like thin pea soup, like turbid urine, like unstrained bouillon, like muddy water, but generally like thin pea soup. It has often a greenish cast and the granular sediment which can be stirred up in a cloud tends to settle in the bottom of the pleura. Strands or flakes of fibrin float up in this or hang from the wall.

Later it rapidly becomes more turbid and thick and assumes a more purulent character, and especially when it is confined in localized areas by adhesions it is often thick whitish green pus. When the pleural cavity has been laid open by resection of the rib the fluid changes somewhat, and if it is secondarily infected with putrefactive organisms it becomes very foul and often blackish green.

It is most characteristic of the streptococcal pleurisy that organization of the fibrinous exudate occurs with great rapidity, causing the pleural membrane to become greatly thickened and converted finally into a thick red velvety granulation tissue from which the dense overlying fibrin can often be brushed off. This is so regular an occurrence that it is noted in 32 of the 42 cases of streptococcal pneumonia analyzed here, whereas it was observed in only one of the seven cases caused by the pneumococcus and then to a slight degree only. It is not meant that the organization of exudate and the consequent thickening of the pleural membrane is necessarily rare in other forms

of infection, but the rapidity and regularity with which this occurs in the streptococcal infection are striking. The formation of adhesions between the lung and the surrounding tissues is of interest to the surgeon. In many cases there were no adhesions when a great quantity of fluid exudate had accumulated and then the lung was found collapsed and retracted and flattened against the mediastinal tissues or occasionally, receiving still a little air, floating on the fluid. The extreme collapse of the lungs and their consequent reduction to a blue pasty mass in which firm nodules were palpable was another striking feature of these cases.

In many instances there were adhesions which limited the displacement of the lung by the fluid or limited the distribution of the fluid. Many of these seemed to be old adhesions which antedated the present disease, others appeared to have been formed in the early days of the disease as a gluing of the surfaces with fibrin, and others still were found in later stages forming a limiting wall about the more or less localized empyema cavity. Occasionally adhesions were obviously due to the presence of an intrapulmonary abscess or other lesion which reached the pleura. In one or two cases such necrotic patches of the pulmonary pleura were well protected by the formation of adhesions.

The topography of adhesions in connection with well developed empyema is of especial interest. Occasionally what seemed to be old adhesions over the whole upper lobe maintained the position of that lobe, while the lower lobe was forced upward by the fluid collected below. In other cases dense adhesions between parts of the lobe or parts of the pulmonary and costal surfaces left communicating channels connecting with the main cavity.

Encapsulated pockets of pus are sometimes found and in this series there were thirteen examples of this. In nine cases the pus was imprisoned between the mesial surface of the lung and the outside of the pericardial sac by adhesions between the anterior margin of the lung and the mediastinum, between the base of the lung and the diaphragm, and between the posterior margin of the lung and the posterior mediastinal tissues. Sometimes as much as 300 cc. of pus were thus enclosed. Of the nine cases three also showed pockets of pus in the adhesions between the lobes of the lung and there were

three others in which this occurred alone. In two cases there was found a collection of 100 cc. of green pus between the base of the lung and the diaphragm, and in one or two there were small collections walled off between the lung and chest wall. While many cases showed encapsulation of exudate at autopsy, it is possible that such pockets were broken in some of the thirteen cases in which the pleura had been opened by the surgeon, although in three of the cases in which pockets of pus were found in these situations at autopsy there had been resection of a rib and drainage. On the whole this is not a large proportion, but the failure to discover such pockets is a constant source of anxiety to the surgeon.

There were eleven cases of lobar pneumonia caused by the pneumococcus, among which two were also infected with the streptococcus and showed large purulent pleural exudates. The others had little or no fluid exudate, but the pleural surfaces were glued together by fibrin. There was no organization of the fibrin nor any thickening of the pleural membrane by granulation tissue.

This stands in sharp contrast to the condition in the streptococcal cases. Indeed in those instances, such as Case 21, in which there were both pneumococcal lobar pneumonia and interstitial bronchopneumonia in the same lung, the pleura was thickened over the lobe affected by the streptococci but thin over that lobe occupied by the lobar consolidation.

There was one case, No. 188, of lobar pneumonia with organization of the exudate over which the pleura was slightly thickened, but another case, No. 45, of long standing in which both pleural cavities were obliterated by fresh fibrous adhesions. In both these cases the lungs contained abundant influenza bacilli. In most of the cases of lobar pneumonia death occurred while the pleura was covered with unchanged fibrin.

The impression seems to prevail that abscess-like accumulations of pus in the mediastinal tissues are common in the cases of streptococcal empyema. I think, however, that it is usually the pocket of pus between the mesial surface of the lung and the mediastinal tissues which is mistaken for a mediastinal abscess. Nevertheless there was in Case 183 a moderate accumulation of turbid purulent fluid in the tissue of the anterior mediastinum below the level of the remnant of the thymus, and a similar infiltration was observed in Case 52.

8. Epidemiological Relations.

The relation of measles to severe and fatal pulmonary inflammations has always been recognized. So too the importance of measles as a predisposing disease in epidemics of pneumonia has been fairly accurately appraised since early times and is definitely mentioned by the writers who describe the pandemic of 1812.

It is not known, however, in just what way measles facilitates the invasion of the streptococcus. Very little is known of the actual changes produced by measles in the respiratory tract. In all the great epidemics of measles death appears to have depended largely upon pulmonary infection or else upon the fatal effects of exposure, starvation, and lack of care that accompanied several of the outbreaks among savage people.

Such autopsies as have been performed upon cases of supposedly uncomplicated measles have left us with only very vague results, and we are in no better position to estimate the part played by measles in the production of the fatal lesions than were those who described the epidemic during the War of 1812, except that we know that in our experience the anatomical changes in the bronchi and lungs are always associated with the presence of *Streptococcus hæmolyticus*. We know further that this streptococcus can cause the same changes without any predisposing measles and that they are produced in practically identical form in children after whooping cough and diphtheria and, from at least one case in an adult, after scarlet fever. We are therefore inclined to ascribe none of the actual anatomical changes which we can see to measles, but all to the secondary invader.

Nevertheless it is certain that measles plays an important part. In the Texas autopsy material, if we exclude 7 cases of uncomplicated lobar pneumonia due to the pneumococcus, there were 28 cases of streptococcal pneumonic infection, and of these 15 had recently had measles or were still covered with the rash. At Camp Dodge, Iowa, of 23 cases of streptococcal pneumonia, 8 had just passed through measles and 3 had had German measles. In this epidemic, however, these particular figures are misleading since they depend upon a fresh outbreak of measles pneumonia at the end of a long epidemic in which measles had played no considerable part, the few cases of measles having been thoroughly isolated in a distant barrack.

This accidental and sudden flare up of streptococcal bronchopneumonia in a barrack of measles patients among whom there had previously been no pneumonia, although a great epidemic was prevailing in the general camp, brings out two important points. First, that in this camp the streptococcus had gained a foothold independently of measles and produced an extensive and fatal epidemic of interstitial bronchopneumonia. Second, that when this infection did attack patients ill with measles the bronchopneumonia was much more severe and more quickly fatal. It was among these cases that we found the freshest lesions in patients who had died 4 to 8 days after the beginning of the bronchial symptoms. It was almost exclusively among these patients too that we observed the hoarseness and loss of voice which was explained by finding deep ulcerations of the vocal cords and laryngeal walls.

Therefore it seems justifiable to conclude that measles brings about a most effective predisposition to infection with the hemolytic streptococcus, although the streptococcus can invade and even cause great epidemics without its aid. In addition it may be emphasized that the combination of streptococcus infection with measles seems to produce a far more intense affection than the streptococcus alone, but in this we cannot yet recognize any anatomical changes that are due to measles itself.

At this point it may be said that these epidemics of streptococcal bronchopneumonia have not been confined to troops in camp but have existed in a more moderate form in the civilian population at many points. Among children the production of typical interstitial bronchopneumonia after measles and whooping cough has been recognized at autopsy in a number of cases.

SUMMARY.

During the winter and spring of 1917–18 there has prevailed a great epidemic of measles among the troops quartered in the army camps. It has been especially prevalent in the southern camps. This is probably partly due to the fact that the recruits in the South are largely from remote rural districts and are therefore more susceptible than those in northern camps where the proportion of city dwellers is larger and the intercourse of rural dwellers more extensive.

Associated with this epidemic in the southern camps there has been a great epidemic of a peculiar form of pneumonia caused by a hemolytic streptococcus.

Although this was found to follow measles in a great proportion of cases it also affected men who were recovering from some other disease such as scarlet fever and frequently spread among those who had suffered no predisposing disease. In at least one northern camp in which we worked there had been no significant outbreak of measles, but an independent epidemic of streptococcal pneumonia arose and caused great ravages. Toward its conclusion some patients with measles who were isolated in a distant barrack became infected and died rapidly with a most intense and acute form of the disease.

Lobar pneumonia caused by the several types of pneumococcus occurred throughout these epidemics, but the number of cases seemed not especially different from what ordinarily occurs during those months of the year. In some cases lobar pneumonia was combined with streptococcal pneumonia. Otherwise there was nothing peculiar about the pneumococcal infections.

The streptococcal infection seems to occur by way of the upper respiratory tract and the illness commonly begins with a sore throat, fever, and cough. The physical signs in the lungs are often indefinite until evidence of accumulation of fluid in the chest appears. Dyspnea of the most extreme type especially during inspiration is characteristic and results in a livid cyanosis. Many of the patients become hoarse or lose their voices entirely. They are alert, apprehensive, and sleepless, and there is often delirium.

Two main types of pulmonary lesions have been described, although these are frequently combined.

The first, designated interstitial bronchopneumonia, is essentially the result of infection of the bronchioles with large numbers of hemolytic streptococci which leads to great changes in their walls and in the adjacent pulmonary tissue.

The most striking accompaniment of this is a patchy atelectasis or collapse of the lung affecting those portions formerly supplied with air by the obstructed bronchi together with the formation of firm nodules of consolidation about the terminal portions of the bronchi. In addition to this there is extreme engorgement of the blood vessels of the lung and hemorrhage into its tissue about the nodules of consolidation.

The walls of the bronchi themselves become densely infiltrated with mononuclear cells and thickened. Extreme hyperemia and the new formation of blood vessels and of connective tissue add greatly to this thickening and to the deformity of the wall. In some cases the whole lining becomes necrotic and coagulated and constitutes a diphtheritic pseudomembrane. Corresponding with the changes in the bronchial wall are those in the walls of the adjacent alveoli which become greatly infiltrated with mononuclear cells, the alveolar capillaries are distended with blood, the epithelium is proliferated rapidly and desquamated into the alveolar cavity. These cavities are found to be filled in the neighborhood of the bronchus with blood, dense fibrin, a few mononuclear cells, and greater numbers of desquamated epithelial cells. Those which are more distant contain diminishing numbers of these cells but are filled with a thick viscid fluid. This rather gelatinous edema gives a semblance of confluence between these areas of consolidation before it is really completed. But there are many cases in which the changes are restricted to the neighborhood of the bronchioles and separated from each other by wide areas of normal air-containing tissue. Streptococci may be found in tangled masses in the lumen of each bronchus or bronchiole mingled with the leucocytes of the exudate, but in most instances they are not found in appreciable numbers in the substance of the tissue or in the alveolar contents.

The lymphatics which run from the pleural network by way of the interlobular septa, bronchial walls, and blood vessel walls to the nodes at the hilum of the lung quickly become a channel for the transport of these bacteria. Great numbers of them are found in these canals and in the sinuses of the lymph nodes at the hilum where they appear to be halted. They cause thrombosis of the lymph channels which become distended to an enormous size and appear to the unaided eye as most conspicuous beaded white strands on the cut surface of the lung extending to connect with the pleural network which may be in places similarly injected and distended with a white infected semipurulent thrombus. These lymphatics are often 2 to 3 mm. in diameter, which is not especially greater than the diameter of the normal channels, but they become conspicuous in a way seldom observed because of their yellowish white contents. Sometimes they might almost be confused with the obstructed bronchi.

It is thought that bacteria extend by growth along these obstructed channels in both directions and thus passing from the lung to the pleura (in a direction opposed to that of the current in unobstructed lymphatics) infect the walls of the pleural cavity and set up the intense inflammation with outpouring of fluid exudate. The pleura itself and all the interlobular septa become edematous and permeated by a serofibrinous exudate with wandering cells.

From the beginning of the infection of the pleura the effusion of fluid exudate becomes a dominant feature of the whole process both in the clinical signs and the anatomical changes. It takes place with extraordinary rapidity and compresses the lung to such a degree as to complete the atelectasis.

When the exudate is present in such large quantities as 2 or more liters the lung becomes a completely airless pasty blue clump of tissue which is usually plastered against the pericardium or back against the side of the vertebral column. The idea that the opening of the chest with the production of pneumothorax could accentuate the collapse of that lung seems rather bizarre, but its ill effects may well come from the influence on the rest of the respiratory tract.

Later the pleural exudate becomes more distinctly purulent, having begun as a thin greenish brown turbid fluid filled with streptococci and disintegrated leucocytes and shreds of fibrin.

Rapid organization of the inflammatory exudate is everywhere characteristic. This affects the alveoar and bronchial contents and they are replaced in part by connective tissue. It results particularly in interstitial new growth of connective tissue which thickens the alveolar walls, the bronchial walls, the adventitia of blood vessels, and the interlobular septa. The thrombosed lymphatics become organized and occluded permanently by fibrous tissue so that new ones must eventually be formed, and absorption in the meanwhile is greatly hampered.

Most striking of all is the rapid organization of the thick layer of fibrin which generally covers the pleura. This results in the formation of thick red vascular granulation tissue on the pleural surface. Adhesions between contiguous surfaces are quickly rendered permanent and in the later stages encapsulated pockets of intrapleural origin filled with pus are not infrequently formed and offer difficulties to the surgeon.

Occasionally large portions of the inflamed lung become necrotic. Such necrotic material is loaded with streptococci and is often discharged through the bronchus, leaving a cavity. When this cavity communicates with the pleura too, pneumothorax may result, or if the chest is already open it appears as a bronchopleural fistula.

Such a disease of the lung betrays at every point its tendency to heal. Everything described above, except perhaps the bronchial exudate, the pleural exudate, and the intrapulmonary necroses or abscesses, partakes of the nature of a barricading process. All the changes tend to limit the advance of the streptococci and indurate the tissue everywhere to this end. The alveolar exudate with its dense fibrin later replaced by connective tissue, the thrombosis of the lymphatics, the thickening and granulation tissue formation in the bronchial walls, interlobular septa, and pleura, and the widespread hyperplasia of lymphoid tissue throughout the lung are all evidences of a considerable power of resistance which allows the body time for defence. The infection is fairly well localized in the respiratory tract and there is no septicemia until perhaps the last few hours of life. Other organs therefore suffer little. The upper respiratory tract is all infected, and ulcerative changes have been described.

The second type, designated arbitrarily lobular pneumonia, is composed of cases in which the streptococci invade in the same way. One does not know how to distinguish the symptoms and yet at autopsy although sometimes even the lungs may look much the same at a casual glance they are really different. There are no firm peribronchial nodules. Instead there are patches of consolidation in which the alveoli are filled with blood and leucocytes and enormous quantities of streptococci. No interstitial changes are there and no signs of resistance; widespread necrosis occurs with final destruction of areas of lung substance. Hemorrhage about these areas is usual and there is often pleural effusion but without any organization of the exudate. There are many cases in which this lobular pneumonia occurs in the pure form, but there are many others in which it is found side by side with the interstitial bronchopneumonia. They are different expressions of reaction to the same infection, but in these the reaction is very feeble. There is nothing new in the forms of pneumonia in this epidemic. They have evidently existed always and with a fair degree of probability one may trace them back to the 16th century. More recognizable descriptions date from 1812, and perfectly clear ones from Delafield in 1884.

Addendum.

Significance of the Presence of Influenza Bacilli.

Since this paper was sent to press another and much greater epidemic has occurred with appalling mortality from pneumonia. The original disease in this epidemic has been spoken of as influenza, and measles has played no part. Attention has been concentrated upon the influenza bacillus of Pfeiffer since it is commonly regarded as the cause of influenza, and much new information has already been published as to the biology of that organism.

Whatever its true status in connection with the epidemic disease, influenza, we have at least learned from numerous autopsies that it must be regarded as a serious pathogenic agent in the production of pneumonia and that it may be found in pure culture associated with a form of pneumonia which is practically identical with the inter-

stitial bronchopneumonia described above, except in the absence of empyema. It is, however, often found with pneumococci and streptococci in other types of pneumonia.

The invention of a new stain for Gram-negative bacteria by Dr. Goodpasture and its successful combination with Weigert's stain for Gram-positive organisms have made it possible to restudy the tissues from the epidemic described above with the assurance of being able to demonstrate influenza bacilli in the tissues whenever they were present and to distinguish them easily from streptococci, pneumococci, and other Gram-positive bacteria. This rests, of course, entirely upon the basis of their morphology, but in many cases it is supported by the results of cultures from sputum or even from the lungs.

I have, therefore, taken the opportunity afforded in the correction of the proof to introduce notes on the presence of these organisms, although the general discussion is left unchanged.

It is evident that owing to unsatisfactory culture methods influenza bacilli were missed in many cases, and it is now proved that the bacilli can be demonstrated in the bronchioles and occasionally in the alveoli of the lungs in 16 of 48 acute cases, while in at least 6 other cases they were present in the sputum. Their distribution among the groups of cases is interesting.

Type of pneumonia.	Total No. of cases.	Influenza bacilli present in.	Case Nos.
Interstitial bronchopneumonia	16	5	15, 32, 37, 49, 191
" and lobular pneumonia	9	4	29, 35, 181, 205
Lobular pneumonia	7	0	
Lobar "	11	5	33, 45, 51, 186, 188
Interstitial bronchopneumonia and lobar pneumonia	5	2	23, 180

It may be said that they tend to be associated with the interstitial and organizing processes, since even some of the cases of lobar pneumonia (Nos. 45, 186, and 188) show a tendency to organization of the exudate and thickening of the interstitial tissue. One might leap to the conclusion that they are responsible for this process or even that they are the forerunners of the streptococcus and pneumococcus in-

fections. It is even suggested in the face of the obvious influence of the epidemic of measles that during the whole period of the winter epidemic there may have been influenza which predisposed to secondary streptococcus infections. But there remain the facts that most of the cases show no influenza bacilli and that in those which are most typical of the form of interstitial bronchopneumonia (Nos. 34, 41, 184, etc.) the most painstaking search through many sections has failed to reveal any of these organisms. It is true that Case 37 shows relatively few streptococci and great numbers of influenza bacilli and is probably to be regarded as essentially produced by the influenza bacillus. But in all the others the streptococcus is the predominant organism, if we except Case 196 in which there were no influenza bacilli and in which the lesion seems to have been caused by pneumococci.

I think it must be recognized that the interstitial forms of bronchopneumonia can be produced by various organisms, including pneumococci, streptococci, and the influenza bacillus. Where there is a mixed infection it is difficult to assign to each its exact part in the process, but it appears that in spite of the frequent presence of the influenza bacillus this was essentially an epidemic of streptococcal pneumonia.

BIBLIOGRAPHY.

Abrahams, A., Hallows, N. F., Eyre, J. W. H., and French, H., *Lancet*, 1917, ii, 377.

Aufrecht, *Verhandl. XIV Versamml. Ges. Kinderh.*, 1898, xiv, 27.

Bard, J., *Am. Med. and Phil. Reg.*, 1814, i, 409.

Bard, L., *Lyon mêd.*, 1889, lx, 43.

