THE HARVEY SOCIETY

THE HARVEY LECTURES

DELIVERED UNDER THE AUSPICES OF

THE HARVEY SOCIETY
OF NEW YORK

1917-1918
1918-1919

BY

DR. W. T. PORTER
DR. LINSLY R. WILLIAMS
PROF. ALDRED SCOTT WARTHIN
DR. HENRY C. SHERMAN
PROF. J. GORDON WILSON
DR. E. K. DUNHAM
MAJOR ROBERT M. YERKES
DR. FREDERIC S. LEE
COLONEL FRANK P. UNDERHILL
DR. YANDELL HENDERSON
DR. STEWART PATON

SERIES XIII and XIV

PHILADELPHIA AND LONDON
J. B. LIPPINCOTT COMPANY

PREFACE

In medicine, as in many other departments of knowledge, notable advances have followed the intensive stimulation of research which the exigencies of the war have made necessary, and in some cases have facilitated through the unusual conditions existing. The problems of hygiene and of epidemiology attendant on the concentration of large bodies of men in camps and at the front, the treatment of the injuries received, the after care of the disabled, the restriction of food supplies, such new developments as military aviation and the use of poison gases, the conditions existing in industrial establishments running at high pressure, these and many other questions have presented opportunities for investigation which have been developed to the full. It is not astonishing, therefore, to find that of the lectures delivered before the Harvey Society during the seasons of 1917-18 and 1918-19 the majority were closely concerned with the war and its effects. How fruitful have been the labors of those who have addressed the Society both on military and non-military subjects is evident from a perusal of the lectures.

The Society extends its thanks to the speakers who so generously gave it their time and efforts under conditions when both were especially precious. Grateful acknowledgement is also due to the editors who have kindly permitted the reprinting of lectures which have already appeared in the pages of the following journals: *The American Journal of Syphilis, The Journal of Industrial and Engineering Chemistry, Archives of Internal Medicine, Science,* and to Mr. Paul Hoeber for permission to reprint Dr. Paton's lecture.

An undesirable consequence of the war has been the necessity of publishing the lectures of the thirteenth and fourteenth series in a single volume, and the delay in its appearance which has resulted. It is also to be regretted that it has not been possible to secure for publication the lecture of Colonel Whitmore on "Infectious Diseases in the Army," and that of Dr. Alsberg on "Scientific Aspects of Current Food Problems."

KARL M. VOGEL,
Secretary.

May, 1920.

THE HARVEY SOCIETY

A SOCIETY FOR THE DIFFUSION OF KNOWLEDGE OF THE MEDICAL SCIENCES

CONSTITUTION

I.

This Society shall be named the Harvey Society.

II.

The object of this Society shall be the diffusion of scientific knowledge in selected chapters in anatomy, physiology, pathology, bacteriology, pharmacology, and physiological and pathological chemistry, through the medium of public lectures by men who are workers in the subjects presented.

III.

The members of the Society shall constitute three classes: Active, Associate, and Honorary members. Active members shall be laboratory workers in the medical or biological sciences, residing in the City of New York, who have personally contributed to the advancement of these sciences. Associate members shall be meritorious physicians who are in sympathy with the objects of the Society, residing in the City of New York. Members who leave New York to reside elsewhere may retain their membership. Honorary members shall be those who have delivered lectures before the Society and who are neither active nor associate members. Associate and honorary members shall not be eligible to office, nor shall they be entitled to a vote.

Members shall be elected by ballot. They shall be nominated to the Executive Committee and the names of the nominees shall accompany the notice of the meeting at which the vote for their election will be taken.

IV.

The management of the Society shall be vested in an executive committee, to consist of a President, a Vice-President, a Secretary, a Treasurer, and three other members, these officers to be elected by ballot at each annual meeting of the Society to serve one year.

V.

The Annual meeting of the Society shall be held soon after the concluding lecture of the course given during the year, at a time and place to be determined by the Executive Committee. Special meetings may be held at such times and places as the Executive Committee may determine. At all the meetings *ten* members shall constitute a quorum.

VI.

Changes in the Constitution may be made at any meeting of the Society by a majority vote of those present after previous notification of the members in writing.

OFFICERS OF THE HARVEY SOCIETY

OFFICERS

1917–1918

E. K. Dunham, *President*
Rufus Cole, *Vice President*
F. H. Pike, *Treasurer*
A. M. Pappenheimer, *Secretary*

1918–1919

Graham Lusk, *President*
Rufus Cole, *Vice President*
F. H. Pike, *Treasurer*
Karl M. Vogel, *Secretary*

COUNCIL

1917–1918

Graham Lusk
George B. Wallace
Frederic S. Lee
Peyton Rous

1918–1919

Graham Lusk
James W. Jobling
John Auer
Frederic S. Lee
The Officers Ex-Officio.

ACTIVE MEMBERS

Dr. John S. Adriance
Dr. F. M. Allen
Dr. Hugh Auchincloss
Dr. John Auer
Dr. O. T. Avery
Dr. George Baehr
Dr. F. W. Bancroft
Dr. S. R. Benedict
Dr. Herman M. Biggs
Dr. Harlow Brooks
Dr. Wade H. Brown
Dr. Leo Buerger
Dr. R. Burton-Opitz
Dr. E. E. Butterfield
Dr. Alexis Carrel
Dr. R. L. Cecil
Dr. P. F. Clark
Dr. A. F. Coca
Dr. A. E. Cohn
Dr. Rufus Cole
Dr. Robert Cooke
Dr. H. D. Dakin
Dr. C. B. Davenport
Dr. A. R. Dochez
Dr. E. F. Du Bois
Dr. E. K. Dunham
Dr. Walter H. Eddy
Dr. W. J. Elser
Dr. Haven Emerson
Dr. Ephraim M. Ewing
Dr. James Ewing
Dr. L. W. Famulener
Dr. J. S. Ferguson
Dr. C. W. Field

Dr. Morris S. Fine
Dr. Simon Flexner
Dr. N. B. Foster
Dr. Alexander Fraser
Dr. Francis R. Fraser
Dr. F. L. Gates
Dr. A. O. Gettler
Dr. H. R. Geyelin
Dr. W. J. Gies
Dr. T. S. Githens
Dr. Frederick Goodridge
Dr. T. W. Hastings
Dr. R. A. Hatcher
Dr. A. F. Hess
Dr. J. G. Hopkins
Dr. Paul E. Howe
Dr. John Howland
Dr. G. S. Huntington
Dr. Holmes C. Jackson
Dr. W. A. Jacobs
Dr. H. H. Janeway
Dr. James W. Jobling
Dr. D. R. Joseph
Dr. D. M. Kaplan
Dr. I. S. Kleiner
Dr. Charles Krumwiede
Dr. R. V. Lamar
Dr. R. A. Lambert
Dr. Frederic S. Lee
Dr. E. S. L'Esperance
Dr. P. A. Levene
Dr. I. Levin
Dr. E. Libman
Dr. C. C. Lieb
Dr. Warfield T. Longcope
Dr. Graham Lusk
Dr. F. H. McCrudden
Dr. W. G. MacCallum
Dr. Franklin C. McLean
Dr. Ward J. MacNeal
Dr. A. R. Mandel
Dr. John A. Mandel
Dr. F. S. Mandlebaum
Dr. W. H. Manwaring, Jr.
Dr. S. J. Meltzer
Dr. Adolf Meyer
Dr. G. M. Meyer
Dr. Edgar G. Miller, Jr.
Dr. L. S. Milne
Dr. C. V. Morrill
Dr. H. O. Mosenthal
Dr. J. R. Murlin
Dr. J. B. Murphy
Dr. V. C. Myers
Dr. W. C. Noble
Dr. Hideyo Noguchi
Dr. Charles Norris
Dr. Horst Oertel
Dr. Peter K. Olitsky
Dr. Eugene L. Opie
Dr. B. S. Oppenheimer
Dr. R. Ottenberg
Dr. W. W. Palmer
Dr. A. M. Pappenheimer
Dr. William H. Park
Dr. F. W. Peabody
Dr. Louise Pearce
Dr. Richard M. Pearce
Dr. F. H. Pike
Dr. Harry Plotz
Dr. Frederick Prime
Dr. T. M. Prudden
Dr. A. N. Richards
Dr. A. I. Ringer
Dr. C. G. Robinson
Dr. Peyton Rous
Dr. H. von W. Schulte
Dr. Otto H. Schultze
Dr. E. L. Scott
Dr. H. D. Senior

ACTIVE MEMBERS—*Continued*

Dr. E. G. Stillman
Dr. C. R. Stockard
Dr. I. Strauss
Dr. H. F. Swift
Dr. Douglas Symmers
Dr. Oscar Teague
Dr. B. T. Terry
Dr. Wm. C. Thro
Dr. Frederick Tilney
Dr. J. C. Torrey
Dr. D. D. Van Slyke
Dr. K. M. Vogel
Dr. Augustus Wadsworth
Dr. A. J. Wakeman
Dr. G. B. Wallace
Dr. Wm. H. Welker
Dr. Clarence J. West
Dr. J. S. Wheelwright
Dr. C. G. Wiggers
Dr. Anna Williams
Dr. H. B. Williams
Dr. R. J. Wilson
Dr. Wm. H. Woglom
Dr. Martha Wollstein
Dr. Francis C. Wood
Dr. Jonathan Wright
Dr. Hans Zinsser

ASSOCIATE MEMBERS

Dr. Robert Abbe
Dr. F. H. Albee
Dr. Pearce Bailey
Dr. T. B. Barringer
Dr. F. H. Bartlett
Dr. Simon Baruch
Dr. W. A. Bastedo
Dr. Joseph A. Blake
Dr. George Blumer
Dr. A. Bookman
Dr. David Bovaird, Jr.
Dr. J. W. Brannan
Dr. Joseph Brettauer
Dr. G. E. Brewer
Dr. N. E. Brill
Dr. Wm. B. Brinsmade
Dr. E. B. Bronson
Dr. S. A. Brown
Dr. J. G. M. Bullowa
Dr. S. R. Burnap
Dr. Glentworth R. Butler
Dr. C. N. B. Camac
Dr. Wm. F. Campbell
Dr. R. J. Carlisle
Dr. H. S. Carter
Dr. A. F. Chace
Dr. C. G. Coakley
Dr. Martin Cohen
Dr. Warren Coleman
Dr. William B. Coley
Dr. C. F. Collins
Dr. L. A. Conner
Dr. C. B. Coulter
Dr. E. B. Cragin
Dr. Floyd M. Crandall
Dr. G. W. Crary
Dr. Edward Cussler
Dr. Charles L. Dana
Dr. Thomas Darlington
Dr. William Darrach
Dr. D. Bryson Delavan
Dr. E. B. Dench
Dr. W. K. Draper
Dr. Alexander Duane
Dr. Theodore Dunham
Dr. Cary Eggleston

Dr. Max Einhorn
Dr. Charles A. Elsberg
Dr. A. A. Epstein
Dr. Evan M. Evans
Dr. S. M. Evans
Dr. E. D. Fisher
Dr. Rolfe Floyd
Dr. John A. Fordyce
Dr. Robert T. Frank
Dr. Rowland G. Freeman
Dr. Wolff Freudenthal
Dr. L. F. Frissell
Dr. H. Dawson Furniss
Dr. Virgil P. Gibney
Dr. S. S. Goldwater
Dr. M. Goodridge
Dr. N. W. Green
Dr. J. C. Greenway
Dr. M. S. Gregory
Dr. R. H. Halsey
Dr. Graeme M. Hammond
Dr. T. Stuart Hart
Dr. John A. Hartwell
Dr. R. S. Haynes
Dr. Henry Heiman
Dr. W. W. Herrick
Dr. August Hoch
Dr. A. W. Hollis
Dr. H. A. Houghton
Dr. Hubert S. Howe
Dr. Francis Huber
Dr. E. L. Hunt
Dr. Woods Hutchinson
Dr. Leopold Jaches
Dr. Abraham Jacobi
Dr. George W. Jacoby
Dr. Ralph Jacoby
Dr. Walter B. James
Dr. S. E. Jelliffe
Dr. Frederick Kammerer
Dr. Ludwig Kast
Dr. Jacob Kaufman
Dr. F. L. Keays
Dr. Foster Kennedy
Dr. C. G. Kerley
Dr. P. D. Kerrison
Dr. E. L. Keyes, Jr.
Dr. Eleanor Kilham
Dr. R. A. Kinsella
Dr. Arnold Knapp
Dr. Linnaeus E. La Fetra
Dr. A. R. Lamb
Dr. Alexander Lambert
Dr. Samuel W. Lambert
Dr. Boleslaw Lapowski
Dr. Berton Lattin
Dr. B. J. Lee
Dr. J. S. Leopold
Dr. Eli Long
Dr. William C. Lusk
Dr. D. H. McAlpin
Dr. Morris Manges
Dr. George Mannheimer
Dr. H. H. Mason
Dr. Frank S. Meara
Dr. Victor Meltzer
Dr. Walter Mendelson
Dr. Alfred Meyer
Dr. Willy Meyer
Dr. Michael Michailovsky
Dr. G. N. Miller
Dr. James A. Miller
Dr. A. V. Moschcowitz
Dr. John P. Munn

ASSOCIATE MEMBERS—*Continued*

Dr. Archibald Murray
Dr. L. K. Neff
Dr. M. Nicoll
Dr. Walter L. Niles
Dr. Van Horne Norrie
Dr. William P. Northrup
Dr. N. R. Norton
Dr. A. T. Osgood
Dr. H. McM. Painter
Dr. Eleanor Parry
Dr. Stewart Paton
Dr. Henry S. Patterson
Dr. Charles H. Peck
Dr. Frederick Peterson
Dr. James Pedersen
Dr. G. R. Pisek
Dr. Sigismund Pollitzer
Dr. Eugene H. Pool
Dr. Wm. J. Pulley
Dr. Edward Quintard
Dr. F. M. Rackamann
Dr. John H. Richards
Dr. A. F. Riggs
Dr. Andrew R. Robinson
Dr. John Rogers, Jr.
Dr. J. C. Roper
Dr. Bernard Sachs
Dr. E. F. Sampson
Dr. T. B. Satterthwaite
Dr. R. H. Sayre
Dr. Max G. Schlapp
Dr. H. J. Schwartz
Dr. N. M. Shaffer
Dr. William H. Sheldon
Dr. H. M. Silver
Dr. M. J. Sittenfield
Dr. Martin de Forest Smith
Dr. F. P. Solley
Dr. F. E. Sondern
Dr. J. Bentley Squier, Jr.
Dr. Norbert Stadtmuller
Dr. Antonio Stella
Dr. Abram R. Stern
Dr. George D. Stewart
Dr. R. G. Stillman
Dr. Wm. S. Stone
Dr. A. McI. Strong
Dr. Mills Sturtevant
Dr. Parker Syms
Dr. A. S. Taylor
Dr. John S. Thacher
Dr. A. M. Thomas
Dr. Wm. B. Trimble
Dr. Philip Van Ingen
Dr. J. D. Voorhees
Dr. John B. Walker
Dr. Josephine Walter
Dr. James S. Waterman
Dr. R. W. Webster
Dr. John E. Weeks
Dr. Herbert B. Wilcox
Dr. Linsly R. Williams
Dr. Margaret B. Wilson
Dr. G. Woolsey
Dr. J. H. Wyckoff
Dr. Charles H. Young
Dr. John Van Doren Young

PERMANENT SUBSCRIBERS

Dr. Charles D. Aaron
Dr. A. D. Blackader
Dr. Charles Goodwin Jennings
Dr. Charles G. Rogers

HONORARY MEMBERS

Prof. J. G. Adami
Dr. Carl L. Alsberg
Prof. J. F. Anderson
Prof. E. R. Baldwin
Prof. Lewellys F. Barker
Prof. F. G. Benedict
Prof. R. R. Bensley
Prof. A. Calmette
Prof. Walter B. Cannon
Prof. A. J. Carlson
Prof. W. E. Castle
Prof. Charles V. Chapin
Prof. Hans Chiari
Prof. R. H. Chittenden
Prof. Henry A. Christian
Prof. Otto Cohnheim
Prof. Edward G. Conklin
Prof. W. T. Councilman
Prof. G. W. Crile
Prof. Harvey Cushing
Prof. Arthur R. Cushny
Prof. Henry A. Donaldson
Prof. D. L. Edsall
Prof. Joseph Erlanger
Prof. William Falta
Prof. Otto Folin
Prof. F. P. Gay
Prof. J. S. Haldane
Prof. W. S. Halsted
Prof. Ross G. Harrison
Prof. Sven G. Hedin
Prof. Ludwig Hektoen
Prof. L. J. Henderson
Prof. Yandell Henderson
Prof. W. H. Howell
Prof. G. Carl Huber
Prof. Joseph Jastrow
Prof. H. S. Jennings
Prof. E. O. Jordan
Prof. E. P. Joslin
Prof. Franz Knoop
Prof. Albrecht Kossel
Prof. J. B. Leathes
Prof. A. Magnus-Levy
Prof. Paul A. Lewis
Prof. Thomas Lewis
Prof. Jacques Loeb
Prof. A. S. Loewenhart
Prof. A. B. Macallum
Prof. J. J. R. MacLeod
Prof. E. V. McCollum
Prof. F. B. Mallory
Prof. L. B. Mendel
Prof. Hans Meyer
Prof. T. H. Morgan
Prof. Friedrich Müller
Prof. Karl von Noorden
Prof. Fred G. Novy
Prof. G. H. F. Nuttall
Prof. Henry Fairfield Osborn
Prof. T. B. Osborne
Prof. G. H. Parker
Prof. W. T. Porter
Prof. J. J. Putnam
Prof. T. W. Richards
Prof. M. J. Rosenau
Prof. Max Rubner
Prof. F. F. Russell
Prof. Florence R. Sabin
Sir E. A. Schaefer
Prof. Adolph Schmidt
Prof. W. T. Sedgwick
Prof. Henry C. Sherman
Prof. Theobald Smith
Prof. E. H. Starling
Prof. G. N. Stewart
Prof. C. W. Stiles
Prof. Richard P. Strong
Prof. A. E. Taylor
Prof. W. S. Thayer

Col. F. P. Underhill
Prof. Victor C. Vaughan
Prof. Max Verworn
Prof. A. D. Waller
Prof. A. S. Warthin
Prof. J. Clarence Webster
Prof. Wm. H. Welch
Prof. H. Gideon Wells
Col. Eugene R. Whitmore
Prof. E. B. Wilson
Prof. J. Gordon Wilson
Prof. R. T. Woodyatt
Prof. Sir Almroth Wright
Major R. M. Yerkes

DECEASED

Dr. Isaac Adler
Dr. Samuel Alexander
Dr. W. B. Anderton
Dr. L. Bolton Bangs
Dr. Carl Beck
Dr. J. B. Borden
Dr. T. G. Brodie
Dr. F. Tilden Brown
Dr. S. M. Brickner
Dr. J. D. Bryant
Dr. John G. Curtis
Dr. Austin Flint
Dr. C. G. Garside
Dr. Emil Gruening
Dr. Frank Hartley
Dr. Christian A. Herter
Dr. Philip Hanson Hiss
Dr. Eugene Hodenpyl
Dr. John H. Huddleston
Dr. Edward G. Janeway
Dr. Theodore C. Janeway
Dr. Francis P. Kinnicutt
Dr. Hermann Knapp
Dr. Gustav Langman
Dr. Egbert Le Fevre
Dr. Charles H. Lewis
Dr. Sigmund Lustgarten
Dr. W. B. Marple
Dr. Charles McBurney
Dr. George McNaughton
Dr. Charles S. Minot
Dr. S. Weir Mitchell
Dr. G. R. Pogue
Dr. Wm. M. Polk
Dr. C. C. Ransom
Dr. Wm. K. Simpson
Dr. A. Alexander Smith
Dr. Richard Stein
Dr. H. A. Stewart
Dr. L. A. Stimson
Dr. William Hanna Thompson
Dr. Wisner R. Townsend
Dr. R. Van Santvoord
Dr. Henry F. Walker
Dr. Richard Weil
Dr. H. F. L. Ziegel

CONTENTS

ILLUSTRATIONS

TRAUMATIC SHOCK *

DR. W. T. PORTER.†
Harvard University.