Bartels, *Virchows Arch. path. Anat.*, 1861, xxi, 65.

Bartholow, R., U. S. Sanitary Commission Memoirs, New York, 1867, 218.

Coiter, *Observ. anat. et chir.*, in Bonet, T., Sepulchretum, sive anatomia practica ex cadaveribus morbo denatis, Lugduni and Geneva, 1700, iii, 191, cited by Hirsch.

Cordes, H., *Virchows Arch. path. Anat.*, 1898, cli, 402.

Cunningham, R. S., *Anat. Rec.*, 1915, ix, 69.

Delafield, F., *Boston Med. and Surg. J.*, 1884, cxi, 484.

Delafield, F., *Med. News*, 1884, xlv, 534.

Delafield, F., *Med. and Surg. Reporter*, 1884, li, 637.

Delafield, F., Studies in pathological anatomy, New York, 1878–91.

Deplaigne, *J. mêd. chir. et pharm.*, 1757, vii, 168.

Dodonæus, R., Medicinalium observationum exempla rara, recognita et aucta, Lugduni, 3rd edition, 1585, chap. 21, 47, cited by Hirsch.
Dürck, H., *Deutsch. Arch. klin. Med.*, 1897, lviii, 368.
Eights, J., *Am. Med. and Phil. Reg.*, 1814, iv, 37.
Finkler, *Verhandl. Cong. inn. Med.*, 1889, 411.
Haeser, H., Lehrbuch der Geschichte der Medicin und der epidemischen Krankheiten, Jena, 3rd edition, 1882, iii.
Hammond, J. A. B., Rolland, W., and Shore, T. H. G., *Lancet*, 1917, ii, 41.
Hart, C., *Deutsch. Arch. klin. Med.*, 1904, lxxix, 108.
Hecht, V., *Beitr. path. Anat.*, 1910, xlviii, 263.
Hirsch, A., Handbook of geographical and historical pathology, translated from 2nd German edition by Creighton, C., New Sydenham Society, London, 1886, iii, 116.
Honl, I., *Wien. klin. Rundschau*, 1897, xi, 833.
Hosack, D., *Am. Med. and Phil. Reg.*, 1814, iii, 448.
Hudson, D., *Am. Med. and Phil. Reg.*, 1814, iii, 495.
Huxham, J., An essay on fevers, London, 5th edition, 1767.
Jochmann, G., and Moltrecht, *Beitr. path. Anat.*, 1904, xxxvi, 340.
Jürgensen, in Nothnagel, H., Specielle Pathologie und Therapie, Vienna, 1895, iv, 31.
Karsner, H. T., and Meyers, A. E., *Arch. Int. Med.*, 1913, xi, 534.
Koester, *Deutsch. med. Woch.*, 1898, xxiv, Vereins-Beilage, 8.
Kromayer, E., *Virchows Arch. path. Anat.*, 1889, cxvii, 452.
Laveran, *Gazz. hebd. méd.*, 1865, ii, series 2, 545.
Low, J., *Am. Med. and Phil. Reg.*, 1814, iv, 20.
McBride, J., *Am. Med. and Phil. Reg.*, 1814, iii, 36.
McReynolds, J. D., *Am. Med. and Phil. Reg.*, 1814, iii, 491.
Mann, J., *Am. Med. and Phil. Reg.*, 1814, iii, 497.
Mann, J., Medical sketches of the campaigns of 1812, 1813, and 1814, Dedham, 1816.
Massa, Liber de febre pestilentiali, Venice, 1556, chap. 18, 72, cited by Hirsch.
Mathers, G., *Tr. Chicago Path. Soc.*, 1915–17, x, 74.
Miller, W. S., *Am. J. Roentgen.*, 1917, iv, 269.
Morgagni, J. B., De sedibus et causis morborum per anatomen indagatis libri quinque, Venice, 1761, i, epist. vii, art. 12, 51, epist. xxi, art. 2, 204, cited by Hirsch.
Mott, V., *Am. Med. and Phil. Reg.*, 1814, iii, 165.
Papers on the Winter Epidemic of 1812–13, *Med. Repository*, 1813, N.S. i, 246.
Renault, A., *Bull. et. mém. Soc. méd. Hôp. Paris*, 1889, vi, series 3, 313.
Russell, I., U. S. Sanitary Commission Memoirs, New York, 1867, med. vol., 319.
de Sauvages de la Croix, F.-B., Nosologia methodica, Leipsic, 1790, ii, 334.
Smith, M., *Am. Med. and Phil. Reg.*, 1814, iii, 152.
Steinhaus, F., *Beitr. path. Anat.*, 1901, xxix, 524.

Wagner, E., *Deutsch. Arch. klin. Med.*, 1884, xxxv, 191.
Webster, N., A brief history of epidemic and pestilential diseases; with the principal phenomena of the physical world which precede and accompany them, and observations deduced from the facts stated, Hartford, 1799, ii.
Woodward, J. J., Medical and surgical history of the war of the rebellion, Washington, 1888, i, pt. 3, 649–661, 751–818.
Wygodzinski, W., Inaugural dissertation, Berlin, 1898.

EXPLANATION OF PLATES.

PLATE 1.

FIG. 1. Case 14. Interstitial bronchopneumonia. Early bronchial lesion with surrounding hemorrhage.

PLATE 2.

FIG. 2. Case 14. Interstitial bronchopneumonia. Early bronchial lesion. Beginning organization of exudate in bronchial lumen.

PLATE 3.

FIG. 3. Case 15. Interstitial bronchopneumonia. Infiltration of alveolar walls and perivascular tissue.

PLATE 4.

FIG. 4. Case 16. Interstitial bronchopneumonia. Right lung with interlobar empyema pocket.

PLATE 5.

FIG. 5. Case 16. Interstitial bronchopneumonia. Atelectasis with organization of bronchial exudate.

PLATE 6.

FIG. 6. Case 32. Interstitial bronchopneumonia. Early bronchial and peribronchial lesion.

PLATE 7.

FIG. 7. Case 32. Interstitial bronchopneumonia. Bronchial and peribronchial infiltration.

PLATE 8.

FIG. 8. Case 34. Interstitial bronchopneumonia. Portion of left lung showing prominent interlobular septa and peribronchial nodules.

PLATE 9.

FIG. 9. Case 34. Interstitial bronchopneumonia. Portion of left lung showing prominent interlobular septa and many distended lymph channels which appear as white beaded canals.

PLATE 10.

FIG. 10. Case 34. Interstitial bronchopneumonia. Interlobular septum with great distension of lymph channels by an infected thrombus.

PLATE 11.

FIG. 11. Case 34. Interstitial bronchopneumonia. Thickening and infiltration of the wall of a small bronchus.

PLATE 12.

FIG. 12. Case 34. Interstitial bronchopneumonia, showing dislodgement of the epithelium of the bronchus, the great thickening and infiltration of the wall, and changes in the adjacent alveoli.

PLATE 13.

FIG. 13. Case 37. Interstitial bronchopneumonia. Right lung, showing the nodular character of the peribronchial lesions. The spleen is included.

PLATE 14.

FIG. 14. Case 37. Interstitial bronchopneumonia. Infiltration of bronchial wall which has lost its epithelium. Dense fibrinous plugs in the adjacent alveoli.

PLATE 15.

FIG. 15. Case 39. Interstitial bronchopneumonia. Right lung.

PLATE 16.

FIG. 16. Case 41. Interstitial bronchopneumonia. Left lung.

PLATE 17.

FIG. 17. Case 41. Interstitial bronchopneumonia. Right upper lobe showing large nodules of consolidation about the bronchi.

PLATE 18.

FIG. 18. Case 41. Interstitial bronchopneumonia. Bronchial thickening produced by lymphoid hyperplasia and great infiltration of the wall.

PLATE 19.

FIG. 19. Case 41. Interstitial bronchopneumonia. Infiltration of bronchial wall. Consolidation of adjacent tissue.

PLATE 20.

FIG. 20. Case 41. Interstitial bronchopneumonia. Small bronchus with thickened and hyperemic wall. Surrounding consolidation.

PLATE 21.

FIG. 21. Case 178. Interstitial bronchopneumonia. Early stage with peribronchial hemorrhages.

PLATE 22.

FIG. 22. Case 178. Interstitial bronchopneumonia following measles. Ulceration of vocal cords.

PLATE 23.

FIG. 23. Case 178. Section passing through pleura and interlobular septum with lymphatic canal, showing valves directed away from the pleura.

PLATE 24.

FIG. 24. Case 178. Interstitial bronchopneumonia. Bronchus with thickened wall, showing masses of streptococci in the purulent contents of the lumen. Infiltration of adjacent alveolar walls.

PLATE 25.

FIG. 25. Case 184. Interstitial bronchopneumonia. Left lung.

PLATE 26.

FIG. 26. Case 184. Interstitial bronchopneumonia following measles. Ulcerative laryngitis. Ulcers of vocal cords and epiglottis.

PLATE 27.

FIG. 27. Case 184. Interstitial bronchopneumonia. Necrosis of mucosa of bronchus. Infiltration and edema of bronchial wall. Infiltration and collapse of adjacent alveoli.

PLATE 28.

FIG. 28. Case 184. Interstitial bronchopneumonia. A mitotic figure is shown in an epithelial cell of the alveolar lining.

FIG. 29. Case 184. Interstitial and lobular pneumonia. Bronchial wall with hyperemia and infiltration and necrosis of the mucosa. Nearby is a patch of lobular pneumonia.

PLATE 29.

FIG. 30. Case 191. Interstitial bronchopneumonia. Left lung.

PLATE 30.

FIG. 31. Case 29. Interstitial bronchopneumonia. Thickening, infiltration, and hyperemia of bronchial wall.

PLATE 31.

FIG. 32. Case 29. Interstitial bronchopneumonia. Infiltration of bronchial wall and adjacent tissue.

PLATE 32.

FIG. 33. Case 29. Interstitial bronchopneumonia. Induration of interlobular septum and of alveolar walls. Thrombosed lymphatic in the septum.

PLATE 33.

FIG. 34. Case 29. Interstitial bronchopneumonia. Infiltration of bronchial wall. Consolidation of adjacent tissue.

PLATE 34.

FIG. 35. Case 181. Interstitial bronchopneumonia. Right lung with cavity in the upper lobe and bronchiectases in the lower.

PLATE 35.

FIG. 36. Case 194. Interstitial bronchopneumonia, combined with lobular pneumonia. Hemorrhagic lobular area in lower lobe.

PLATE 36.

FIG. 37. Case 205. Bilateral hyaline degeneration of rectus abdominis muscle with rupture and hemorrhage.

PLATE 37.

FIG. 38. Case 205. Interstitial bronchopneumonia. Left lower lobe with projecting peribronchial nodules.

PLATE 38.

FIG. 39. Case 205. Combined interstitial bronchopneumonia and lobular pneumonia.

PLATE 39.

FIG. 40. Case 20. Lobular pneumonia with large area of necrosis and hemorrhage. Distended lymphatics run to the pleural surface.

PLATE 40.

FIG. 41. Case 26. Lobular pneumonia with empyema. Distended lymphatics run to the pleural surface. Left lung.

PLATE 41.

FIG. 42. Case 55. Lobular streptococcal pneumonia with extensive necroses and empyema. Left lung.

PLATE 42.

FIG. 43. Case 55. Lobular streptococcal pneumonia with abscesses. Right lung.

PLATE 43.

FIG. 44. Case 187. Lobular streptococcal pneumonia. The consolidation is confluent in the upper lobe but focal in the lower part of the lung. Left lung.

PLATE 44.

FIG. 45. Case 187. Confluent lobular streptococcal pneumonia. Hyaline thrombi in alveolar capillaries.

FIG. 46. Case 187. Lobular streptococcal pneumonia. One alveolus from the preparation shown in Fig. 45. The hyaline fibrinous thrombi in the capillaries stain deeply and streptococci are seen with leucocytes in the alveolus.

PLATE 45.

FIG. 47. Case 192. Hemorrhagic lobular pneumonia. Left lung.

PLATE 46.

FIG. 48. Case 192. Hemorrhagic lobular pneumonia. Right lung.

PLATE 47.

FIG. 49. Case 192. Hyaline degeneration in the rectus abdominis muscle.

PLATE 48.

FIG. 50. Case 25. Lobar pneumonia. Pneumococcus infection. Infiltration of alveolar walls with leucocytes.

PLATE 49.

FIG. 51. Case 188. Lobar pneumonia. Pneumococcus Type II and *B. influenzæ*. Right lung.

PLATE 50.

FIG. 52. Case 21. Combination of lobar pneumonia (pneumococcus infection) with interstitial bronchopneumonia (streptococcus infection). Left lung.

PLATE 51.

FIG. 53. Case 31. Typical lobar pneumonia. Pneumococcus Type IV. Left lung. The other lung showed interstitial bronchopneumonia with streptococcus infection.

PLATE 52.

FIG. 54. Case 180. Combined lobar pneumonia and interstitial bronchopneumonia in the same lung. Pneumococcus Type II and streptococcus. Right lung.

PLATE 53.

FIG. 55. Case 196. Interstitial bronchopneumonia. Lobar pneumonia in the opposite lung. Pneumococcus Type II.

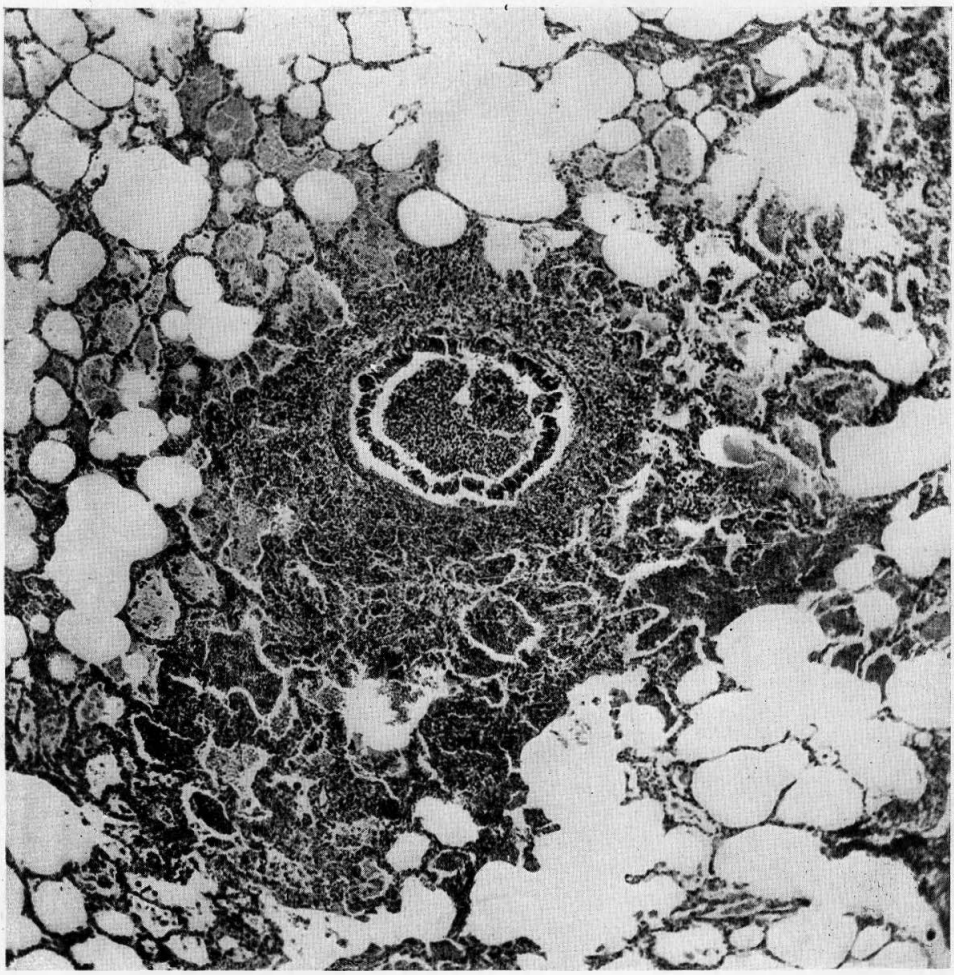
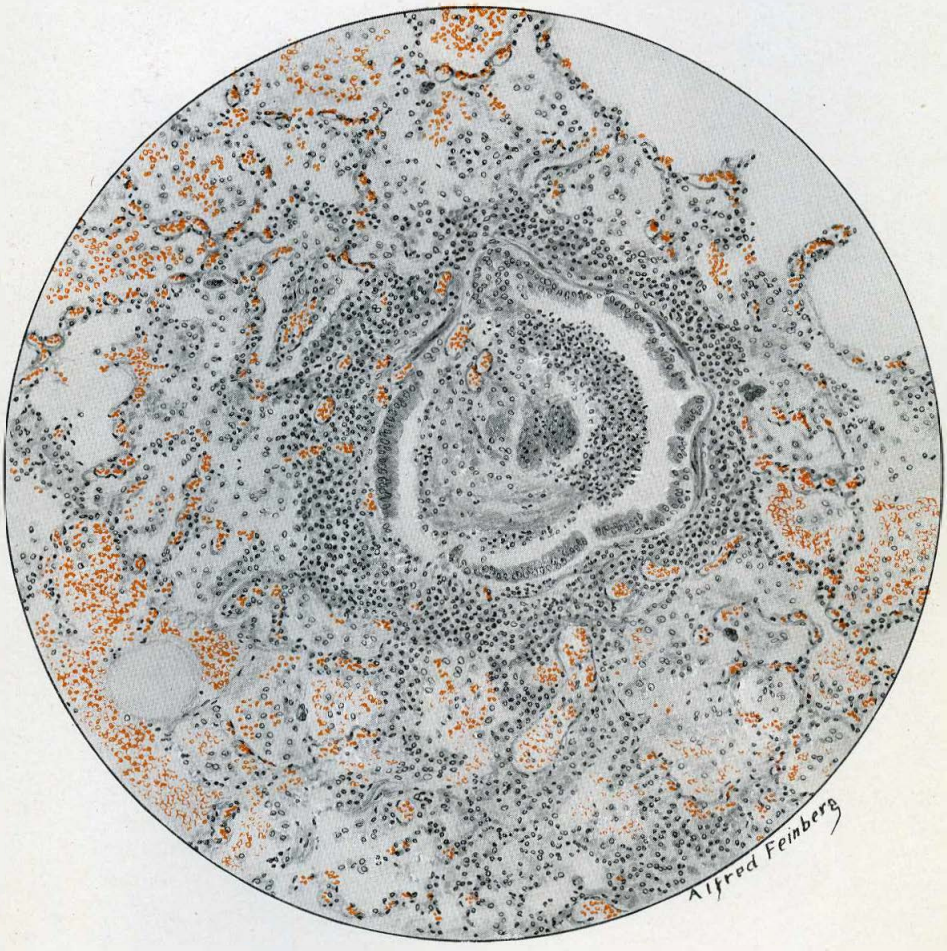


FIG. 1.

(MacCallum: Pneumonia in army camps.)