I

THE history of traumatic shock during the past thirty years has been marked by hypotheses that have caused much confusion. These hypotheses give as the cause of shock (1) the exhaustion of the vasomotor centre; (2) the excitation of sensory nerves; (3) a hydrostatic fall in blood-pressure; (4) vibration injuries; (5) direct wounds of the vasomotor apparatus; (6) hemorrhage. Some of these ideas are erroneous; others are imperfectly grasped.

The hypothesis that shock is caused by exhaustion of the vasomotor centre, for long a mere speculation, was given finally a serious position by two much quoted studies. One of these studies was by a surgeon who enjoys deservedly a great reputation; the other by physicians not less celebrated. Both were grounded on failures. The surgeon failed to obtain a satisfactory reflex rise of blood-pressure on stimulation of afferent vasomotor fibres in animals with experimental shock—the physicians in animals with diphtheria.

Against the first of these negative results, I brought the following positive experiment:

At 9.15 A.M. on September 24, 1903, the stimulation of the depressor nerve caused the blood-pressure to fall from 67 to 36 mm. Hg, a fall of 46 per cent. The animal then lay for eight hours with exposed intestines painted with nitric acid. All the signs of shock were present. The rectal temperature was 11° C. below normal. At the end of these eight hours of shock, at five

---

* Delivered October 27, 1917.

† This review of my researches on shock has been brought to date (December, 1919) by including certain experiments made after this Harvey lecture was delivered.

o'clock in the afternoon, the stimulation of the depressor nerve caused the blood-pressure to fall from 40 to 22 mm., a fall of 45 per cent.[1]

Since the depressor nerve can affect the blood-pressure only through the vasomotor centre, it is clear that the vasomotor centre is not exhausted in shock.

Nor is it exhausted in the last hours of infectious diseases such as diphtheria and pneumonia.

On December 20, 1913, the central ends of the divided vagus nerves were stimulated in a cat near death with pneumonia. The blood-pressure fell from 100 mm. Hg to 65 mm. This is the usual depressor fall obtained in normal animals.

January 2, 1914, the central end of the sciatic nerve was stimulated in another cat near death with pneumonia. The blood-pressure was at 55 mm.; it rose to 125 mm., an absolute rise of 70 mm. This was even more than the usual normal rise.[2]

A rabbit weighing 1400 grams received in the ear vein .004 c.c. diphtheria toxin at 1.05 P.M., January 18, 1914. The morning of January 20, the rabbit seemed listless. It was placed on a table and observed continuously from 9 A.M. As the day wore on, the rabbit could not hold up his head, nor regain his feet when laid upon one side. Finally, about 3.15 P.M., he lay prone, the head stretched on the table, and the respiration feeble and labored. At 3.30 he seemed so near death that he was placed on the operating board. Death at once followed; there was no corneal reflex, no respiration, no heart beat, the carotid artery seemed empty, and the rectal temperature was 32° C. The rabbit was completely insensitive. It was quickly tracheotomized and artificial respiration was established. Warm normal saline solution was injected into the external jugular vein. The heart began to beat, though feebly, scarcely raising the writing point of a membrane manometer, completely undamped. The carotid pressure rose to about 80 mm. Hg. Both vagi were now cut and the depressor nerve was stimulated.

The carotid pressure fell on stimulation from 80, 70, and 72 mm. Hg to 52, 40, and 45 mm., respectively; an absolute fall of 28, 30, and 27 mm. Hg, and a percentile fall of 35, 43, and 38.[3]

Thus, normal reaction from the vasomotor centre was obtained.

This animal was not simply ill with diphtheria; he had died of it.

The vasomotor centre is therefore not exhausted in shock. Nor is it exhausted in the infectious diseases, such as diphtheria and pneumonia.

In truth, it is doubtful if the vasomotor centre can be "exhausted," provided it continue to receive its minimum blood supply.

On February 9, 1909, at 10 A.M., I stimulated the depressor nerve with a current of 1000 Kronecker units; the blood-pressure fell 35 mm. Hg. The stimulus was repeated at frequent intervals throughout the day. At 5.40 P.M. the same stimulus caused the blood-pressure to fall 42 mm. Hg. The observation could probably have been continued some hours longer.[4]

Experimental evidence shows that failure of the vasomotor centre is due to anæmia rather than to stimulation. If the blood-pressure in the nutrient capillaries falls below the critical nutrient level—a very low level—the vasomotor cells are at once affected. Bulbar anæmia may be a consequence of prolonged shock, especially when the bulb is allowed to be higher than the trunk—for a man with shock is a gravity animal and his cerebral circulation then depends chiefly on small differences in hydrostatic level—but an injury after shock is not to be confused with an injury causing shock.

In short, exhaustion of the vasomotor centre is a taking phrase, but it is nothing more.

II

A second heresy of recent years was the notion that shock can be produced by the stimulation of nerves. This idea was overthrown by experiments published in 1907.

In 1905, 1906, and 1907, the central ends of the sciatic nerve, the brachial nerves, the posterior spinal roots, the lumbar branches of the spinal nerves, the great splanchnic, the cœliac ganglion, the superior mesenteric plexus, the gastric branches of the vagi, and various parts of the abdominal sympathetic, were stimulated for hours with strong induction currents, in animals anæsthetized with ether.

These numerous stimulations uniformly failed to give a significant fall in blood-pressure.[5]

An apparent exception must be taken to the conclusion that shock cannot be produced by the stimulation of nerves. It relates to a condition of great importance, namely the *sensitization* of the vascular apparatus.

My first encounter with this condition was in 1894, where I found that ligation of the descending branch of the left coronary artery caused fibrillation in 64 per cent. of the dogs to which morphine and curare had been given and in only 8 per cent. of those in which morphine and curare were not employed.[6]

In working with the isolated heart, and especially with strips of ventricular muscle fed through a branch of the coronary artery, I have repeatedly been able to notice instances in which stimuli ordinarily limited in their results produced on these occasions profound and far-reaching reactions. Thus, in 1905 I found that when the auricle of the tortoise heart is stimulated with a short series of induction currents at the rate of one a second, a tonus contraction is called forth. This contraction lasts usually about thirty seconds. In one case a similar stimulus caused a very strong tonus contraction lasting 64 minutes.[7]

In 1906, a rat was etherized and the carotid pressure written with a membrane manometer. A small quantity of very dilute curare solution was injected slowly into the external jugular vein. The blood-pressure was now 70 mm. The difference between diastolic and systolic pressure was about 20 mm. On stimulating the brachial nerves the individual heart beats almost disappeared from the curve, the blood-pressure fell 20 mm., and the writing lever traced an almost unbroken line. On injecting warm saline solution, the heart improved and the difference between systolic and diastolic pressure rose to about 15 mm. An effort was now made to stimulate the central end of the already divided sciatic nerve. When the severed nerve was gently raised upon a thread, the heart again failed, and the above phenomena were repeated. Thirty-six minutes later, a saline injection was given, the heart gradually recovered, the blood-pressure rose to 110 mm., and stimulation of the brachial and sciatic nerves caused a rise of about 20 mm. Hg.[8]

The following case occurred in the practice of a well-known surgeon. I quote his words: In operating on a sarcoma, "a mass of glands in the neck had been freely exposed by the high incision and was readily enucleated. Several large branches of the brachial plexus, however, were spread out over the growth and a secondary division of this portion consequently was necessitated. When this was done, the patient's radial pulse immediately became impalpable. It continued thready and almost imperceptible during the remainder of the operation, which was rapidly completed, and for almost twenty-four hours afterward."[9]

Cases of persistent inhibition of the heart, similar to the one just cited, are often mistaken for true shock.

These instances all relate to the heart. Since the heart is a modified blood-vessel, the sensitization of the heart would lead us to expect sensitization of the arteries. I have at present no experimental evidence of this. Yet there is clincial evidence of prolonged contraction or relaxation of the blood-vessels following stimuli ordinarily uneventful. Such is the tonic arterial contraction in certain migraines, and the long relaxations in urticaria. But the evidence in hand, unquestionable for sensitization of the heart, does not as yet warrant the dogmatic inclusion of sensitization of the arteries among the sources of confusion in shock. The evidence does, however, point strongly in this direction.

I do not discuss at length the possible causes of sensitization, because such a discussion would be at present too speculative. There is here a great and fruitful field for research.

III

A third source of confusion is hydrostatic lowering of the blood-pressure. A simple hydrostatic fall of blood-pressure is not shock. When the intestines are exposed, the largest vascular area in the body dilates and the arterial pressure falls. If this low pressure continue long enough to impair the nutrition of the vascular apparatus, shock may occur. An admirable example of the hydrostatic fall of blood-pressure is seen when a spinal injection of novocain reaches the splanchnic nerve-cells. The arterial pressure falls to the shock level, but the fall is usually too transitory to cause shock.[10]

The shock so often observed in abdominal injuries is unquestionably frequently due to this hydrostatic fall. The vasomotor apparatus of the intestines is remarkably sensitive to an invasion of the peritoneal cavity. When the vessels of this great area have dilated and the blood-pressure has fallen profoundly, the stimulation of the depressor nerve has little or no effect. What more natural than to conclude that the vasomotor centre is then exhausted? The following experiment shows what a pit here yawns for the unwary observer.

On October 26, 1899, both splanchnic nerves were severed in a rabbit. Stimulation of the depressor had little or no effect upon the blood-pressure. The carotid blood-pressure was now raised to 75 mm. Hg by injecting normal saline solution, whereupon a renewed stimulation of the depressor nerves caused a fall to 38 mm. (49 per cent.).[11]

In these abdominal cases there is again the danger that cause and effect may be confused. If the dilatation of the splanchnic vessels finally brings the nutrient level of the vasomotor cells below the irreducible minimum, the vasomotor cells will be injured, but their impairment will be primarily an effect and not a cause.

IV

A fourth example of loose thinking is the confusion of vibration injuries with shock.

In experiments 3 and 21, performed in 1904 and 1907, a heavy blow on the skull caused the blood-pressure to fall 70 per cent. In five observations, the level reached by the descending pressure averaged 33 mm. Hg.[12] This is about the level to which the blood-pressure sinks after the destruction of the spinal cord.

Exploding shells, particularly those that burst within a dugout, sometimes shake the vasomotor cells so violently that their control of the blood-pressure is greatly impaired. Many such cases were communicated to me in 1916 at one of the great hospitals in Amiens. The recovery from this shaken or shattered state depends naturally on the extent of the damage to the vasomotor cells. In the experiments of 1907, the blood-pressure rose again in a few moments. In the soldiers at Amiens, recovery required in some cases several days. It is these vibration injuries which make shock in civil practice so difficult of study.

V

Vibration injuries may no doubt at times be severe enough to rank as wounds of the vasomotor apparatus, but it is convenient to reserve the latter rubric for cases in which the vasomotor cells or the paths connecting them are directly damaged by foreign bodies. When a shell fragment enters the abdomen, such damage can never be excluded. It is, therefore, a constant source of error in any hypothesis of shock after abdominal wounds.

No satisfactory instance of surgical wounds of the vasomotor cells or tracts can be presented here, but I wish to say a few words regarding experimental injuries in the bulbar vasomotor region. Annually, for many years, I have demonstrated an experiment not hitherto published. It consists in burning away parts of the floor of the fourth ventricle in the rabbit. A hole about one centimetre in diameter may be made in the region of the vasomotor centre without a significant fall in the blood-pressure. Some of the vasomotor cells certainly escape destruction, in spite of the wide ruin, and these cells continue to function successfully within a millimetre or two of the black calcined hole left by the destruction of their companions. They are not inhibited.

VI

I approach the subject of hemorrhage with a sigh. It seems almost hopeless to combat the prejudice of the profession with regard to hemorrhage in relation to shock. Military surgeons may be as invulnerable as those in civil practice. I remember a surgeon general in whose mental armor the high explosives of physiology did not leave a single dent. In his own trenches he was an excellent officer, but he was not good at going over the top. He had seen thousands of wounded, he knew that shock appears once in every hundred casualties, but he had not noticed that among the other ninety-nine there were practically always men who had bled more than the shocked but who nevertheless had no shock. Every surgeon knows that from a pint to a quart of blood can be taken from a healthy young man without serious results. Every surgeon also knows that on the operating table the loss of a small quantity of blood may sometimes cause shock. Here is the source of the confusion.

The relation of hemorrhage to shock is too complicated to be treated here, despite the generous limits of your patience. But five important facts may be offered as food for reflection: (1) Upon the field of battle hemorrhage is not a frequent cause of shock. (2) Above the critical level of the blood-pressure, blood may be drawn by the hundred cubic centimetres without shock. The " critical level " of blood-pressure in shock is that point below which the blood-pressure will not usually rise without assistance. With the Vaquez instruments used by me in France, the normal diastolic pressure was 97, and the critical level about 60, *i.e.,* between two-thirds and three-fifths of the normal. Certainly, the normal diastolic pressure varies with the instrument employed. It is possible that the critical level shows a similar variation. (3) At the critical level, the loss of 50 cubic centimetres may be vital. (4) If the blood-pressure is at the critical level, the arteries are partly empty; to empty them still further may be mortal. There is, therefore, in these conditions a great difference between bleeding from an artery and bleeding from a vein, especially an abdominal vein. (5) Respiratory and nutritive metabolism, particularly of the higher nerve-cell units, may be so affected that 50 cubic centimetres of blood will only do the work of ten. The loss of blood is then a grave disaster. For the critical level varies with the condition of the nerve-cells and other tissues. A blood-pressure high enough to maintain a sufficient nutrition in normal bulbar nerve cells is too low to maintain life in cells which have already suffered from malnutrition. In that case a blood-pressure raised by the surgeon to a point above the usual critical level will shortly sink again. Hence the importance of frequent readings of the blood-pressure until shock patients are clearly out of all danger.

VII

Some of the sources of confusion which I have enumerated are especially operative in civil practice. In railway collisions, automobile accidents, falls from buildings, and in many other casualties brought to the civil hospitals, it is often impossible to exclude direct violence to the vasomotor cells. The perfect material is the young soldier, not too close to the exploding shell, wounded by a hot steel fragment, and seen within two hours, before infection has blurred the picture. There are great advantages in the laboratory study of shock controlled by such observations on the battlefield.

At the request of the Rockefeller Institute for Medical Research, I went to France to do such work.

My first effort was to discover whether the conditions under which men live in the trenches predispose to shock. At Nieuport, on the Yser, I lived with the third regiment of the French, which there held the line. The effect of what is called the habitual bombardment was carefully observed. I went into the trenches to measure the blood-pressure. The trenches lay on the other side of the Yser. We crossed a pontoon bridge. Spare pontoons were anchored in the river, in case the bridge should be struck by a shell. We entered a communication trench. Here and there were signs, "Obligatory," "Forbidden," "In View of the Enemy," where men had been killed often enough to show that a German sniper had marked that particular spot.

Our trench is narrow and it is deep enough to protect the head. It winds through fields covered with long grass and poppies. These overhang the edge and brush our faces. The bottom of the trench is covered with a slatted walk about eighteen inches wide. We meet great pots of hot food, borne on a pole hung between two men. Happily, we are not fat; we slide by without being burned.

Soon we are in the lines. Here are real defensive works, heavily timbered, and with space for many men. At frequent intervals are the burrows in which the men live. Telephone wires run near the bottom of the trench, on the side next the enemy; they are fastened to the earth with long wire staples. From time to time we peep through an observation hole, but we do not stand more than two minutes in any one spot; always there are aeroplanes and tower observers on watch, and we may get a shell. The shells are now flying over us, with a noise like the tearing of a great sheet. Presently, we reach the point nearest the enemy. It is near indeed; about the length of a tennis ground. I look through a periscope and there, as clear as in a clean looking-glass, are long mounds of earth and sandbags—the German "trenches," one hundred and fifteen feet away. Apparently deserted, absolutely silent, they lie heavily on the unkempt fields, mile upon mile. Their sinister quiet speaks louder than the screaming shells.

The *poilus* are delighted with the blood-pressure apparatus. It is a game. Their faces are wreathed with smiles. They take off their tunics, roll up their sleeves and are proud to be told they are "normal." We keep our voices low and hug the front wall of the trench, but otherwise we might as well be in the Boulevard des Italiens, though now I think of it, that also is a dangerous place.

The war at Nieuport was all in the day's work. After two years, the daily round was the daily round, and it was nothing more. The habitual bombardment did not affect the blood-pressure.

In this first summer, in spite of every effort, I succeeded only in living under the habitual bombardment. In my second summer, fortune favored me greatly. I took part in one of the battles at the Massif de Moronvillers, under artillery fire said to be more violent than that in the great drive at Verdun.

On May 22 I found myself about 300 metres from the crest of Mont Blond, one of the low summits in the Massif de Moronvillers, a long ridge which commands the plain beyond Châlons-sur-Marne. The strategic importance of this ridge is very great. In April it was still held by the enemy. The French offensive against the Massif began April 16. Owing probably to insufficient artillery preparation, this first attack failed; little or no ground was gained, and the losses were very heavy. One ambulance, of which I knew, prepared for 3000 wounded; they received

18,000. Since that date, the French had won all the ridge except that part above my station. On May 25, the French finished the job. It was a beautiful and interesting operation. I quote from a letter written on my knee during the last hours of the battle:

"My *poste de secours* was dug by the Germans. It consists of a cellar about 8 by 10 feet, and 6 feet deep. The roof is proof against fragments, but not against direct hits.* A ladder leads to a cave, 7 by 8 feet, the floor of which is 15 feet below the surface of the ground.