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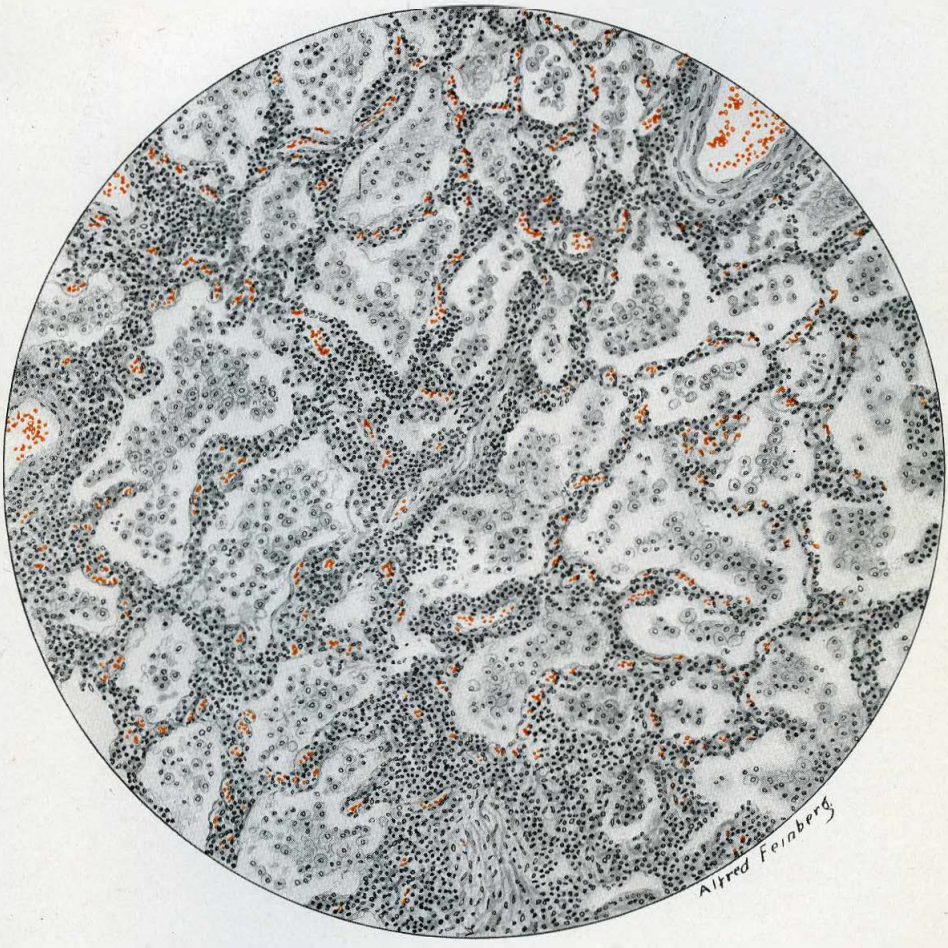
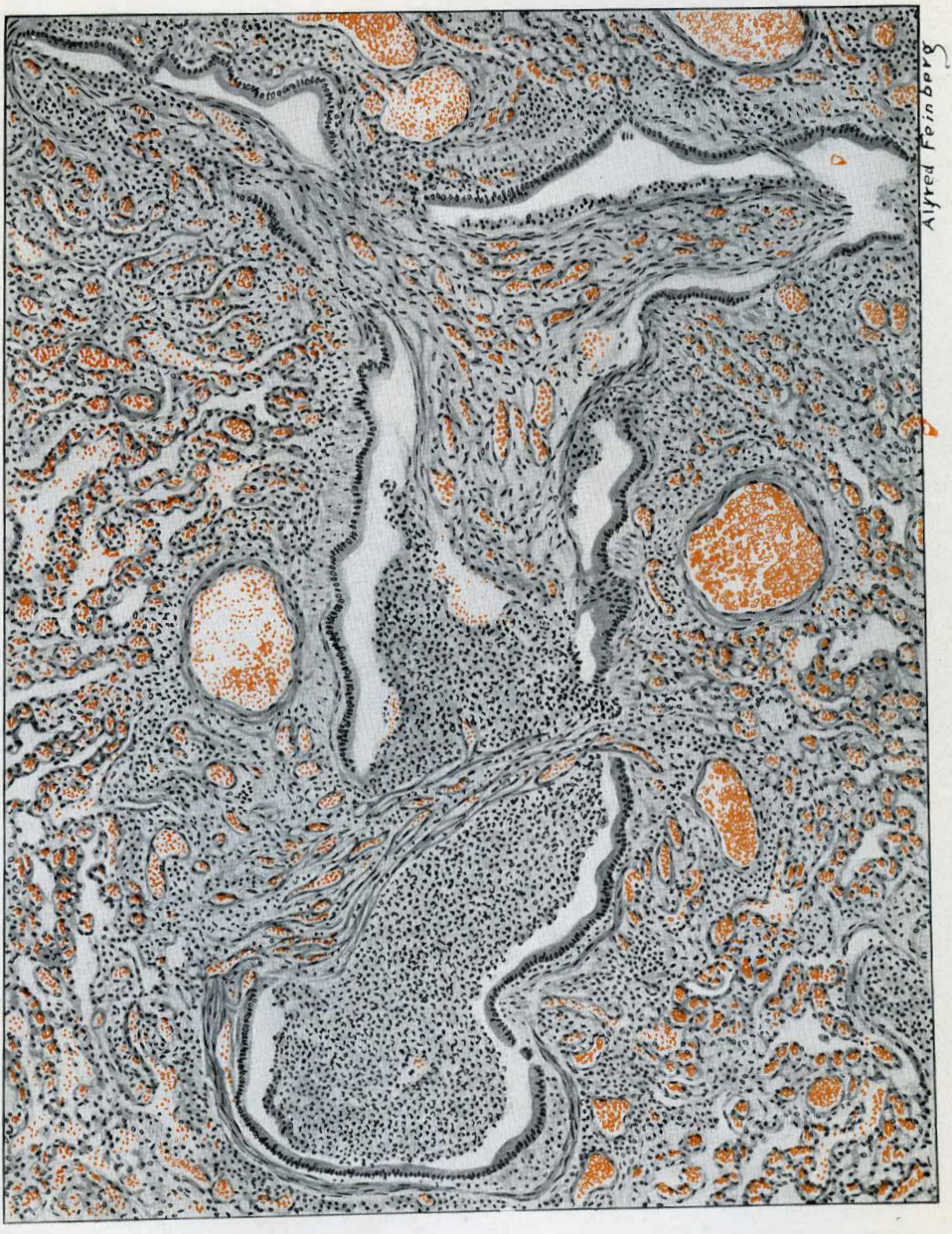


FIG. 3.

(MacCallum: Pneumonia in army camps.)

FIG. 4.

(MacCallum: Pneumonia in army camps.)



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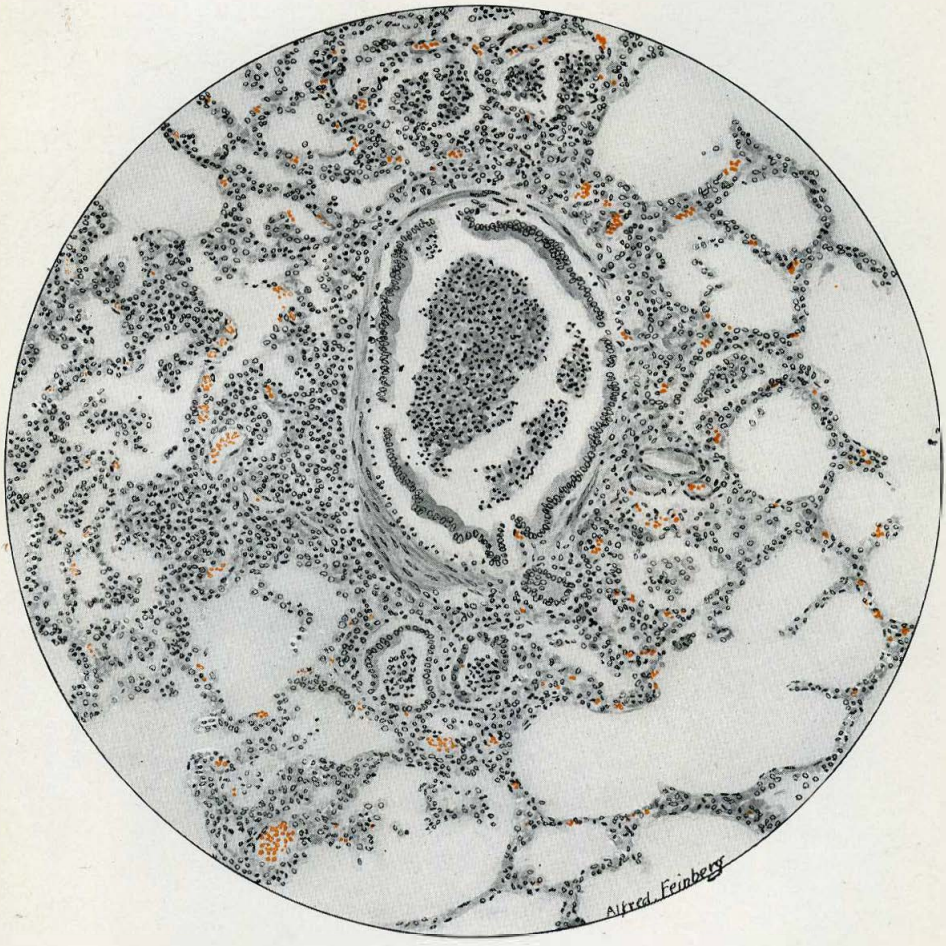

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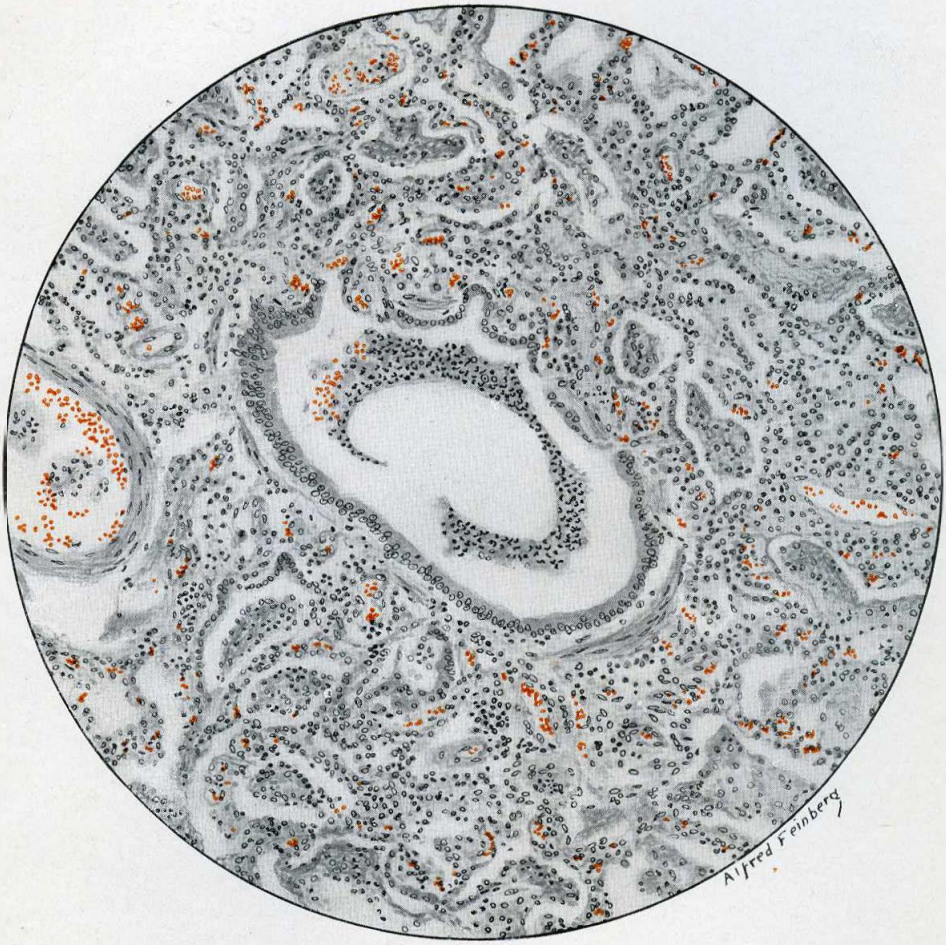


FIG. 7.

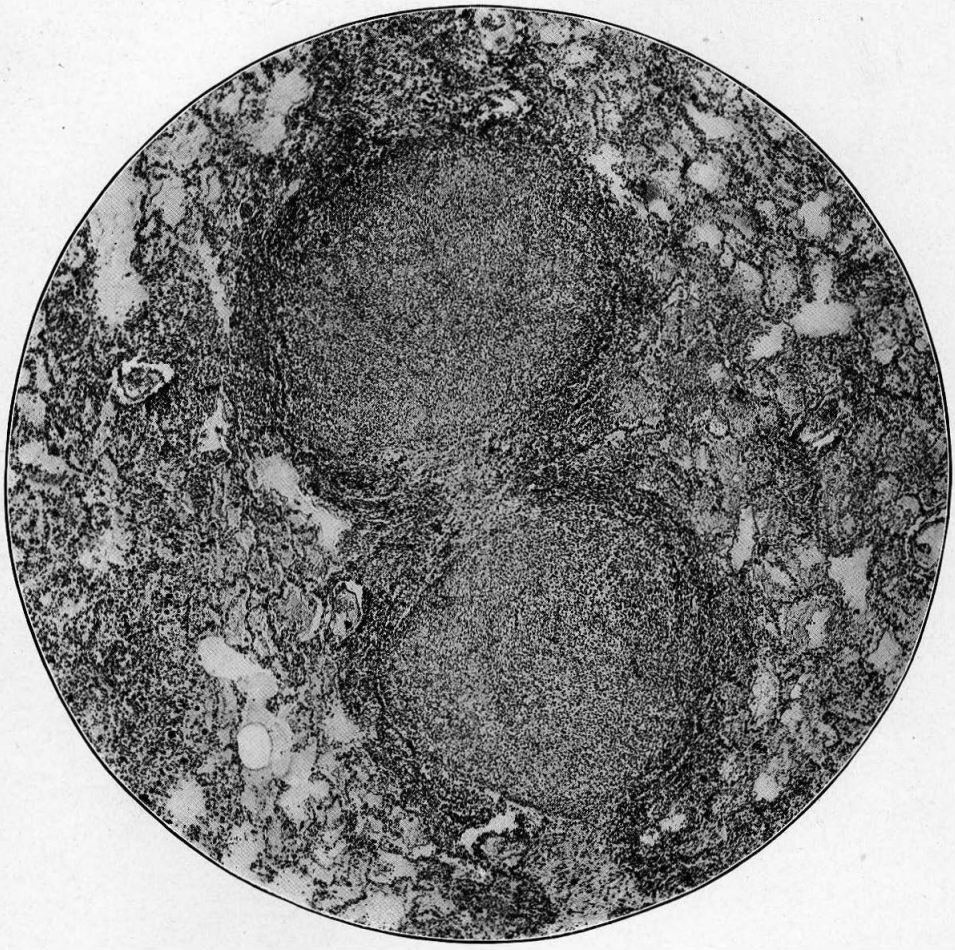
(MacCallum: Pneumonia in army camps.)

FIG. 8.

(MacCallum: Pneumonia in army camps.)

FIG. 9.

(MacCallum: Pneumonia in army camps.)



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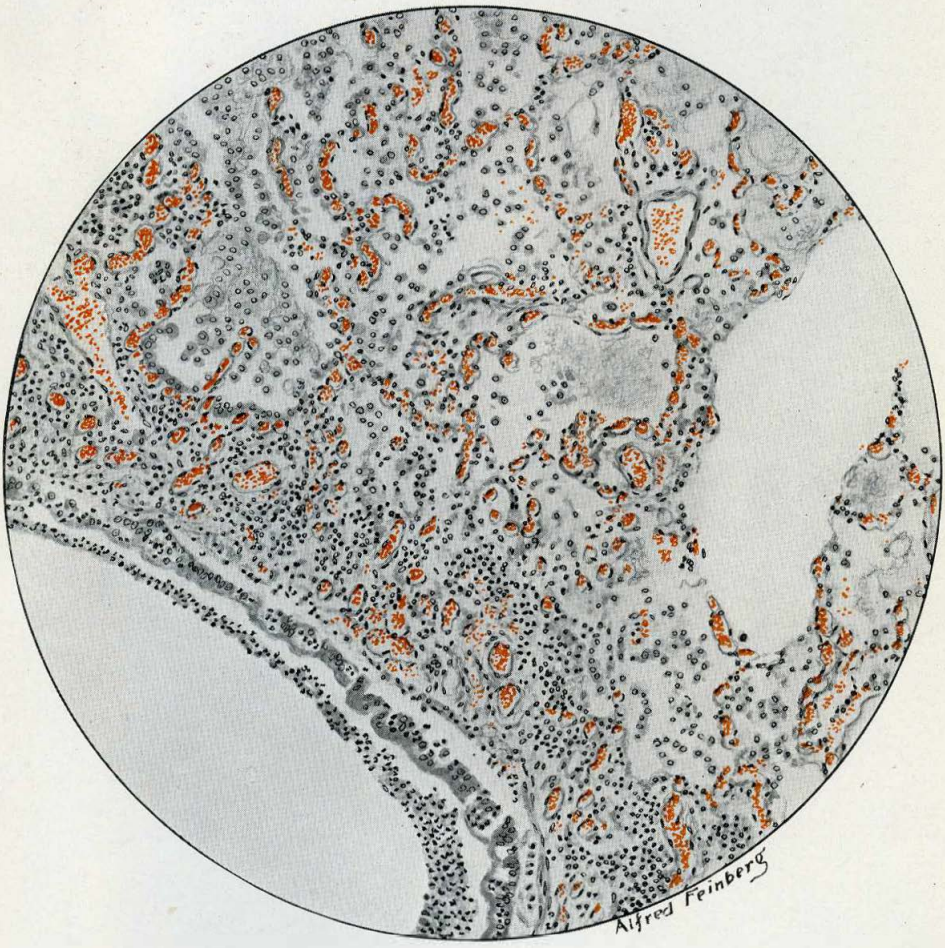

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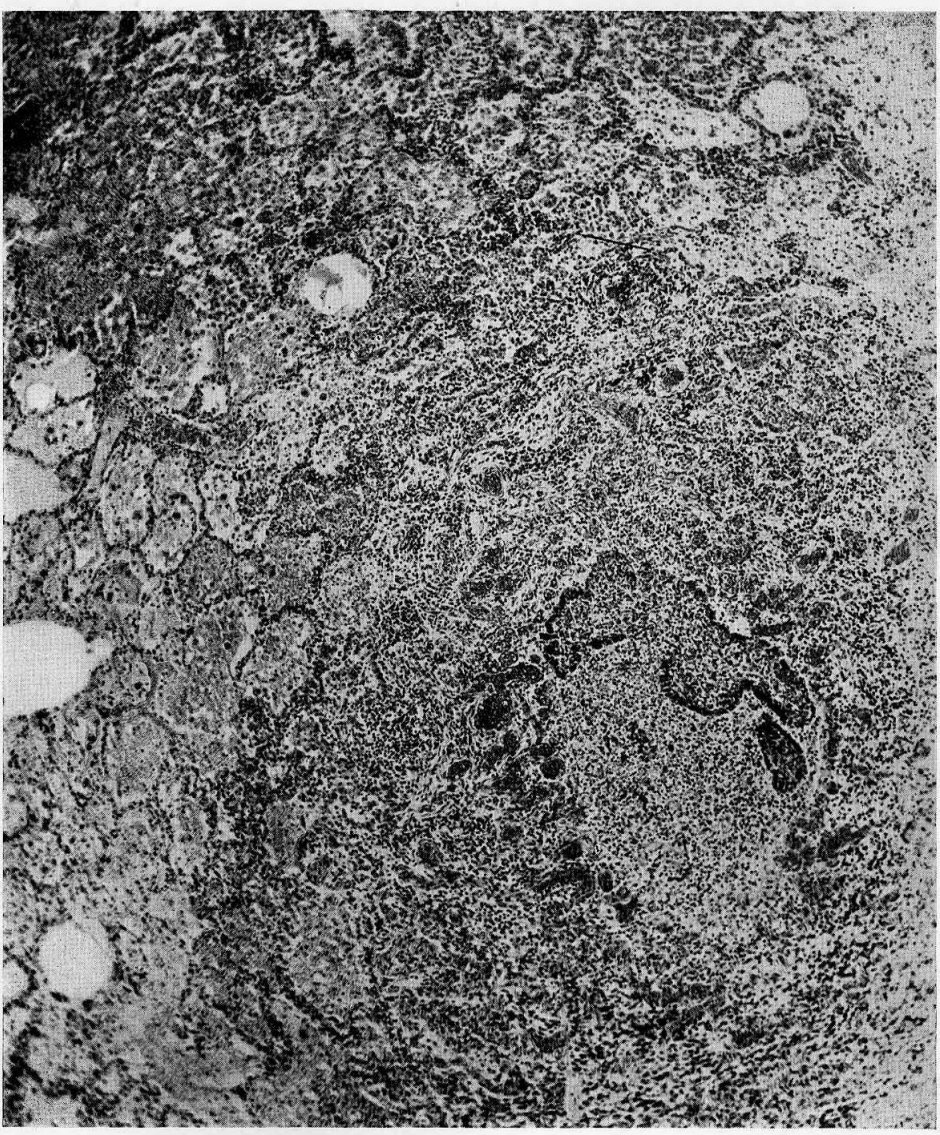