"Yesterday afternoon, at three o'clock, the French began to prepare for storming the crest of Mont Blond—the white ridge just before my eyes. In an hour the Germans made up their minds that an assault was intended. The artillery fire, which was continuous before, now swelled to a torrent. Each side placed a barrage. The German barrage covered the little valley behind the crest. We were on the slope nearest the crest. The bottom of the valley was about 150 metres from us, consequently we were within the barrage. Between four o'clock and midnight, more than 10,000 heavy shells fell within a radius of 1000 feet from our cave. I took the count from time to time with my watch. We were driven at once into our deeper refuge. The little stuffy hole was packed with men, knee to knee; stretcher-bearers, surgeons, my orderly, and myself. The three surgeons played baccarat. I sat on the edge of a plank and watched the game. We had an acetylene light. The shells fell all around, shaking the place and repeatedly putting out the light. The noise was remarkable. The air was filled with screams, hisses, and loud reports, followed by the slide of masses of earth. Many shells were so close that a strong push of hot gas was felt. At six o'clock the Moroccans took the ridge by storm. At midnight the bombardment slackened but did not cease. With the dawn the wounded came in a stream. They were laid in the upper room. The wounds were of all sorts. The worst was a completely crushed jaw, in a man with a dozen slighter wounds. One man

---

* Two days after my departure, a shell entered the poste next mine, killing two surgeons and five of the stretcher-bearers.

had a hole through the temple into the brain—a hole two inches long and half an inch wide. Another had a smashed leg, a bad head, and in the thigh a wound the size of a small orange. I watched the blood-pressure carefully. Imagine a cellar with a plank floor covered with clay an eighth of an inch deep. A horrible tub full of bloody dressings. Two stretchers on the floor. Ten men in a space of 8 by 10 feet, shoulder to shoulder. Two candles. Sand-bag walls. The roof so low that I am always hitting my helmet against the beams. The air thick with the smell of blood, sweat, alcohol, iodine, vomit. Everywhere a smear of clay—the chalky clay of Champagne. The continuous scream, roar, crash of shells. A rain of small stones, dirt, pieces of steel. Every few seconds a profound trembling, as a shell strikes closer. Four men passing bandages and iodine in the half light, over backs, under arms. The cries of the wounded. The litter of bloody garments. The fresh cases, obliged to lie outside, under the fire, until the room is cleared. The brancardiers, bent under the load of the stretcher, slouching off with the dressed wounded. The dawn, the failing moon, the thick vapors and acrid stench of the barrage. The blasted hillsides smoking under the continual rain of death. Countless fresh shell holes all around us. The graves reopened.

"They are bringing down the dead. They lie sprawling on the slope just below us, half-sewed up in burlap, like pieces of spoiled meat."

In spite of these conditions, of which I have made a faithful report, the blood-pressure remained normal, not only in the unwounded men, but also in the wounded. Yet many of the wounds were grave.

My previous observations at Nieuport, at the Mort Homme, and on the Somme, showed that the blood-pressure is not lowered under the habitual bombardment. These new observations show: (1) That the blood-pressure is not lowered under a barrage fire, said to be as violent as the worst in the great drive at Verdun; and (2) that shock probably is not immediate, but develops some time after the wound.

VIII

In 1916, while stationed at the celebrated hospital in La Panne, I proposed to Doctor Depage the systematic treatment of shock upon a new plan.[13]

It is true that the remedies employed had long been known; they were the inclined position, heat, and certain intravenous injections, such as normal saline solution and adrenalin. But up to this time, so far as I am aware, these remedies had not been based on systematic, repeated measurements of the *diastolic* blood-pressure. This is a matter of great importance. Treatment not based on repeated readings of the blood-pressure is not intelligent and it may be harmful. I found in the hospitals that the blood-pressure was not systematically taken—usually it was not taken at all. I did not see a single case in which the *diastolic* pressure had been observed. Now in shock the heart beats feebly. The systolic pressure falls more than the diastolic pressure falls. Conversely, when remedies are used they often raise the systolic pressure more than they raise the diastolic pressure.

Conclusions drawn from the systolic pressure may easily err 15 millimetres or more. But in shock the blood-pressure is at a critical level; a change of even 15 millimetres may be a matter of life or death. The error in using the systolic instead of the diastolic pressure may therefore do much harm.

Also new, to the best of my belief, was the principle that in the treatment of shock by injections, the diastolic pressure should not be raised to normal but only to a height 15 or 20 millimetres above the critical level. I have seen the hasty injection of a litre of normal saline raise the pressure suddenly to 190 millimetres. Such a sudden rise is not free from danger.

The essential points in this method of treatment are: (1) that the hospital shall be within a very few miles of the first line; (2) that the patient shall be taken directly from the ambulance to the trained shock specialist—minutes are precious; (3) that the trained observer shall not leave the case until the patient is out of danger; (4) that the treatment shall be based on repeated readings of the diastolic blood-pressure; (5) that the aim shall be to keep the blood-pressure 10 to 15 millimetres above the critical level.

Here I must again declare, even at the risk of wearying you, that an understanding of the critical level is of the first importance in the study and treatment of shock. If the blood-pressure just touches the critical level, a difference of 10 millimetres of mercury may be the difference between life and death. A few millimetres above this level, recovery will usually occur spontaneously; a few millimetres below, death will follow unless skilled aid be at hand. It follows from this vital fact: (1) that procedures which at ordinary blood-pressures are not harmful, or are but slightly harmful, may kill the patient at the critical level; (2) remedies which raise the blood-pressure but 10 or 15 millimetres will save the patient when this rise carries the blood-pressure from just below to just above the critical level.

It is my experience that when the principles here set forth are neglected, the majority of the shock cases die. When the method is carried out with the necessary intelligence and devotion, by far the greater number get well.

IX

In my first summer in France, in 1916, I was sent, among other places, to the Carrel Hospital in Compiègne. The surgeons there informed me that shock occurred most frequently after shell fracture of the femur and after multiple wounds through the subcutaneous fat. I have been able to verify this statement from my own observations at Mourmelon-le-Petit and elsewhere.

Mourmelon-le-Petit is a small village in the plain of Châlons-sur-Marne. It is the seat of an *ambulance de triage*—a sorting station. To this station, which is within shell-fire of the German lines, were brought all the wounded from a number of *postes de secours* on the Massif de Moronvillers. At this *triage*, I saw more than one thousand freshly wounded. Aside from a few abdominal cases, in which there was probably direct injury to the vasomotor nerves of the abdominal vessels, the only shock was that caused by shell fracture of the femur or by multiple wounds through the subcutaneous fat. I do not make this statement to exclude other causes of wound shock but to make clear the great frequency with which wound shock follows the two conditions named.

In multiple wounds through the subcutaneous fat and in shell fracture of the femur, fat embolism is known to be present.

On February 2, 1917, I proved that fat embolism was a cause of shock. Fat embolism had been studied experimentally for two and one-half centuries. The following facts had been established: (1) The fat in bones is in a condition peculiarly favorable to its entrance into the blood-vessels after fracture. (2) Large quantities of fat have repeatedly been found in the blood-vessels after fracture. (3) The entrance of fat into the blood-vessels begins immediately after the wound. (4) Frequently, if not always, there is fat embolism of the brain and other organs. (5) These facts have often been observed in men; they are equally true of animals in which fat is injected into a vein.

Notwithstanding the very numerous clinical and pathological studies of fat embolism, there has been, heretofore, no attempt to demonstrate by measurements of the blood-pressure a causal relation between fat embolism and the shock of the battlefield. Yet the following experiments will show that this relation can hardly be denied.[14]

In the first experiment, February 2, 1917, about 3 c.c. of the officinal emulsion of olive oil was injected slowly into the jugular vein. Very soon there was a fall in the carotid blood-pressure. It was recorded by a membrane manometer, which also recorded the force and frequency of the ventricular contractions. In two further experiments thick cream was used, and in the remainder the fat was neutral olive oil. The injection of from 2 to 4 c.c. of olive oil in a large cat has never failed to produce a fall of blood-pressure to one-half or less the normal level. Thus, on February 5, the diastolic blood-pressure fell quickly from 140 to 65 mm. Hg, and later to about 40 mm. In this cat the tracing showed that the fall in blood-pressure could not be ascribed to changes in the heart beat. The same is usually true when the injection is not made too rapidly. The clinical picture is essentially similar to that of traumatic shock in human beings.

When these experiments were first published efforts were made to discredit them as simple cases of embolism of the lungs. No one who had made the experiments would be likely to make this criticism. The symptoms of clinical pulmonary embolism are rarely present. Still more rare is failure of the heart from embolism of the coronary arteries.

Embolism of the lungs is entirely excluded by the following experiments, which further provide an explanation of the mechanism of this variety of shock.

July 29, 1918, a rabbit weighing 2 kilos was lightly curarized and artificial respiration was begun. The carotid diastolic blood-pressure was 160 mm. Hg. The subclavian artery was ligated at its origin from the aorta and also at a point beyond the origin of the vertebral artery. The internal mammary branch was ligated, but two muscle branches were left open. By means of a cannula in the subclavian, one-fifth cubic centimetre of neutral olive oil was injected. Part entered the muscle branches and part the vertebral. In a few moments, the blood-pressure began to fall. In fifteen minutes, the diastolic pressure had fallen to 40 mm.[15]

The outstanding fact discovered in this and many similar experiments is that a minute quantity of fat will produce the characteristic fall in blood-pressure, and the concomitant symptoms of wound shock, whenever the blood supply to the vasomotor region is interrupted by the plugging of its capillaries. In the experiment cited, the quantity of oil injected was one-tenth cubic centimetre per kilo. There is every reason to believe that less than this small quantity can be used with success. Moreover, a part of this 0.1 c.c. per kilo was lost in the unligated branches of the subclavian artery; another part was lost in filling the subclavian and vertebral arteries between the point of injection and the bulbar cells; finally, some oil necessarily found its way into the capillaries supplying portions of the bulb other than the vasomotor region, for the vasomotor cells occupy but a very small fraction of the bulb. It follows that the amount of oil actually used to produce shock in this experiment was exceedingly small.

It must at once be recognized that the quantity of oil with which we have produced experimental shock by embolism of the vasomotor centre is far less than the amount which has repeatedly been found in the blood-vessels of human beings after fracture of the femur.

A microscopic examination of sections through the vasomotor region, stained with Sharlach R, abundantly supports the conclusion that minute quantities of fat may produce shock. When the amount of oil injected is relatively large (for example, in the cat, 0.4 c.c. per kilo) fat is readily found in many sections. When the fat injected is as little as 0.1 c.c. per kilo of body weight, the stopped capillaries are hard to find. Yet the physiological evidence is beyond question. The injected fat has gone only to the brain; all parts of the brain can be cut away without lowering the blood-pressure, if only the vasomotor centre be respected; hence the vasomotor region in our present experiments must have been injured.