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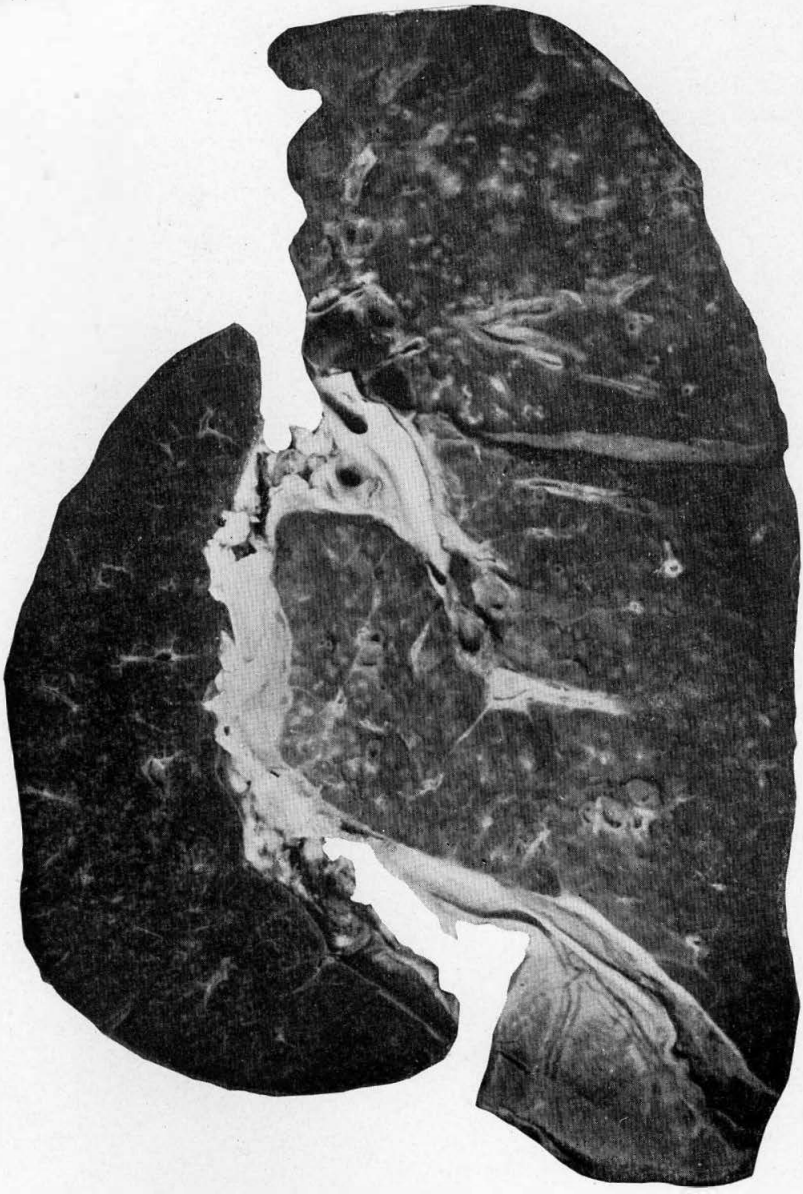


FIG. 13.

(MacCallum: Pneumonia in army camps)

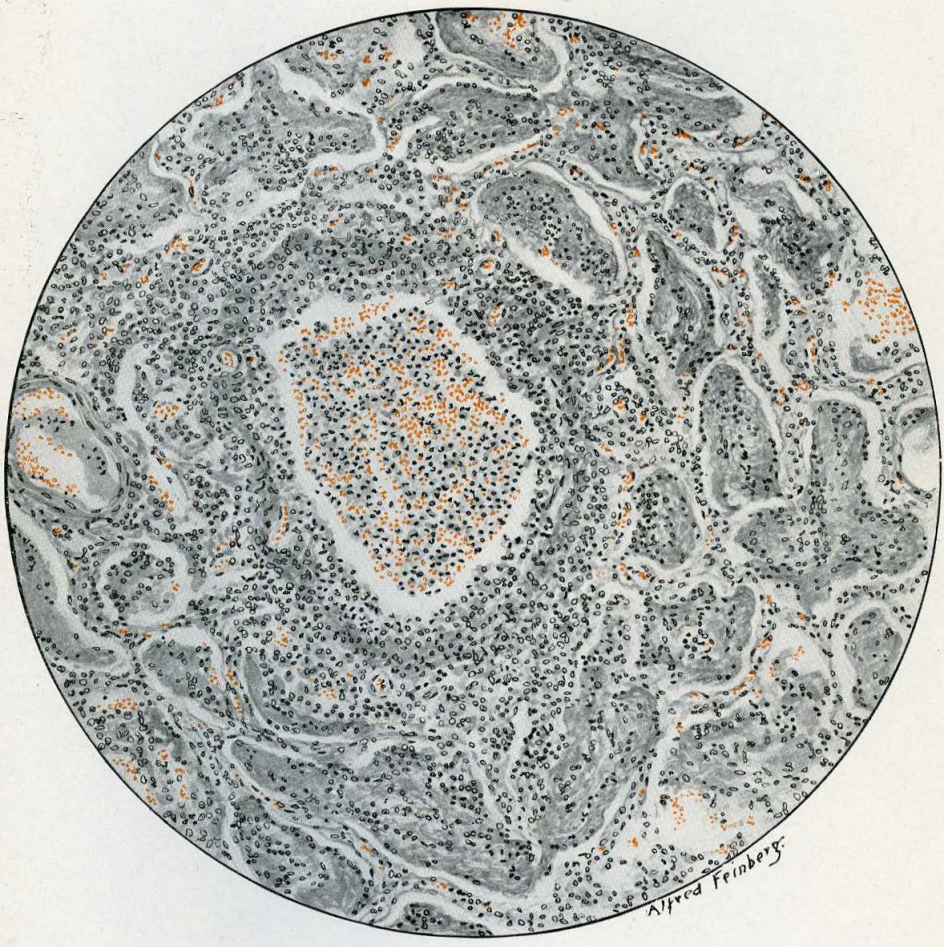


FIG. 14.

(MacCallum: Pneumonia in army camps.)

FIG. 15.

(MacCallum: Pneumonia in army camps.)

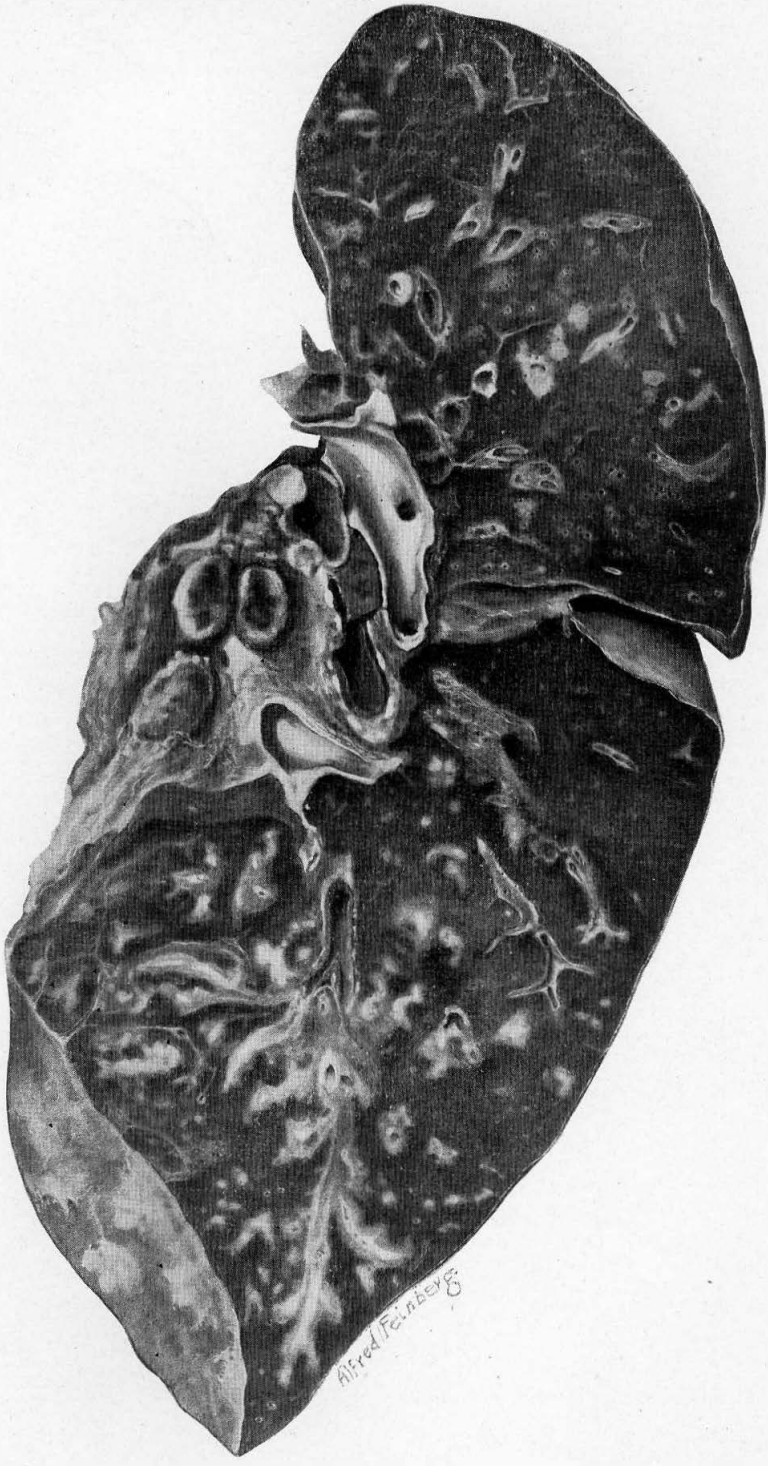


FIG. 16.

(MacCallum: Pneumonia in army crmps.)

FIG. 17.

(MacCallum: Pneumonia in army camps.)

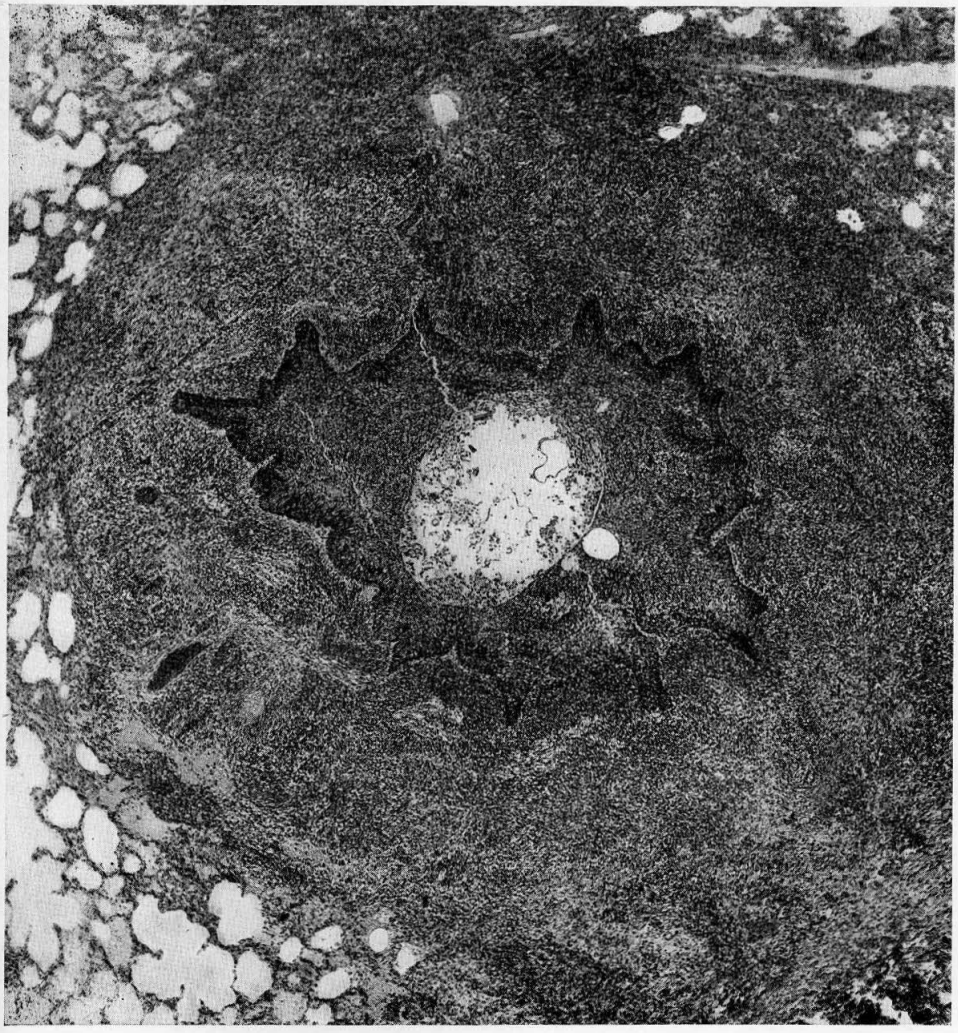
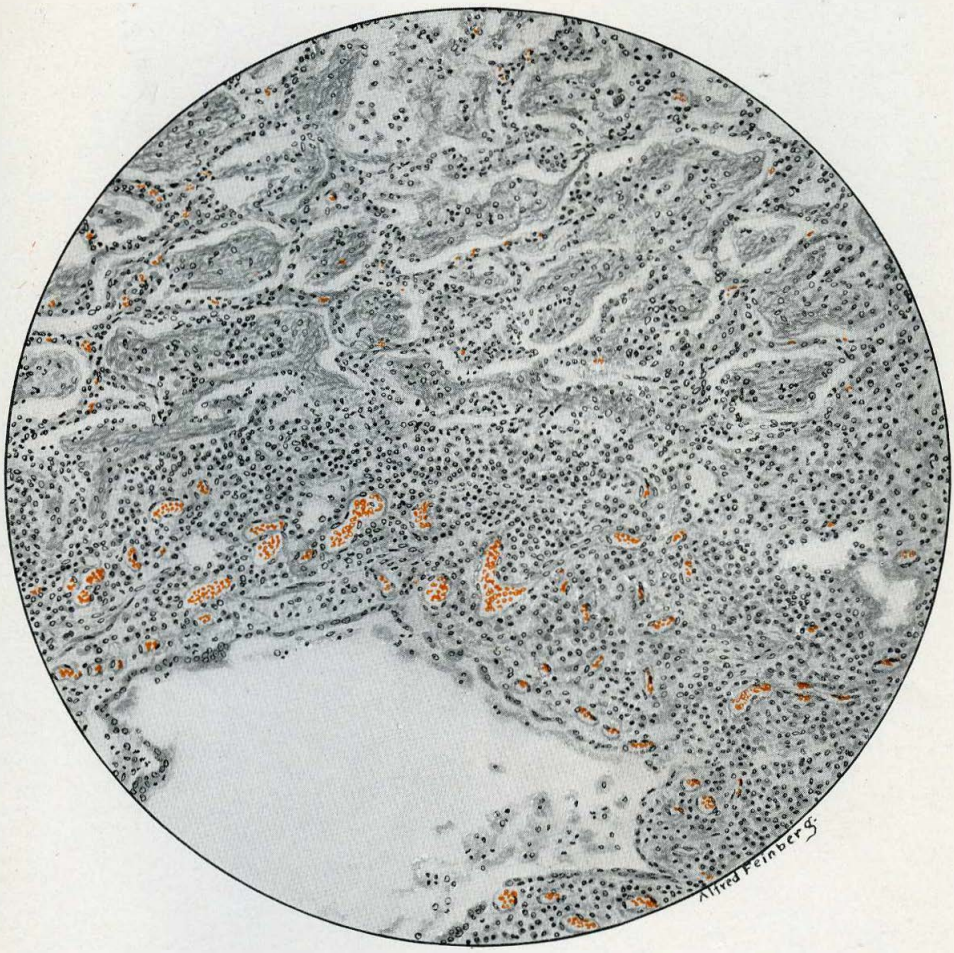


FIG. 18.

(MacCallum: Pneumonia in army camps.)



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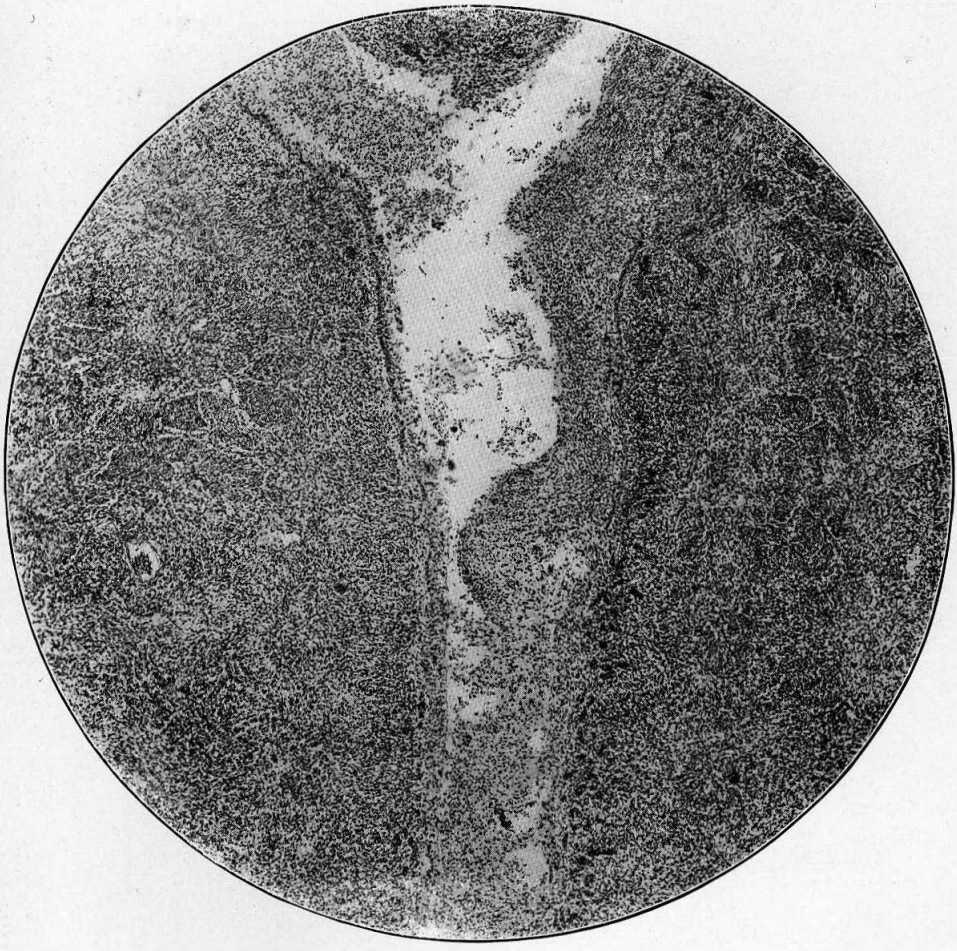

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(MacCallum: Pneumonia in army camps.)

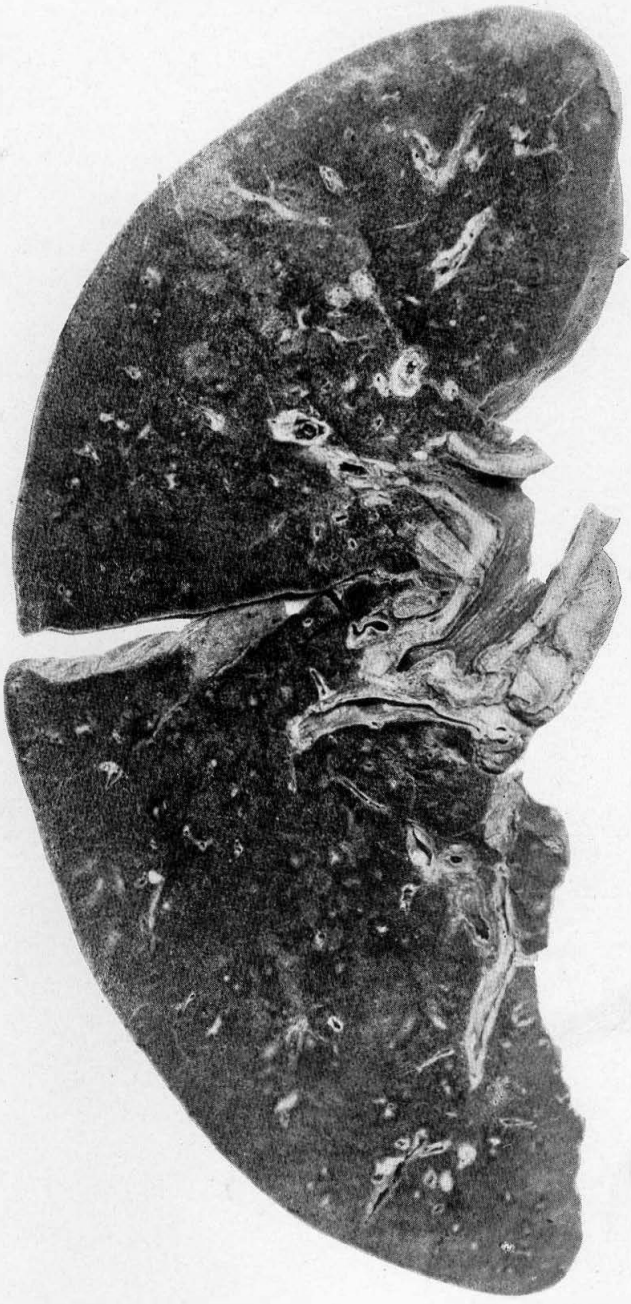

FIG. 21.

(MacCallum: Pneumonia in army camps.)

FIG. 22.

(MacCallum: Pneumonia in army camps.)

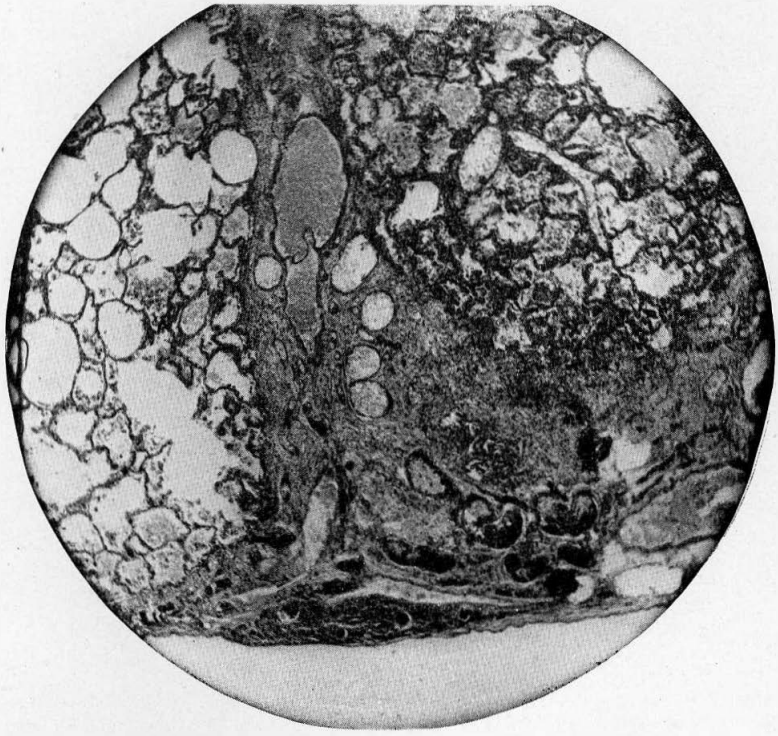

FIG. 23.

(MacCallum: Pneumonia in army camps.)

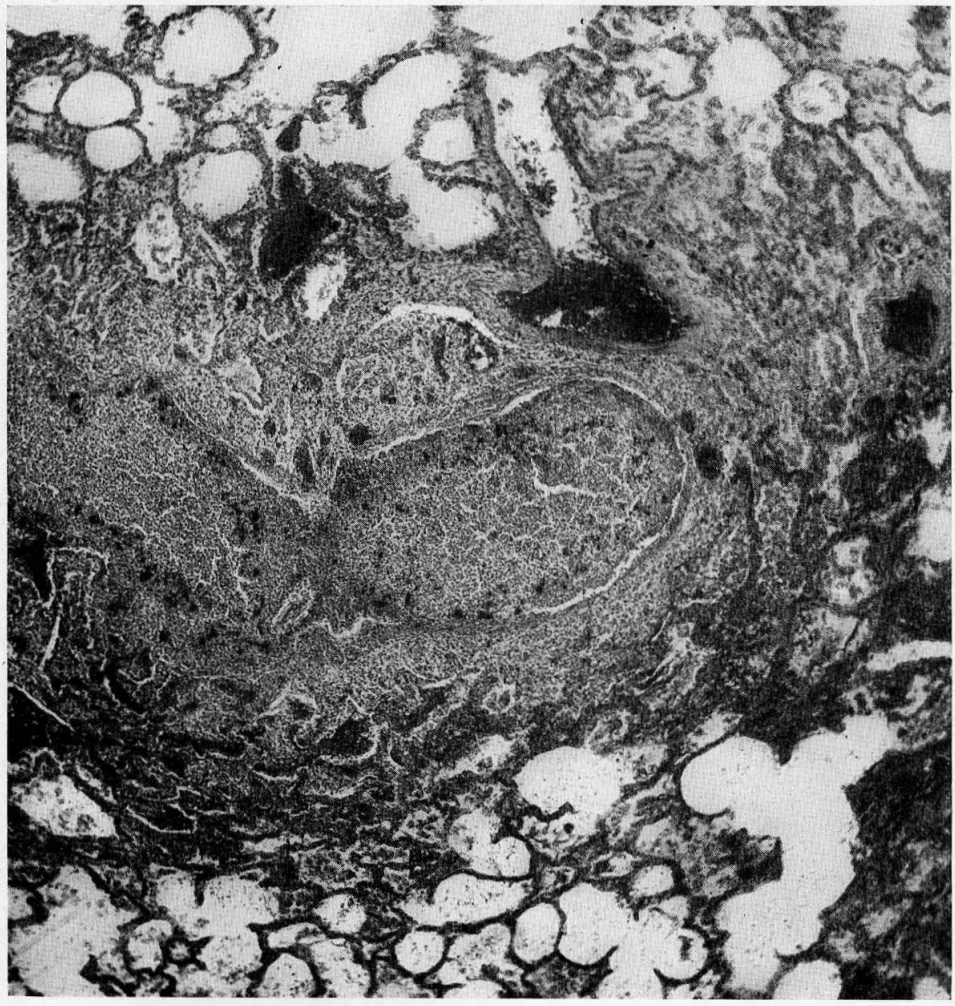

FIG 24.

(MacCallum: Pneumonia in army camps.)

FIG. 25.

(MacCallum: Pneumonia in army camps)

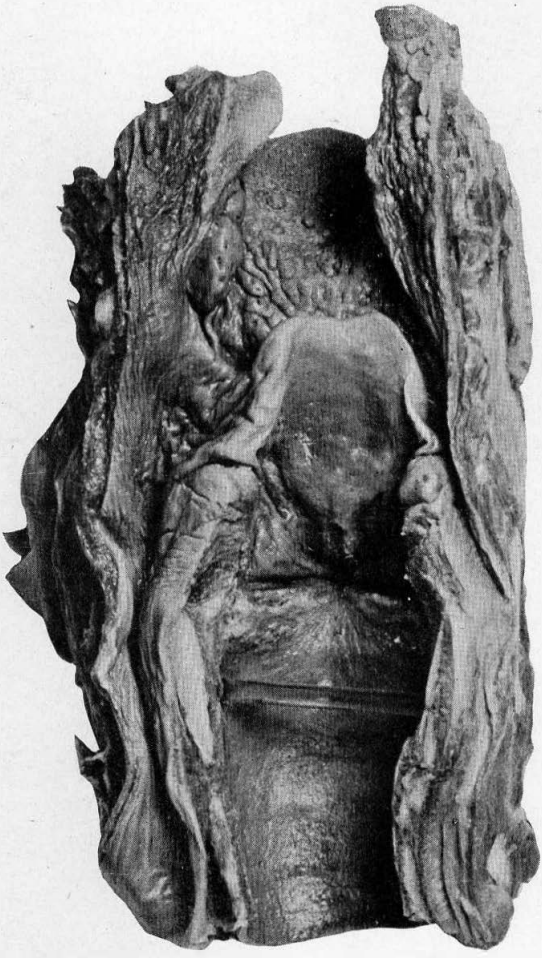

FIG. 26.

(MacCallum: Pneumonia in army camps.)

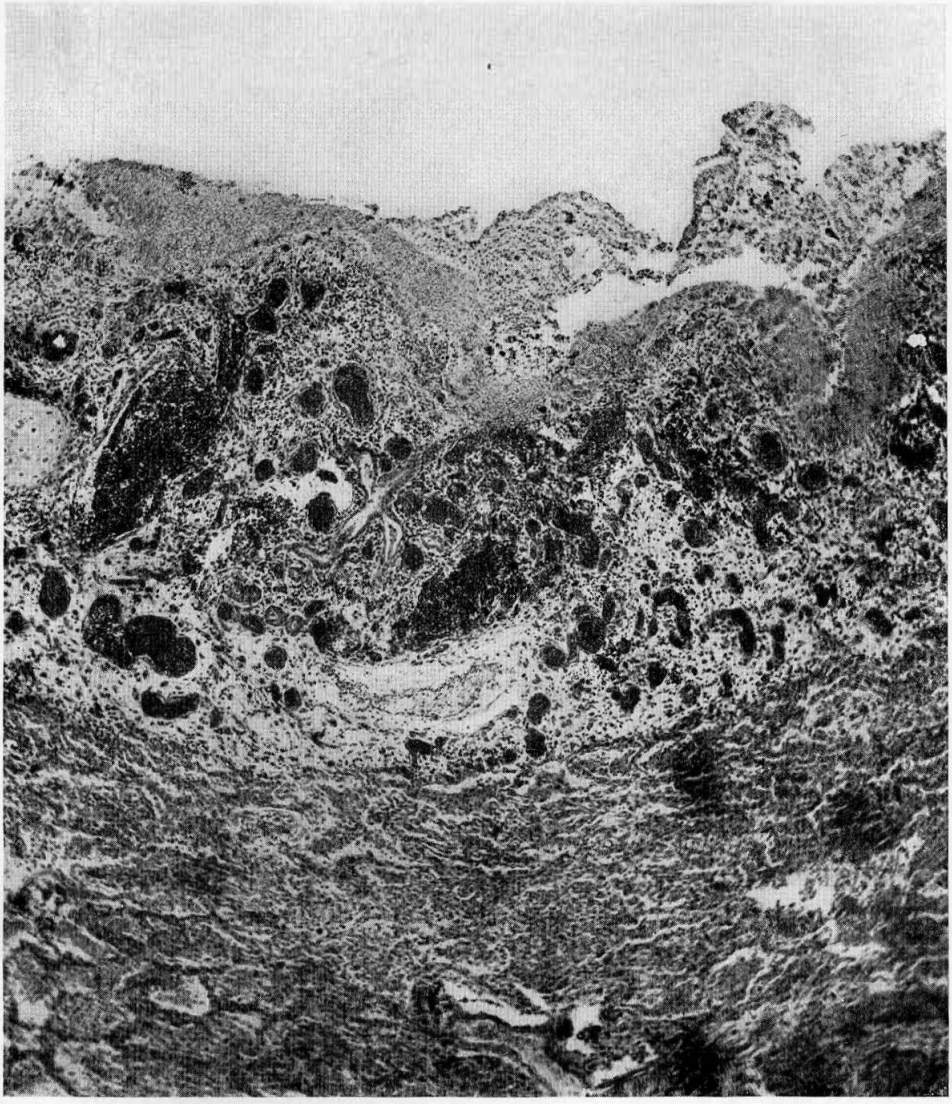

FIG. 27.

(MacCallum: Pneumonia in army camps.)

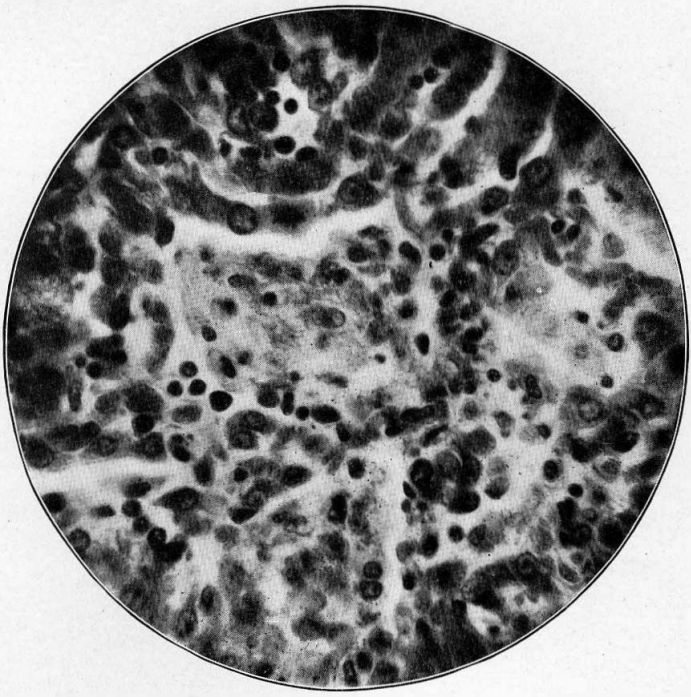

FIG. 28.

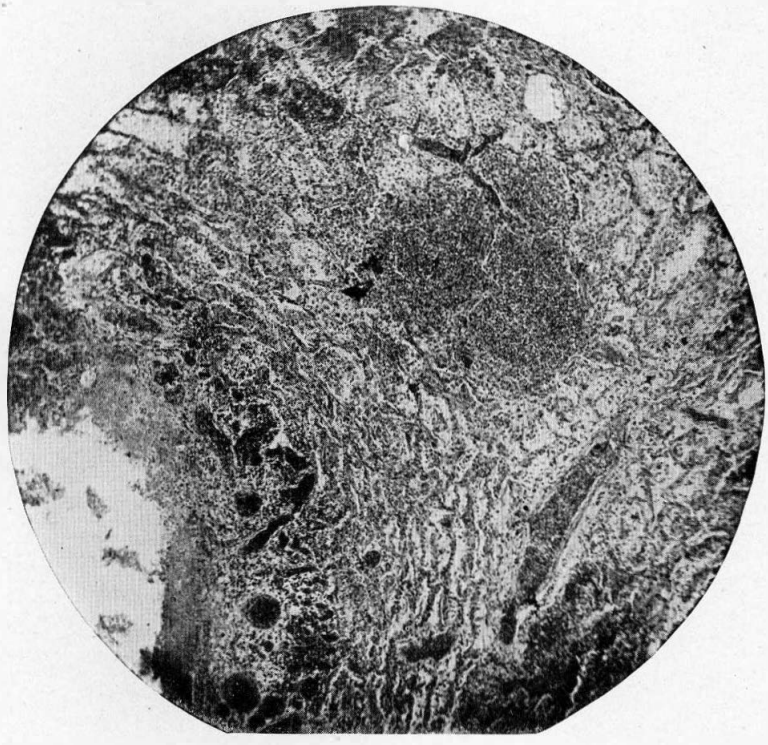

FIG. 29.

(MacCallum: Pneumonia in army camps.)

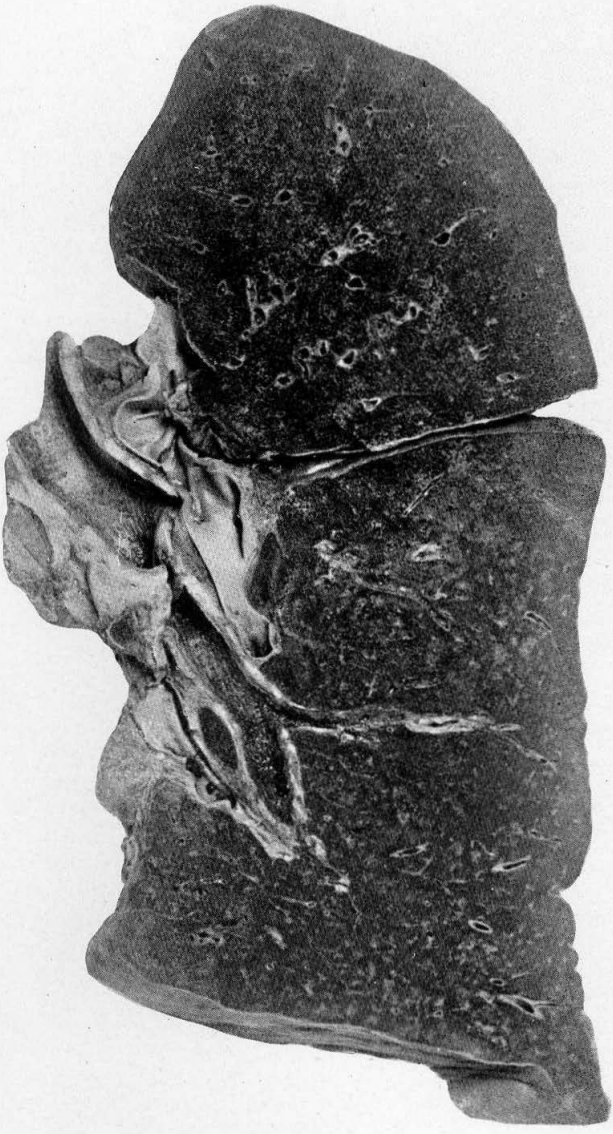

FIG. 30.