The demonstration of fat embolism of the vasomotor centre as a cause of wound shock is as follows: (1) Excluding abdominal wounds, in which a hydrostatic fall in blood-pressure may follow an invariable local injury to the largest vascular area in the body, the most frequent causes of shock in wounded soldiers are shell fracture of the femur and multiple wounds of the subcutaneous fat. (2) In fracture of the femur and in multiple wounds of the subcutaneous fat, considerable numbers of fat globules are found in the blood. (3) A quantity of fat much smaller than that known to circulate in the blood in the injuries most often followed by shock will produce shock when the nutrient vessels of the vasomotor region are stopped.

It has seemed worth while to prove by two other methods that fat embolism shock cannot be explained by embolism of the lungs.[16]

The first of these methods produces shock by injections through the peripheral end of the carotid artery. This may excite surprise. Not long ago an experimenter of repute strengthened, as he thought, the case for embolism of the lungs by failing to produce shock by the injection of oil into the peripheral end of the carotid artery. His failure to lower the blood-pressure by embolism of the brain seemed to him to leave the field clear for embolism of the lungs.

The unsuccessful experimenter could hardly have forgotten that the vasomotor region is supplied by the basilar artery and not by the carotid. Probably he reasoned that the circle of Willis is an open road through which oil injected into the peripheral end of the carotid would easily reach the nerve centres in the bulb. That the circle of Willis is a generous anastomosis cannot be disputed. But the direction taken by a drop of oil entering this circle will not finally depend on the anatomical relations. The vascular pressure is the warder of these gates. The circle of Willis is a balanced pressure ring, in which the pressure from the basilar area contends with that from each carotid area. So clear is this, that experiments would seem superfluous, were it not for the peril inherent in *a priori* reasoning. But the experiments are not less clear.

If 1 c.c. of neutral olive oil is injected into the peripheral end of one carotid in a cat weighing 4 or 5 kilos (both vertebrals and the other carotid artery being free), shock rarely follows. Obviously, the oil enters parts of the brain anterior to the bulb and does not plug the vessels in the vasomotor region. If, on the contrary, a clamp be placed temporarily (4 minutes) on one carotid while the oil is passing through the other carotid, shock usually does follow.

Like the injection of oil into the vertebral artery, this experiment is doubly destructive against the hypothesis that shock is due to embolism of the lungs; for it leaves the lungs free and produces shock by the embolism of a particular region of the brain.

The second of the two new methods compares two procedures, A and B, in each of which 0.5 c.c. of neutral olive oil per kilo of body weight is injected into the external jugular vein of cats. The rate of inflow is about 1 c.c. in 15 seconds.

In series A, both carotid arteries were closed but both vertebral arteries were free. Shock usually took place.

In series B, both carotid arteries were free but both vertebral arteries were closed. Shock seldom took place.

Yet the lungs were emobilized equally in both series. In fact, the method in series A was identical with that in series B, except that in A the fat passing through the lungs into the general circulation could reach the brain through the vertebral arteries, whereas in B it could enter the brain only through the carotid arteries. Obviously, the state of the lungs being identical in both series, the difference in the result of the two series must be due to a factor outside the lungs. The experiments point clearly to embolism of the vasomotor region as the cause of the shock observed in series A, in which the vertebral arteries were open.

The three methods detailed above lead to the same conclusion. Fat embolism shock is not explained by embolism of the lungs.

X

In dealing with surgical shock, it should always be borne in mind that life and death here depend on a relatively slight change in the arterial pressure. The diastolic pressure may fall from normal to the critical level with little or no danger—a further fall of even 10 millimetres may be fatal, unless skilled assistance be at hand. Conversely, in dangerous shock, lifting the diastolic pressure 15 millimetres will save life, as a rule.

I have elsewhere insisted on the importance of the inclined position. In shock, the sufferer bleeds into his own abdominal veins. They take the blood from the heart and brain. The inclined position feeds the heart and brain by gravity. But gravity is slow and death draws swiftly on. Time may be gained by adrenalin and by injecting normal saline into the veins. Both tend to fill the heart; one by narrowing the arterial outlets, the other by adding to the volume of the blood. Neither is a logical remedy, for neither brings back the blood from the congested veins into the arteries and thus into the feeding capillaries. The veins store but do not feed. We should pump the blood from these fatal wells into the heart. Such is the logical ideal.

The thoracic pump satisfies this ideal.[17]

When the diaphragm descends in inspiration, the cavity of the thorax is enlarged. It is as if a squeezed rubber bulb were expanded under water; the surrounding fluid enters the sucking ball. So do surrounding fluids enter the chest. The air is sucked in through the trachea and blood is sucked in through the veins. In man, this suction may balance a column of mercury 30 millimetres high, equal to a column of blood 15 inches high—a value one-third the total normal diastolic arterial pressure. Without this respiratory suction, a man of weak arterial tonus would faint every time he stood up. This potent force should be of use in traumatic shock.

If the normal contractions of the diaphragm so aid the circulation, its powerful contraction will aid still more. Powerful and frequent contractions are within our command. We have but to increase the carbon dioxide in the inspired air to call forth deep and rapid respiration. The necessary amount of carbon dioxide is not injurious.

The following cases of shock, observed at the Chemin des Dames in 1917, illustrate the value of the respiratory treatment in man: [18]

Case 1.—June 25, 7 a.m. Both legs amputated. Diastolic arterial pressure, 51 mm. When carbon dioxide was inhaled, until the quantity of air entering the chest was about doubled, the diastolic pressure rose to 60 mm. At 11 a.m. the patient was out of danger.

Case 2.—June 26, 8.25 a.m. Two deep wounds in the back. Multiple wounds elsewhere. Diastolic pressure, 53 mm. Inclined position and hot normal saline in vein caused pressure to rise to 70 mm. Operation at 10.15 a.m., lasting a quarter hour. At 10.30 the diastolic pressure was 52 mm. An injection of adrenalin brought it to 57 mm. for a short time only. At 11.05 the pressure was 53 mm. At 11.15 the respiration was deepened by inhaling carbon dioxide; at 11.20, diastolic pressure, 60 mm.; 11.25 carbon dioxide was stopped and the pressure thereupon fell to 53 mm. At 11.35, the gas was again employed and the pressure rose to 61 mm. This man recovered.

From these cases it appears that increased respiration from the administration of carbon dioxide is of advantage in shock.

In the observations at the Chemin des Dames, the head of the wounded man was placed in a wooden box, the length, breadth and height of which were each about 35 cm. The end for the neck was in two pieces. The lower piece was fixed and had a semi-circular opening for the back of the neck. The upper piece was movable. It had a semi-circular opening for the front of the neck. This piece slid down upon the neck like a guillotine. Cotton was placed between the edges of the openings and the skin. A hole of about 2 cm. in diameter was made in each of the two sides of the box. Cotton was placed in these holes to regulate the amount of carbon dioxide and air. The carbon dioxide entered one of these holes. It came from a cylinder provided with a regulating valve. On its way it bubbled through a water bottle. The volume of gas employed was judged by the number of bubbles per minute. Enough gas was used to double the respiration. The patient was in the inclined position, the feet 30 cm. higher than the head.

XI

This brief account of my researches, to which you have so kindly listened, may be summarized as follows:

1. The vasomotor centre is not exhausted in shock.

2. The vasomotor centre is not exhausted in infectious diseases such as diphtheria and pneumonia.

3. The prolonged stimulation of sensory nerves is not a cause of shock.

4. The heart and probably the blood-vessels may be sensitized. In this state, stimuli usually innocent may cause prolonged contracture or prolonged inhibition of the heart, simulating shock. It is possible, and even probable, that in these sensitized states such stimuli may cause prolonged relaxation of the arteries, in which case the clinical picture of shock would be produced.

5. Hydrostatic lowering of the blood-pressure may, if continued, cause shock.

6. Vibration injuries may temporarily reduce the blood-pres-

sure to the level at which it stands when the vasomotor system is destroyed.

7. Hemorrhage is not a frequent cause of shock. Its danger depends on its relation to the critical level of blood-pressure.

8. The critical level of the blood-pressure in shock is that point below which the blood-pressure will not usually rise again without assistance An understanding of the critical level is of the first importance in the study and treatment of shock.

9. The blood-pressure was found to be normal in soldiers under habitual bombardment and during a heavy barrage. There is no evidence that such conditions predispose to shock.

10. A successful treatment for shock at the front was developed. This treatment was first of all systematic. It was based on repeated measurements of the diastolic blood-pressure, which it aimed to keep 15 to 20 millimetres above the critical level.

11. Observations on freshly wounded men at La Panne, the Massif de Moronvillers, and the Chemin des Dames show that shock, excluding abdominal wounds, occurs most frequently after shell fracture of the thigh and after multiple wounds through the subcutaneous fat.

12. Fat embolism of the vasomotor centre is proved to be a cause of shock.

13. Increased action of the thoracic pump, brought about by the inhalation of carbon dioxide liberally mixed with pure air, will raise the blood-pressure from 15 to 20 millimetres in normal and in wounded men. When the blood-pressure is near the critical level this procedure is of advantage.

REFERENCES

[1] Boston Med. and Surg. Jour., 1903, cxix, 455; also: American Journal of Physiology, 1907, xx, 501.

[2] Boston Med. and Surg. Jour., 1914, clxx, 125; also: American Journal of Physiology, 1914, xxxv, 1.

[3] American Journal of Physiology, 1914, xxxiii, 439.

[4] American Journal of Physiology, 1910, xxvii, 282, fig. 3.

[5] American Journal of Physiology, 1907, xx, 444.

[6] Jour. Exp. Med., 1896, i, 49.

[7] American Journal of Physiology, 1905, xv, 9.

[8] American Journal of Physiology, 1907, xx, 448.