(MacCallum: Pneumonia in army camps.)

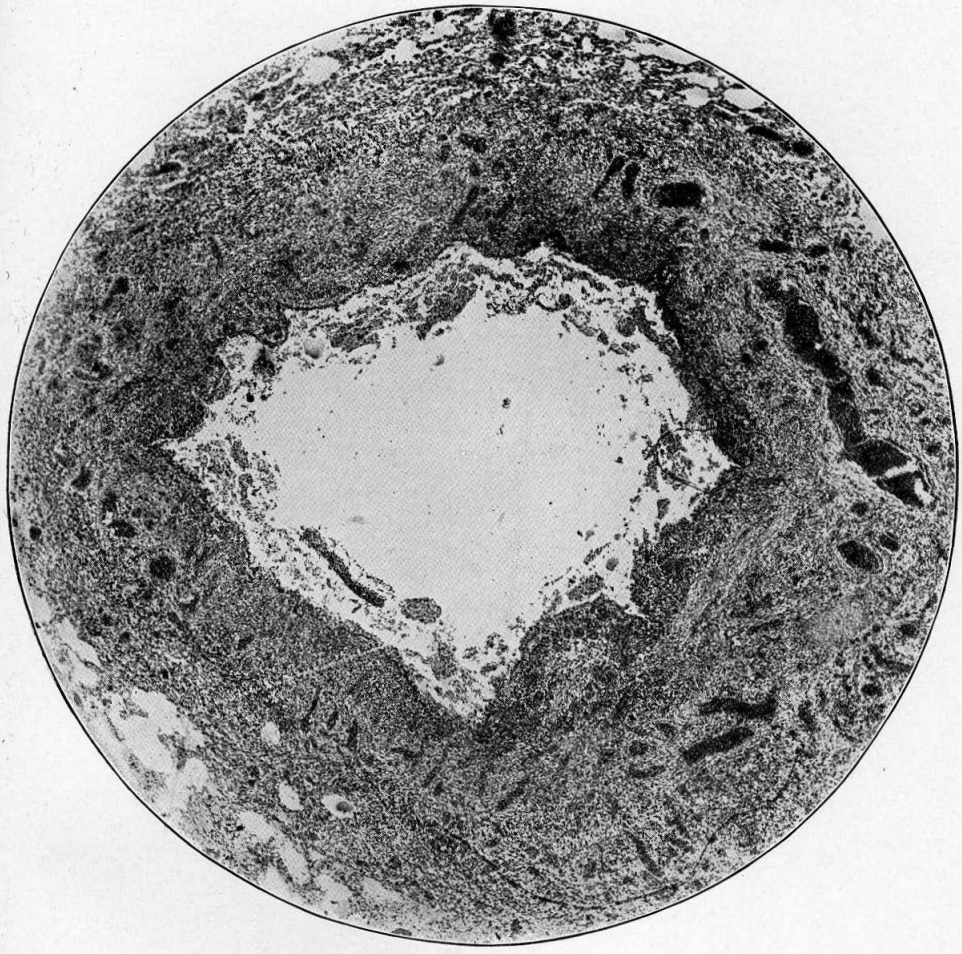

FIG. 31.

(MacCallum: Pneumonia in army camps.)

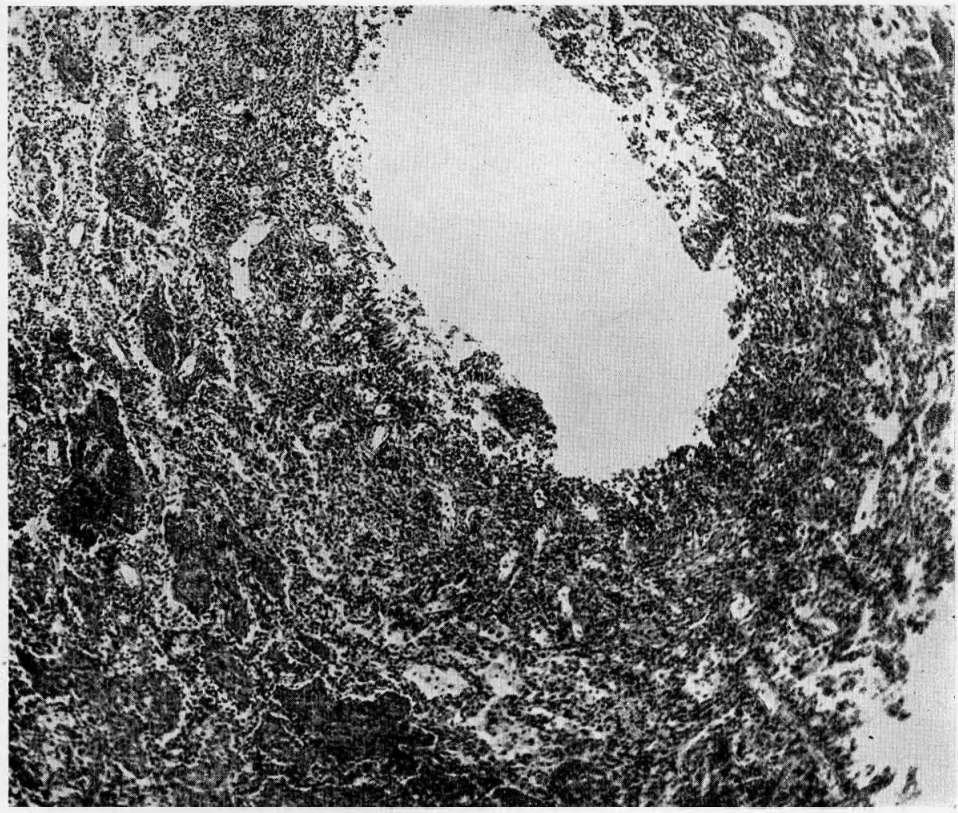

FIG. 32.

(MacCallum: Pneumonia in army camps.)

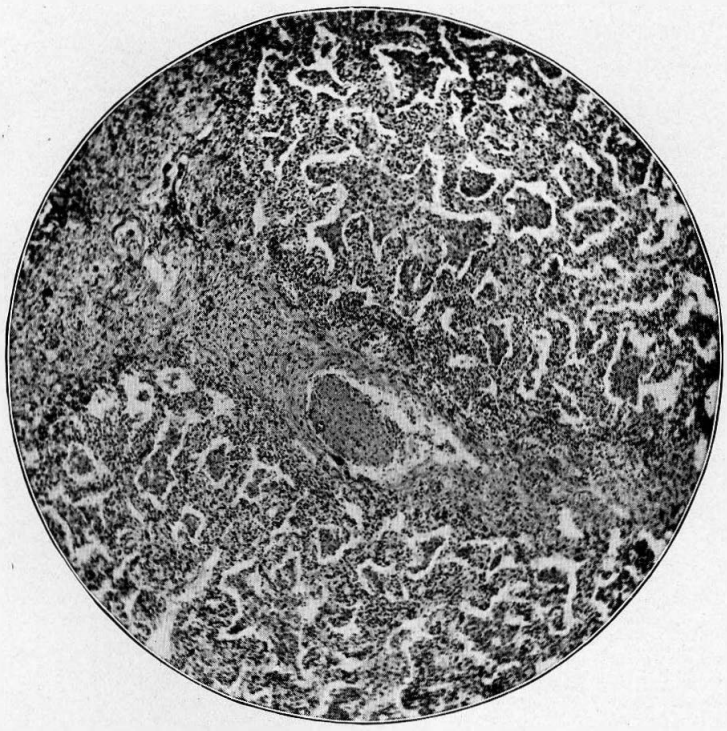

FIG. 33.

(MacCallum: Pneumonia in army camps.)

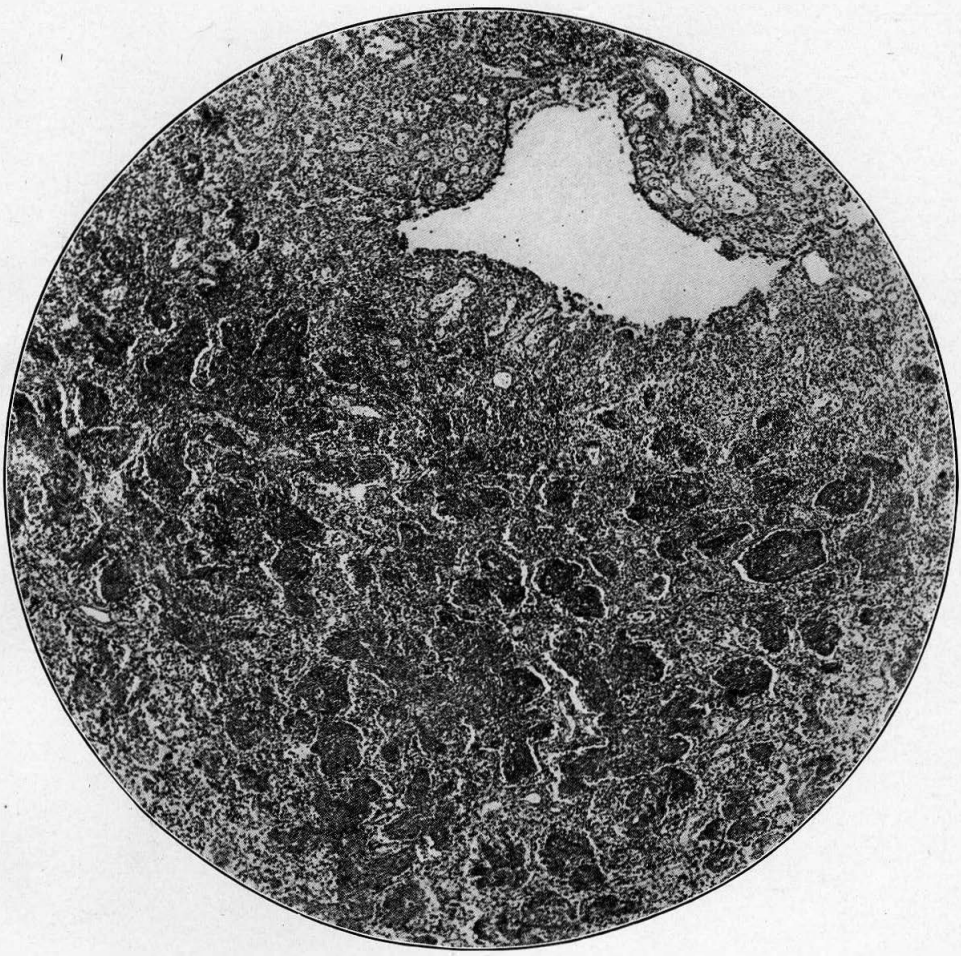

FIG. 34.

(MacCallum: Pneumonia in army camps.)

FIG. 35.

(MacCallum: Pneumonia in army camps.)

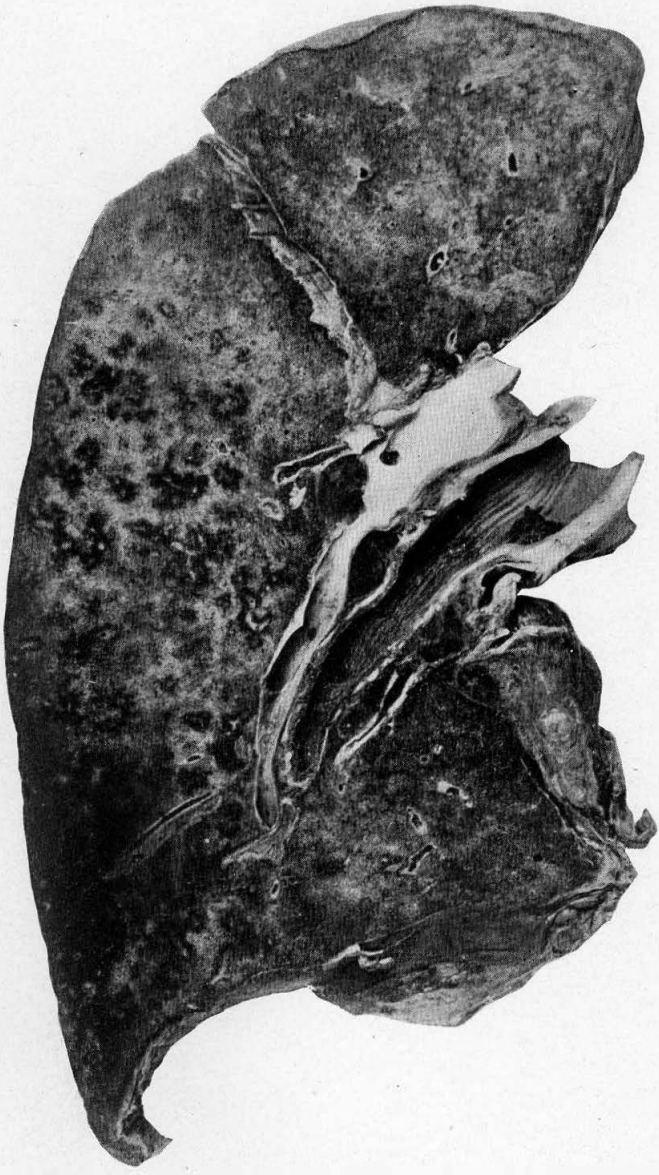

FIG. 36.

(MacCallum: Pneumonia in army camps.)

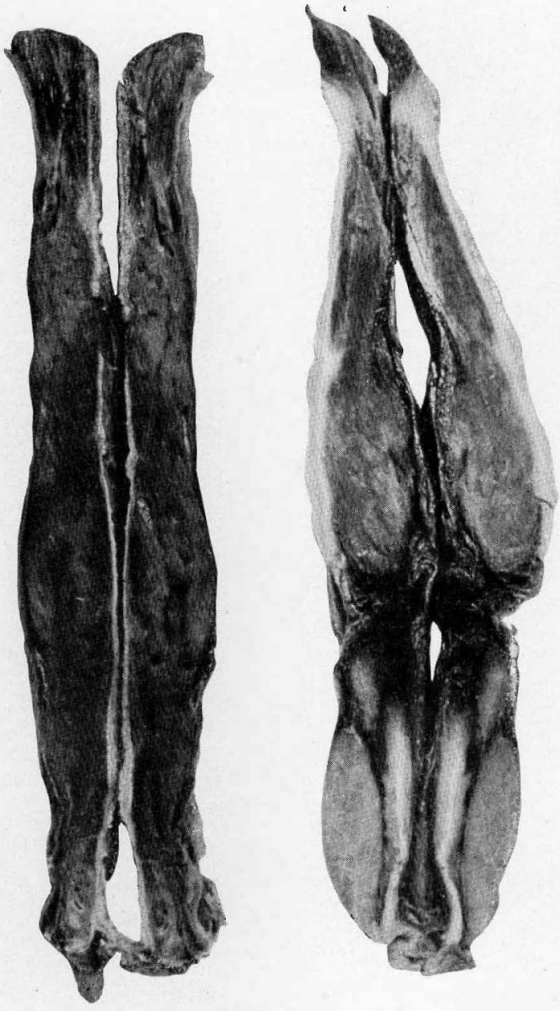

FIG. 37.

(MacCallum: Pneumonia in army camps.)

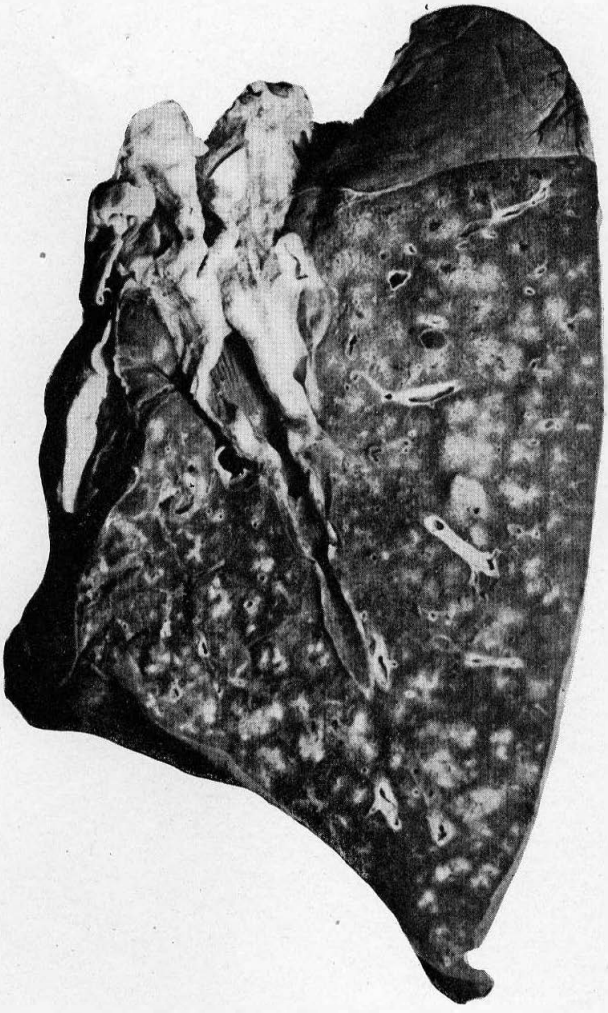

FIG. 38.

(MacCallum: Pneumonia in army camps.)

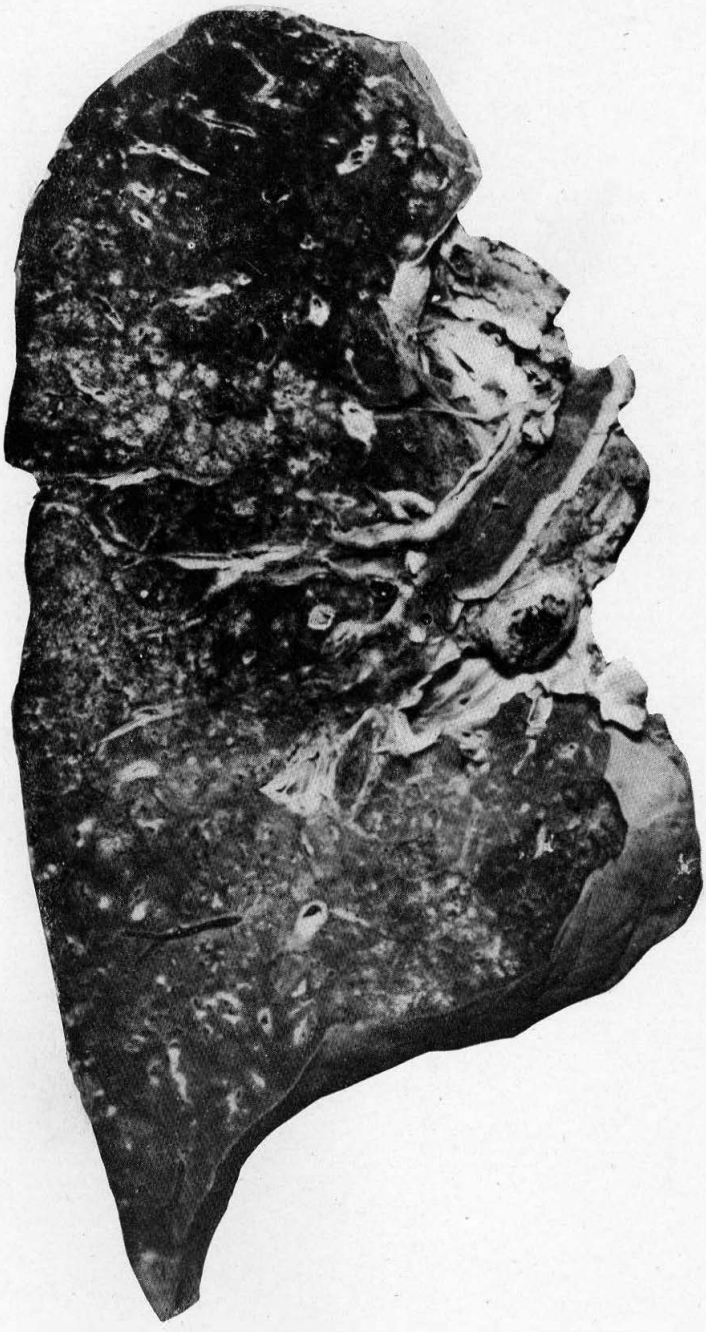

FIG. 39.

(MacCallum: Pneumonia in army camps.)

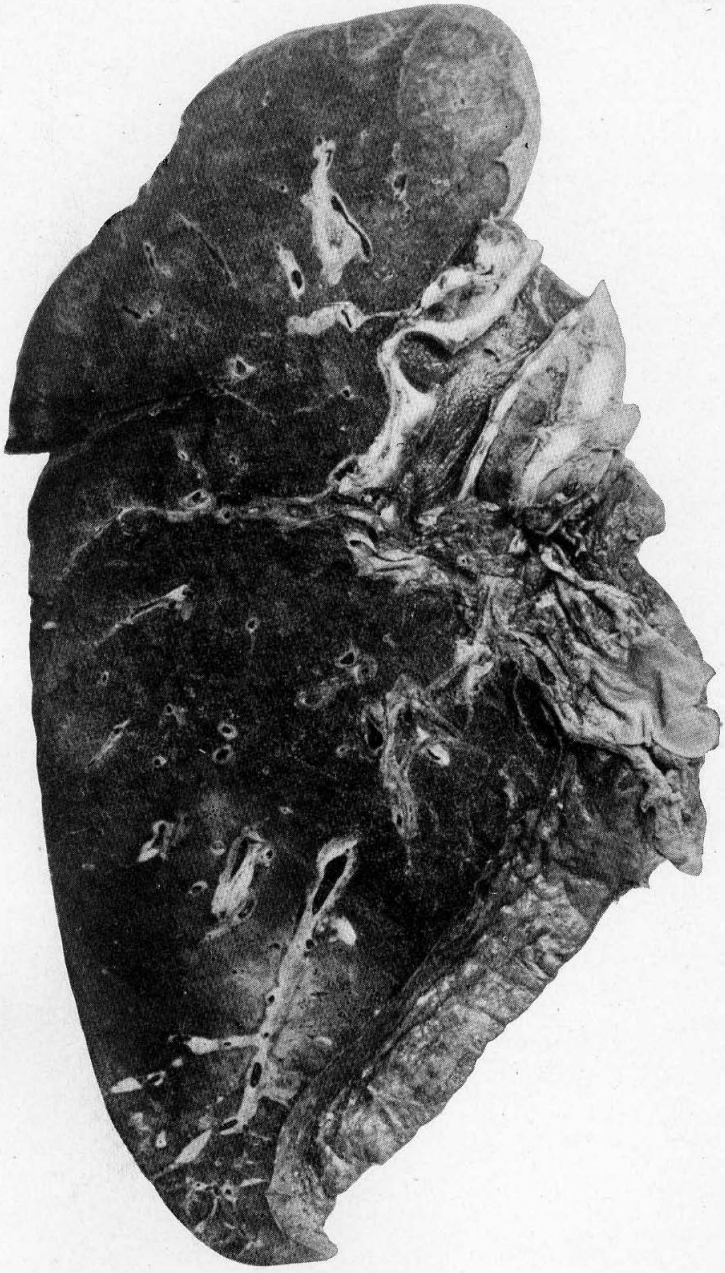

FIG. 40.

(MacCallum: Pneumonia in army camps.)

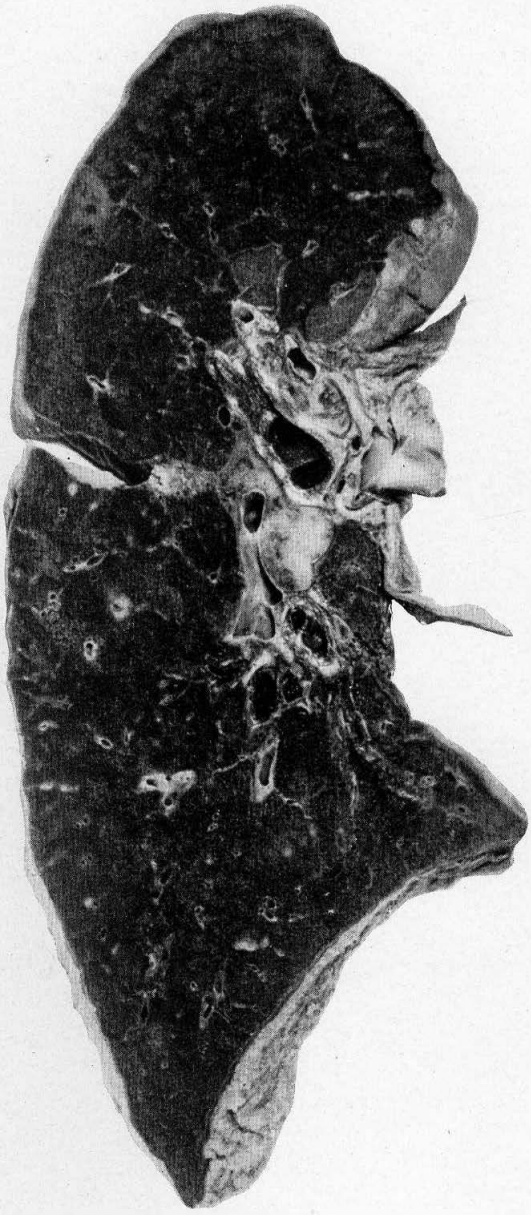

FIG. 41.

(MacCallum: Pneumonia in army camps.)

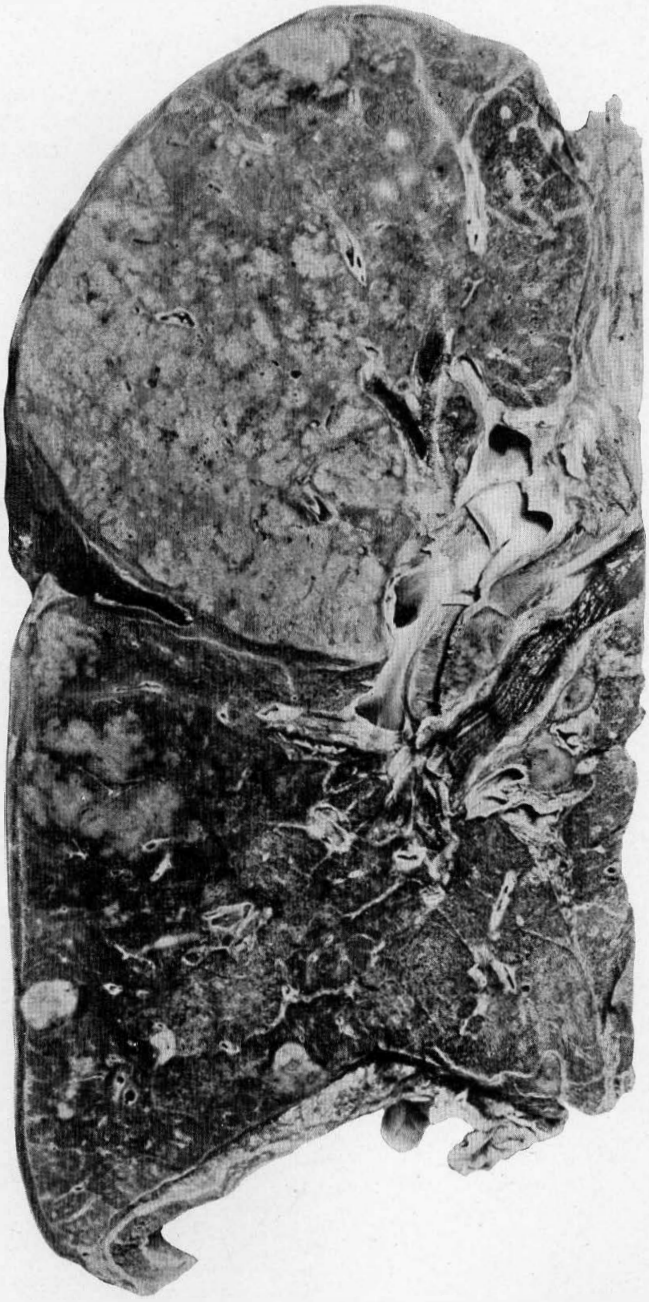

FIG. 42.

(MacCallum: Pneumonia in army camps.)

FIG. 43.

(MacCallum: Pneumonia in army camps.)

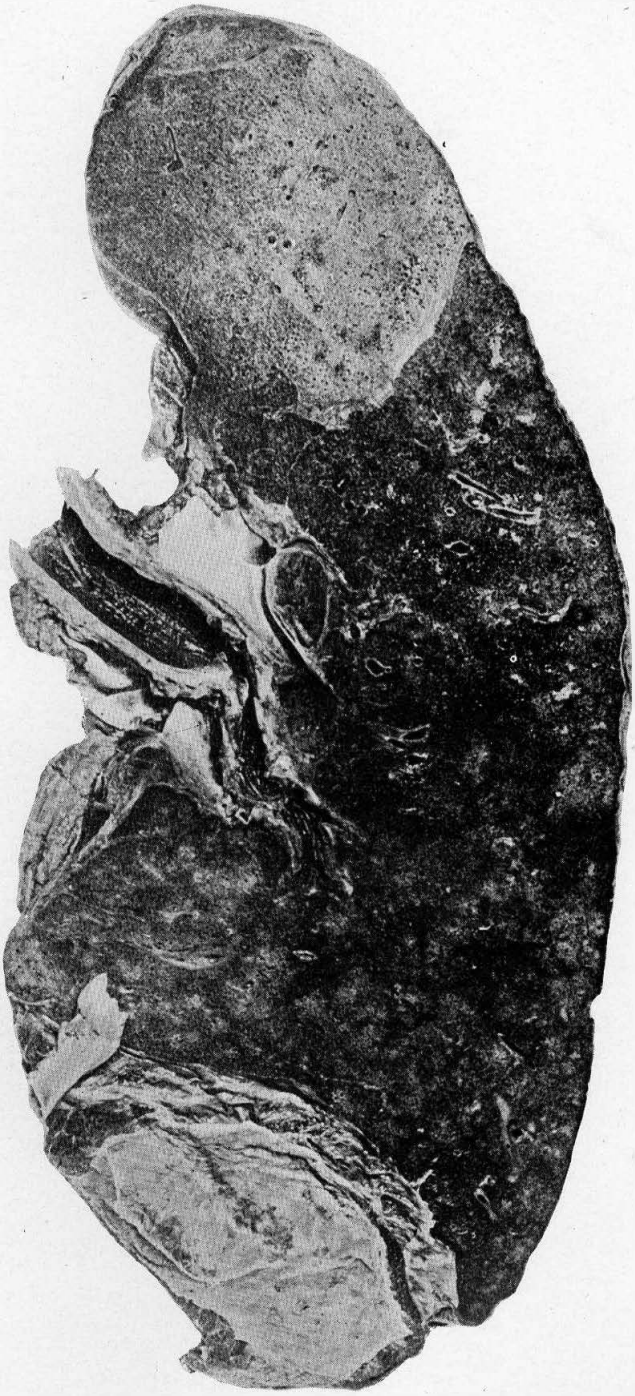

FIG. 44.

(MacCallum: Pneumonia in army camps.)

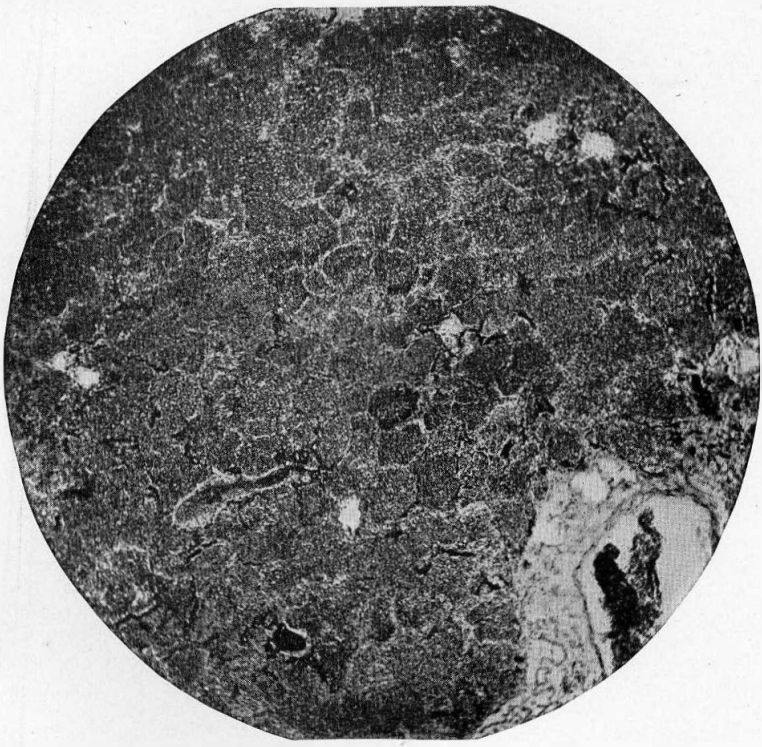

FIG. 45.

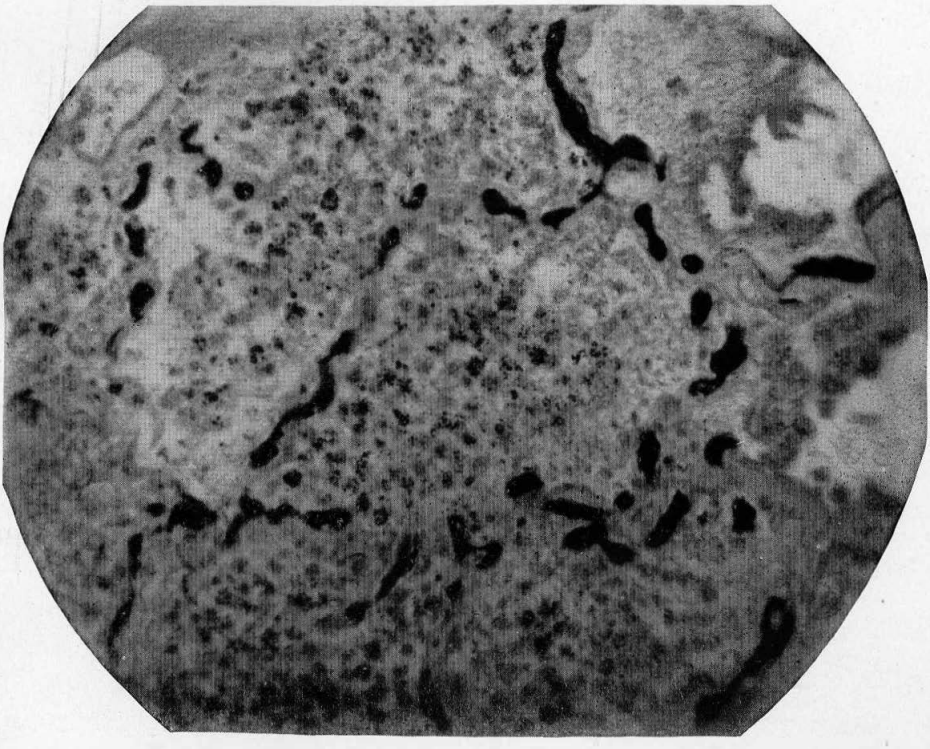

FIG. 46.

(MacCallum: Pneumonia in army camps.)

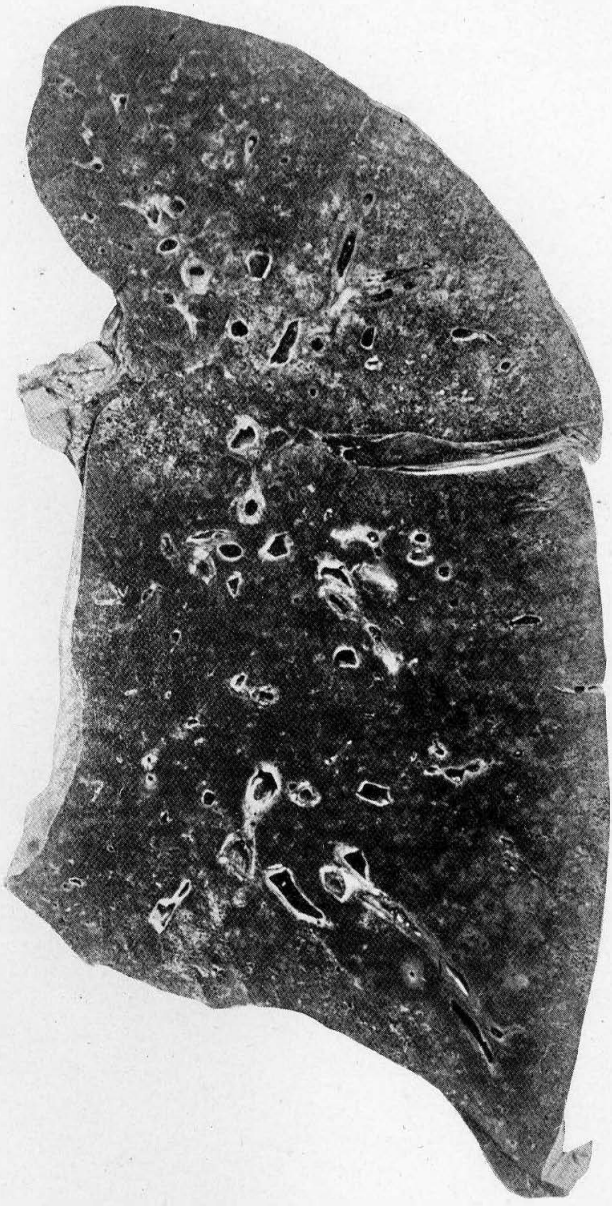

FIG. 47.

(MacCallum: Pneumonia in army camps.)