[9] Ann. Surg., 1902, xxxvi, 324.
[10] American Journal of Physiology, 1915, xxxviii, 108.
[11] American Journal of Physiology, 1900, iv, p. 295, and fig. 4.
[12] American Journal of Physiology, 1907, xviii, 181.
[13] Boston Med. and Surg. Jour., 1916, clxxv, 854.
[14] Boston Med. and Surg. Jour., 1917, clxxvi, 248.
[15] Boston Med. and Surg. Jour., 1918, clxxix, 273.
[16] Boston Med. and Surg. Jour., 1919, clxxx, 531.
[17] Boston Med. and Surg. Jour., 1917, clxxvi, 699.
[18] Boston Med. and Surg. Jour., 1917, clxxvii, 326.

Further papers by the author dealing with shock:

Boston Med. and Surg. Jour., 1908, clviii, 73; *ibid*, 1918, clxxviii, 657.

Comptes rendus de l'Académie des Sciences, Paris, Oct. 30, 1916, t. 163, p. 492; *ibid*, July 23, 1917, t. 165, p. 164.

Proceedings of the Institute of Medicine of Chicago, 1918, II, p. 24.

MEDICAL PROBLEMS AND THE WAR *

DR. LINSLY R. WILLIAMS,
Major, Medical Reserve Corps.

IT would not be possible to describe all the medical problems which have arisen since the outbreak of the war in Europe or to give any detailed scientific description of scientific problems, but only a general view of some of the problems will be presented in an endeavor to show their variety and difficulty.

Every modern nation has a Medical Service or Medical Department for the care of the sick and wounded. The duties of the service in each country are similar. They are, first, to keep the well from becoming sick; second, to care for the sick and wounded; third, to remove the wounded from the battlefields as rapidly as possible. It will be seen then that the medical problems are those of hygiene and sanitation, the professional care of the sick and wounded and the organization and administration of the hospitals where the sick are cared for, the organization of an ambulance service to evacuate large numbers of wounded, to give them first aid and to transport them to zones of safety where the wounded can be given skilled surgical treatment.

The work of the army surgeons covers nearly all the varied types of medical, surgical and special work that occur in civil life, as well as a number of additional medical problems peculiar to the army. During peace times armies are comparatively stable as to numbers; new recruits are added to existing units in small numbers. In some armies these recruits are isolated for two weeks to diminish the likelihood of outbreak of infectious disease. The men are quartered in permanent barracks. Sickness is small in amount and death rates are lower than in civil life. With the outbreak of war the situation immediately changes. In the nations of Continental Europe where large standing armies have been the rule, all reserves are mobilized. For example, in the summer

* Delivered November 24, 1917.

of 1914 the French Army consisted mainly of boys who had become 19 years old during 1912 and 1913. The mobilization order called for all classes of men who had become 19 years old from 1889 to 1912. About five million men were suddenly drawn from civil pursuits, all of whom had had two years of military service and who within a fortnight after the order was issued had joined their regiments and many of whom were on their way to battle.

These men, young and middle-aged, came from all parts of France. Many had been exposed to contagious disease, many were carriers of infective disease, many with incipient or healed tuberculosis and many with parasitic diseases. For such an enormous number of men with such an immediate need for soldiers, physical examination to weed out the unfit is not possible nor is the administration of typhoid prophylaxis. Nor do comfortable barracks and adequate facilities for the disposal of human waste spring up in a fortnight. Lucky the man who has a tent overhead and a blanket to wrap around him. Surprising, too, that food, clothing, equipment and rifles are ready. The expected happens, forced marches, hard work, changed food, exposure to weather and communicable disease cause the weak to break down, undetected heart disease develops, the incipient tuberculosis case becomes feverish, the lesion of the quiescent consumptive becomes active, the typhoid carrier pollutes the water and the unprotected soldier develops typhoid and paratyphoid, and other infections follow. Contrast this situation with that in which we find ourselves now. In April we had a Regular Army of about 125,000 men. Recruits have come in from 50 to 1000 a day, distributed in a number of stations. National Guard organizations have been under constant though not extensive medical supervision. New recruits are not the order in the National Guard and the units all come from the same locality. The National Army approaches more nearly the mobilization of Continental Armies. But, the National Army is not mobilized at once, but only five months after the declaration of war, and even then only five per cent. is mobilized at first. Meantime, barracks have been built, hospitals and infirmaries constructed, and a medical service organized, the majority of the new medical officers receiving two or three months' intensive training. Potable water supplies are secured and distributed through water mains. Water carriage systems of sewerage disposal for the removal of human wastes are installed. All new recruits are carefully selected at home for physical fitness and re-examined at the cantonment on arrival, and typhoid and paratyphoid prophylaxis and vaccination against smallpox are performed immediately. Medical problems arise, however, even under these circumstances; men are gathered together from different localities and placed in barracks in close proximity to each other, and there is constant danger of respiratory infection, especially during cold weather, when adequate ventilation is uncomfortable. At the outset communicable diseases develop; scarlet fever, measles, cerebrospinal meningitis, mumps and chicken-pox being the most likely. Immediate isolation of each case is feasible, as also quarantine of exposed persons. Separation of immunes is not practicable as training must go on, but daily medical inspection is performed and early cases are immediately removed and isolated. Epidemics are therefore rare where the medical service is adequate. Epidemic meningitis offers a different problem, for the infective material is not only transmitted from the sick to the well, but also from the meningitis carriers to the well. A patient affected with meningitis is usually isolated and is a menace only to his attendants. Carriers, however, are not readily detected and the disease is usually spread by them. Individuals may carry meningitis germs for many months and infect many other individuals. Consequently it is of the greatest importance to detect and isolate carriers. If a company has 250 men and a dozen or more meningitis carriers are detected, steps should be taken to isolate these carriers from the normal individuals in the company. This procedure is difficult, for it means the military rearrangement of companies, which is very discouraging to the line officers. The problem of treatment is also a difficult one, for it has been found that many sera for the treatment of cerebrospinal meningitis are ineffective. The researches of Dopter in France, Gordon and Flack in England, and Flexner in this country show that there are cases of meningitis in which the organisms differ immunologically from the ordinary intracellular micrococcus. Dopter has described a parameningitis organism and Gordon and Flack a variety of organisms divided into four groups. Strains of all these organisms are now used for the production of meningococcus sera, and treatment with this serum accomplishes very satisfactory results. The detection of carriers remained a difficult problem until a suitable method and instrument for obtaining swabs from the nasopharynx was devised by West; this instrument consists of a curved hollow glass tube which contains a copper wire, around the top of which is a pledget of cotton. Both ends of the tube are sealed with a cotton plug and sterilized. In order to take the swab, the tongue is depressed, the cotton at the curved end of the tube is removed and the curved tip of the tube is inserted up and behind the soft palate, the copper wire is pushed out through the end of the tube, the vault of the nasopharynx is swabbed and the copper wire is drawn again within the tube. This method prevents the contamination of the swab with the mouth organisms. The material from the swab is then planted in special media and incubated.

TREATMENT OF CARRIERS

Many experiments have been carried on during the past three years, especially by English army surgeons, for the eradication of meningitis carriers. Different methods have been tried and excellent results are claimed for each method. Steam inhalations impregnated with some chemical have been the usual method tried. Chloramin-T, zinc sulphate, and iodine have been tried, as also snuffling, gargling and spraying the nose and throat with weak solutions of potassium permanganate. Investigation of each method of treatment shows that the carrier state may persist for two or three months under any one of these treatments. Difficult as it may be, carriers should be detected, isolated and treated.

The respiratory diseases, particularly pneumonia, are a common accompaniment of camp life, particularly when men are housed in barracks or tents in winter. In winter ventilation is frequently difficult on account of lack of heat, and when off duty men will collect around the stove and cough and expectorate or sleep in such close proximity that in coughing and sneezing the spray from one individual may be conveyed to the mucous membranes of another. The researches of the past few years by Cole, Avery and others have proven that the causative organism of pneumonia is not the same, but that the bacteria may be readily divided into at least four minor groups. A specific pneumonia serum has been developed which has proven to be very effective in two of the groups. The use of this serum offers technical difficulties, for it is necessary to determine the type of pneumonia before administering the sera. This is determined by injecting some of the sputum of the patient into the peritoneal cavity of a mouse and testing the growth obtained in the peritoneum against serum from the different strains of pneumococci.

The efficacy of pneumonia serum was proven during the winter of 1916 on the Mexican border, where a number of cases were successfully treated with pneumococcus sera.

In both the French and British Armies special laboratory workers are assigned to the different camps and cantonments and detection, isolation and treatment of cases and carriers are being carried on satisfactorily.

The isolation and treatment of pneumonia had not been undertaken in the French and British Armies last spring, but undoubtedly will be in the United States Army after the work of medical organization has been completed.

VENEREAL DISEASE

No more trying problem exists than the prevention and control of venereal disease. Whether venereal disease exists more frequently in the army than in civil life amongst males of the same age group is impossible to answer. When the Royal Commission on Venereal Diseases began its investigations in England, in 1913, it found that no satisfactory statistics regarding the amount of venereal diseases existed, except the army statistics. It found that among a thousand men in the British Army at least fifty were admitted and treated for venereal disease, and in some posts, such as London and in India, there were over a hundred admissions per thousand men per year. No other statistics were available and the Army was forced to bear the brunt of criticism. During 1916 rumors were prevalent of the enormous increase of venereal disease in the British Army, particularly among officers. Undoubtedly true numerically, but not proportionately. The Army increased from about a hundred thousand in 1914 to about four million in 1916, about fortyfold, but the number of cases of venereal disease did not increase fortyfold but only thirty-five times as many, and in the British Expeditionary Force in France the number of cases per thousand was less than in England. These rates, too, are far lower than the rates of the United States Army published in the report of the Surgeon General of the Army for the year 1915. Too much reliance, however, should not be placed on the amount of venereal disease, as inaccuracy frequently occurs in reporting these diseases. Whether the number of cases of venereal disease is greater in military life than in civil life cannot yet be answered, but the number in the Army is far larger than it should be and steps are being taken in the French, British and United States Armies to limit these diseases to a minimum. Army authorities must limit the amount of venereal disease and it cannot be done by one method. Venereal diseases are communicable and must be so considered; segregated districts mean the maintenance of centres of infection in the neighborhood of army camps. Fortunately this is forbidden in the United States by the Federal Law, which forbids the maintenance of houses of prostitution, the sale of liquor and gambling within five miles of camp. Federal authorities are enforcing this law. The substitution of various forms of recreation plays a large part in reducing temptation and the activities of the Young Men's Christian Association, Young Women's Christian Association, and the National Committee on Training Camp Activities in this country play an important part in diminishing these diseases. The Army further punishes all soldiers who become affected with venereal disease by stopping their pay when unable to perform duty on account of illness from one of the diseases. Further, if the soldier fails to report for treatment after exposure to venereal disease and he subsequently develops venereal disease, the soldier's pay not only stops, but he is court-martialed and punished by fine or imprisonment. While affected with venereal disease, he may not leave the camp or post. These regulations apply to officers as well as enlisted men. Early treatment or prophylaxis is given and for the same reason that antitoxin is given in diphtheria. The child exposed to diphtheria is protected from danger and similarly the soldier is protected from danger by early treatment. Prevention of venereal disease not only protects the soldier himself but protects his future wife and children, for it is unfortunately too true that not only in military but in civil life many men affected with one of these diseases may later infect their innocent wives and children.