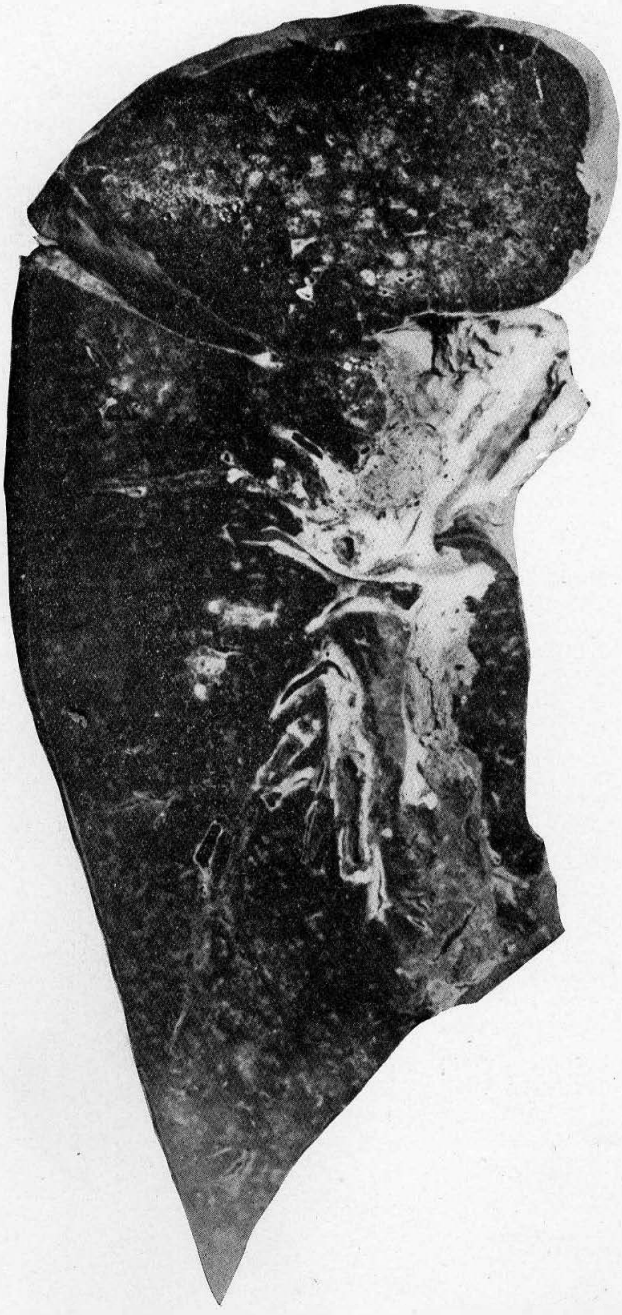

FIG. 48.

(MacCallum: Pneumonia in army camps.)

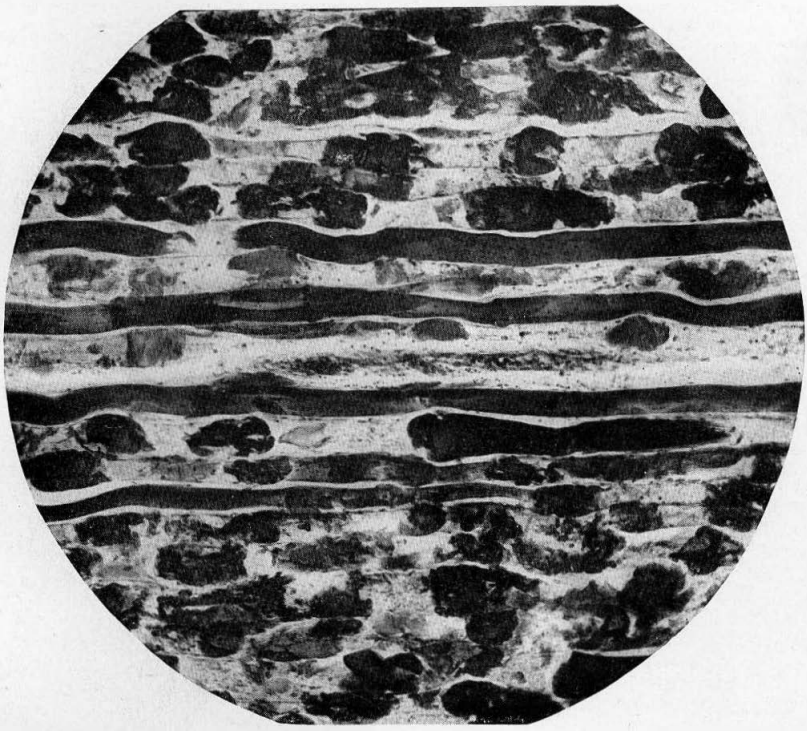

FIG. 49.

(MacCallum: Pneumonia in army camps.)

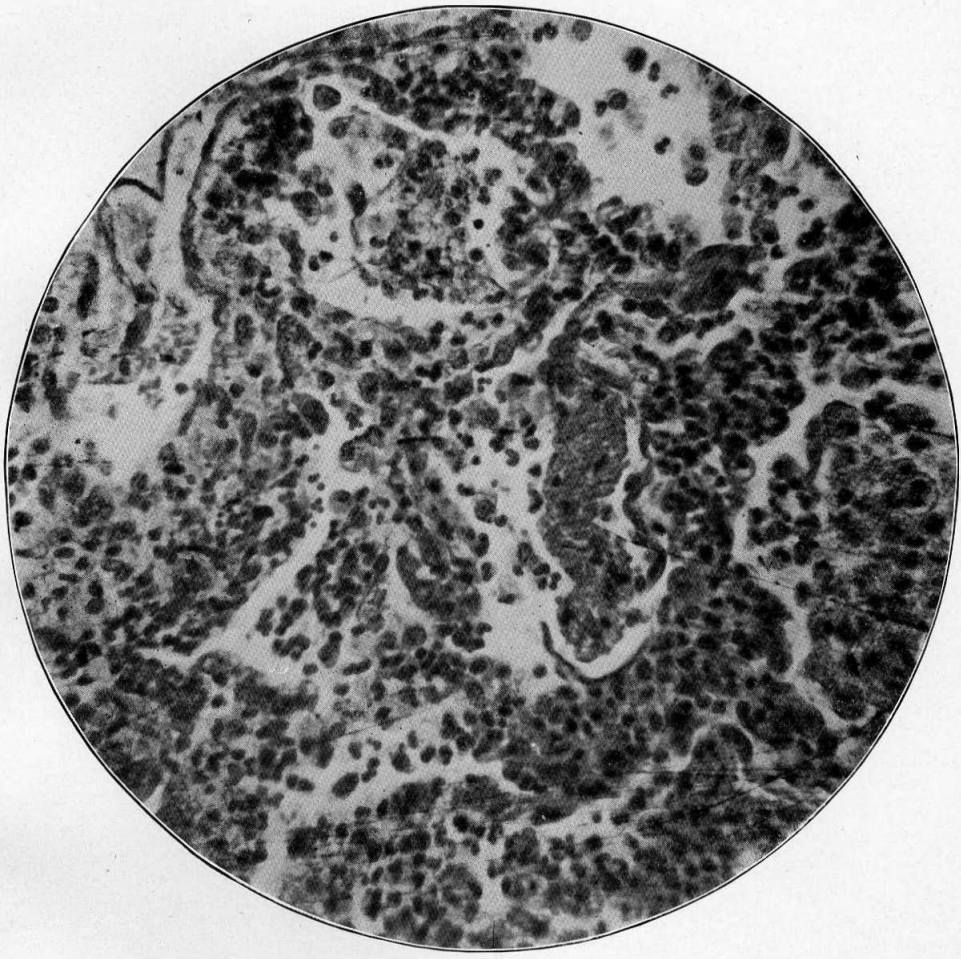

FIG. 50.

(MacCallum: Pneumonia in army camps.)

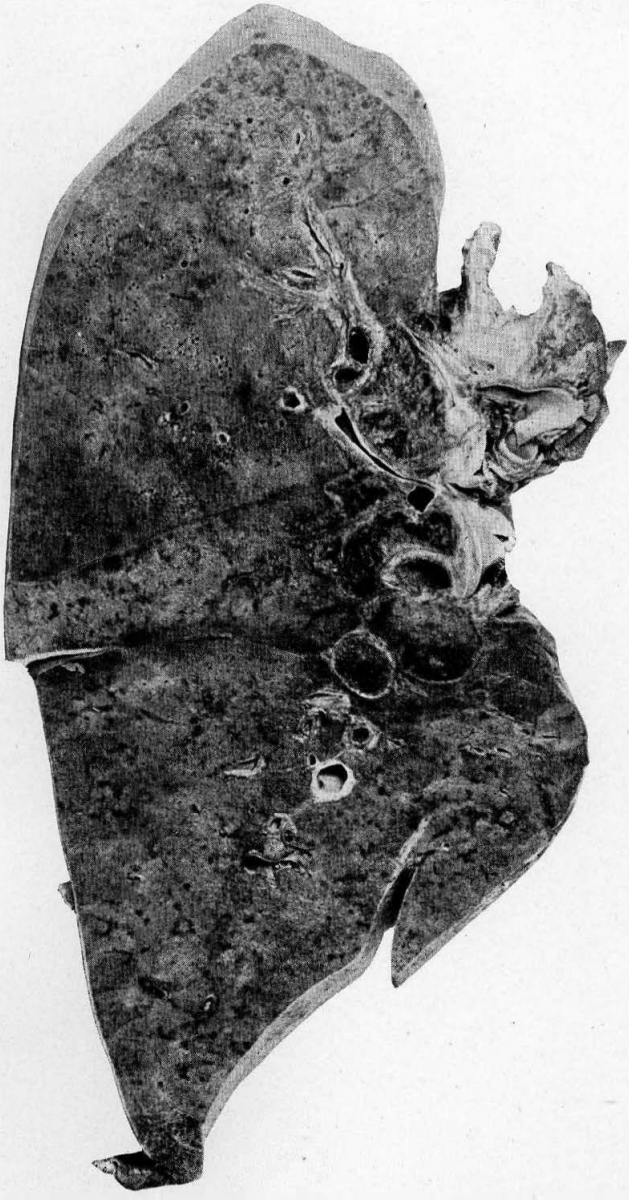

FIG. 51.

(MacCallum: Pneumonia in army camps.)

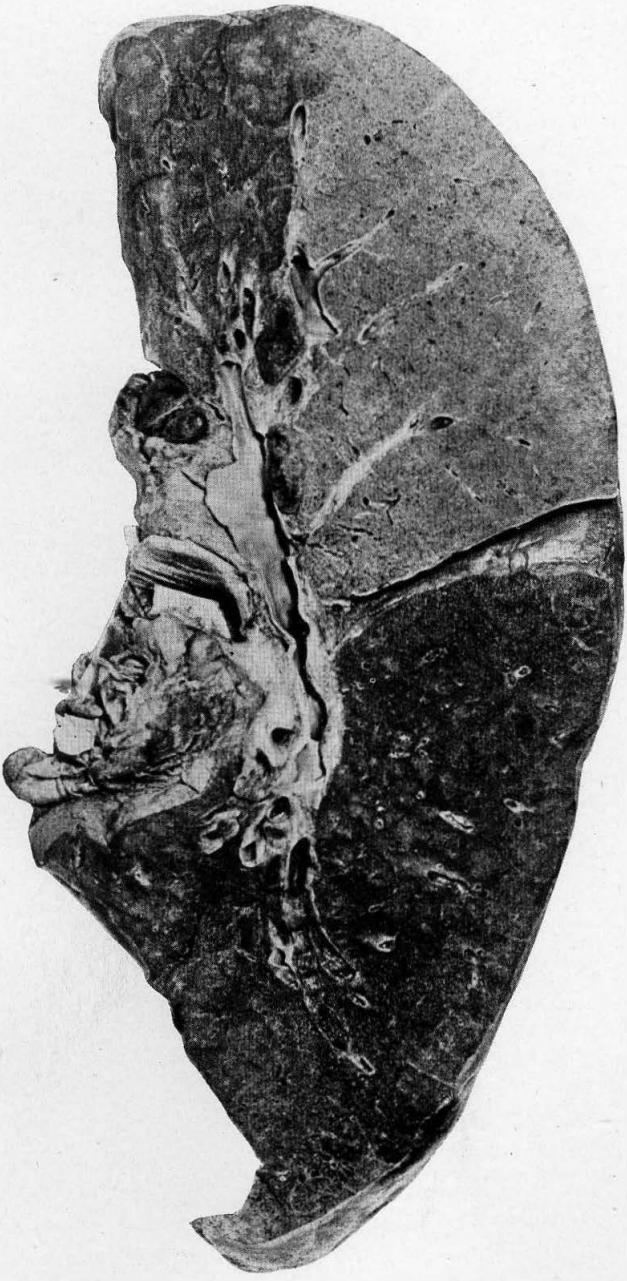

FIG. 52.

(MacCallum: Pneumonia in army camps.)

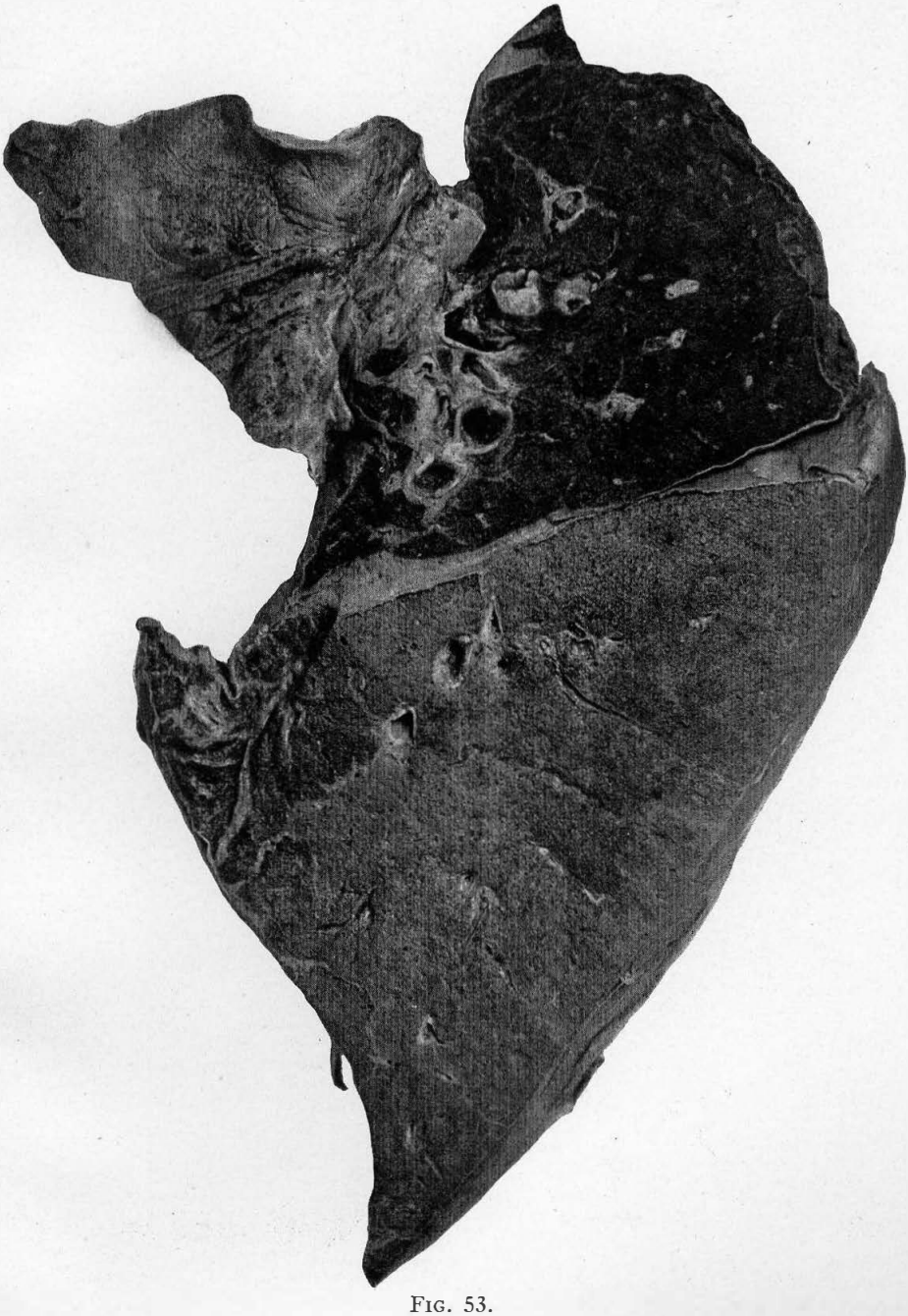

FIG. 53.

(MacCallum: Pneumonia in army camps.)

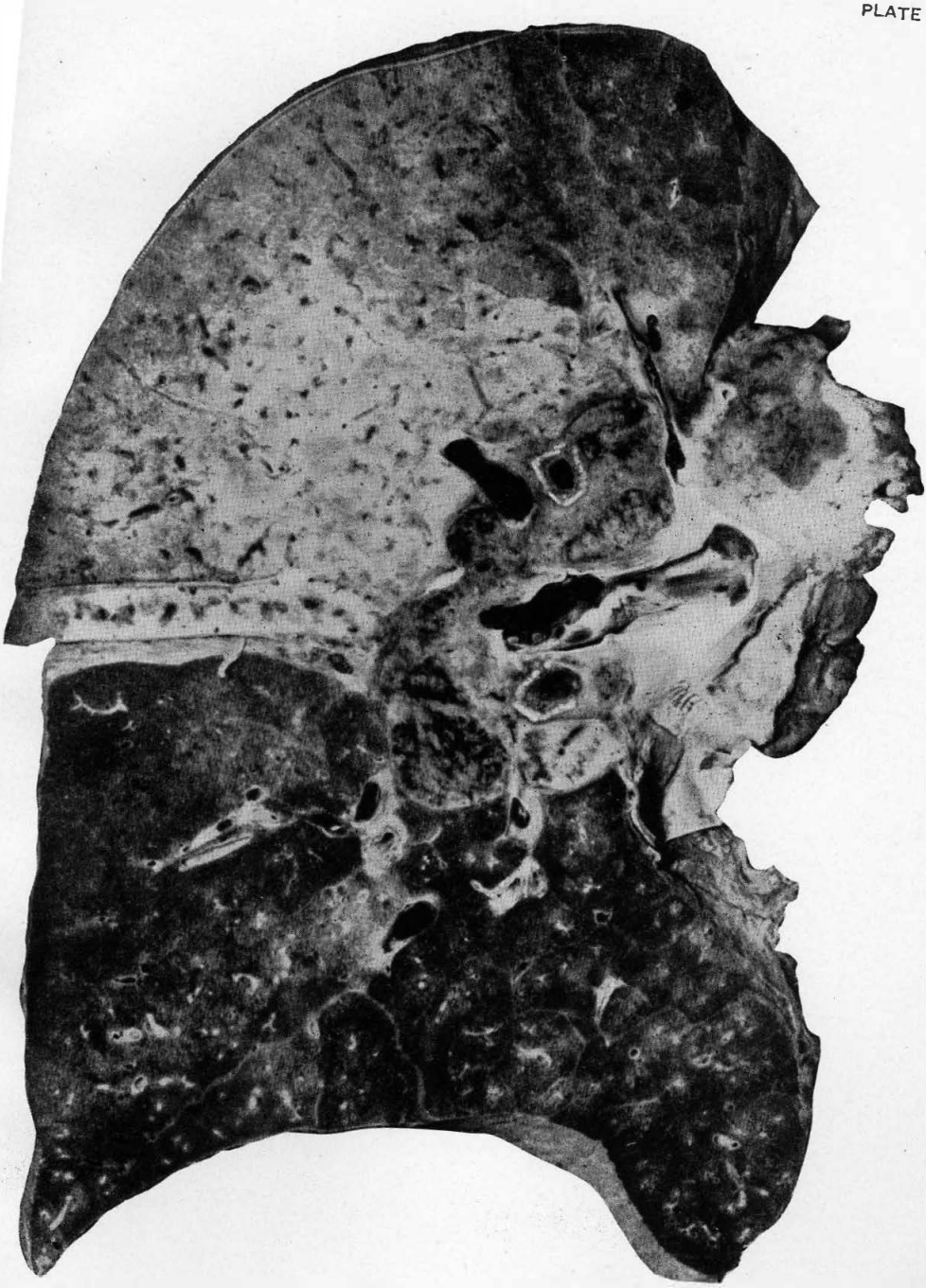

FIG. 54.

(MacCallum: Pneumonia in army camps.)

FIG. 55.

(MacCallum: Pneumonia in army camps.)

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