SANITARY PROBLEMS

As well as the problem of preventing communicable disease, there are the general sanitary problems of camp and cantonment life. These problems include securing a safe and adequate water supply, pure food, the practical methods of the disposal of sewage so as to prevent infection, the inexpensive and safe methods of disposal of human wastes, the appropriate methods for the disposal of garbage, either by feeding it to hogs, reclaiming the grease or by incineration, the spreading of manure upon distant fields, transporting it to suitable points for fertilizer or disposing of it by burning. The disposal of cans, wastepaper and trash offers another problem usually left to medical departments to determine. Other problems are the prevention of overcrowding, the maintenance of adequate ventilation, proper cleansing facilities for bathing and for washing clothes. United States Army Regulations require all officers and enlisted men alike to wash their hands and face before meals and after attending to the necessities of nature. Facilities must be provided for this. Cleansing and airing of bed clothes is also a problem for the prevention of lice and other vermin. Suitable laundry facilities must be provided, not only for the soldiers' use but for hospital linen and garments used by men in the hospital.

ACTIVE CAMPAIGN AND COMBAT

When forces take part in an active campaign and engage in battle occasionally, or constantly, as is frequently the case in the present war, all the medical problems of camp and cantonment not only remain, but are intensified and made more difficult. The housing of troops in billets and tents makes the control of men more difficult, the ground is not of one's selection, water supplies are usually limited in quantity and poor in quality. Drainage may be difficult if possible at all. These problems must then be solved by the Medical Department. The first-aid, transportation and care of the wounded alone is a problem of the first magnitude, attended with constant danger to medical officers and enlisted personnel. During the past hundred years the number of killed and wounded in battle is somewhat greater, due to the improvement in firearms, and the total number of wounded has increased with the steadily increasing number of men engaged in battle. The number of casualties in a modern battle varies from 10 per cent. to 25 per cent. of the number of men engaged. Suppose 100,000 men engage the enemy and there are 20,000 casualties, on the average one man is killed to five who are wounded; 4000 killed, of the 16,000 wounded; 8 per cent., or 1080 are mortally injured and cannot be transported; 20 per cent., or 3200, must be transported, but are able to sit up; 12 per cent., or 1920, are severely wounded and must be transported lying down; 28 per cent., or 4480, are able to walk a short distance to a dressing station; 12 per cent., or 1920, are very slightly wounded, have their wounds dressed promptly and return to the fighting forces. It is difficult in the present war to determine the actual percentage of men who are killed or wounded in battle. We read of an attack on a nine-mile front, perhaps twelve divisions amounting to 100,000, are engaged on this front; perhaps 30,000 in the front line, 40,000 in the second and 30,000 in the reserve. The latter may never see any fighting and yet the advance could not be made without them. Artillery preparation may extend to the right and left of the nine-mile front occupied by fifteen more divisions which are never engaged but which may suffer losses from the responsive fire of the enemy's artillery.

Exaggerated stories have been circulated stating that the average duration of life of a soldier in the present war is but a few weeks. Perhaps this would be true if one assumes that the soldier is continuously in the front line of trenches. This, however, is not true, for he takes his turn in the trenches and sometimes weeks or months may pass without any trench fighting for an individual soldier. A division actively engaged, consisting of 27,000 men, may have 15 to 25 per cent. of casualties, a brigade of 6000 men may have 50 per cent. or nothing, and a regiment may have 75 per cent., or none, or be practically wiped out. In the Battle of Mukden one Japanese regiment had 68 per cent. of its number killed and wounded. If a regiment is said to be completely wiped out the ratio of killed and wounded remains about the same, and if of full strength this would mean 2400 men wounded and probably 1480, or 70 per cent., would be back in that regiment within six weeks. Notwithstanding the enormous losses in the battles of the present war, the proportion of killed and ratio of killed and wounded has increased but little over the Russo-Japanese war and never over the losses in some of the bloody battles of the Civil War. The number, however, has been enormous, and at the outset of the war neither France nor Germany had made plans for the evacuation of such vast numbers of wounded men, perhaps neither had realized the many millions of men who would be engaged in battle at one time. Wounded were sadly neglected, dumped into cattle cars and transported to distant points after the Battle of the Marne, lying on the bare floors for four, five, six, even seven days without medical attention, and often without food or water. Many died en route and the suffering of those who survived was extreme. The adequate care of the wounded in battle depends primarily on the organizations developed for the evacuation of the wounded, which will permit of wounded soldiers being brought rapidly to points of comparative safety for temporary treatment and then to zones of safety where permanent treatment can be given. The organization now used by the French, English and United States Armies has been developed from the plan first employed by Doctor Lettermann, Chief Surgeon of the Army of the Potomac. The organization now fully developed consists of sanitary troops attached to regiments who act as stretcher-bearers and carry wounded to first-aid stations established by surgeons attached to regiments. Here bandages are applied and men with very trivial wounds return to their regiment. Wounded who can walk, but cannot fight, return to a designated dressing station in the rear and are there more carefully treated and then sent to the hospital. Severely wounded are helped by the regimental stretcher-bearers and carried back to a dressing station, in the present war situated usually in a dugout, where a station has been established by the ambulance companies and which is equipped similarly to an accident ward in a civil hospital. Ambulances convey patients from this point to a field hospital, or if roads are good and distances not too great, to an evacuation hospital situated on a railroad. The evacuation hospital is a stationary hospital usually beyond shell-fire and patients may remain here if seriously wounded or are transported by rail to a more permanent and larger hospital some miles to the rear.

SURGICAL PROBLEMS

During the early period of the present war patients were removed as promptly as possible to a point far in the rear of the fighting lines. This soon brought up another medical problem. Contrary to expectation, nearly every wound became infected, and every effort to prevent this failed. How can infection be prevented and how can infection be cured after it has once developed? Early treatment by having hospitals nearer to the front, and cleansing wounds and cutting away damaged parts has nearly solved the first part of the problem and deep irrigation of wounds devised by Carrell with the use of Dakin's solution or similar solutions if properly carried out has largely solved the latter part of the problem. Problems of a surgical nature have been many and varied. When to operate and how much lacerated tissue to remove, problems of plastic surgery, resection of nerves, early incision and closure of joint injuries or late incision and drainage, surgical apparatus for the transportation and treatment of fractures, the treatment of burns, the detection, location and extraction of foreign bodies and special problems of surgical treatment for injuries of special parts of the body are all matters requiring study. The hardness of the fighting, the intensity of shell-fire, the hardships of trench life, the exposure to cold and wet, the difficulties of providing adequate food, clothing and shelter have all brought up a number of additional medical problems. Chilblains, frost-bite and frost-bite gangrene, all of which are designated as " trench feet," have incapacitated tens of thousands of soldiers in Europe at one time. Exposure and, some few think, infections, have produced many cases of albuminuria, in some instances nephritis being caused. Similar outbreaks have been described by Civil War surgeons during the period of trench life occurring during the siege of Petersburg, Va.

NERVOUS PROBLEMS

The many neurotic and hysterical conditions incident to the strain of civil life have been intensified in the terrors of trench life and many cases of traumatic hysteria, hysterical paralysis, and neurasthenia have developed and latent epilepsies, dementia præcox and other mental abnormalities have been brought to light, many of these conditions being loosely described as "shell-shock," even in cases which have never heard shell-fire. Inability to change personal clothing has resulted in a pest of lice which in the eastern countries has resulted in widespread epidemics of typhus fever, notably in Serbia in 1915. Difficulty in securing adequate and safe water has compelled the soldiers during an advance to drink water from shell holes and ground springs, frequently polluted with dead bodies and excretions from the living. This has caused outbreaks of dysentery, diarrhœa and typhoid fever. Even as late as midwinter, 1915, the French and English colonial troops were not fully protected against typhoid and paratyphoid fever.

With the development of disease of such varied types it was only natural that civilian physicians of experience should urge that specialists should receive commissions and investigate their special problems, and in army medical services which previous to the war contained only surgeons who were assumed to know all the branches of medical science, now nearly every recognized specialty is represented, with results of untold value. These efforts have resulted in a better understanding of the diseases in question by the surgeons and medical officers. Special wards and special hospitals have been developed for the more adequate and thorough treatment of different disease groups. Special hospitals now exist for surgical injuries of the head, plastic surgery, genito-urinary surgery, injuries of the eye, convalescents, heart disease, nervous diseases, insanity, contagious diseases, venereal diseases, and in England and France special hospitals for women and children. The perfection of the organization and the method of administration, coupled with the solution or partial solution of many of the surgical problems have resulted in a marked improvement in the care of the patients and a diminution in the length of time necessary for a cure and has increased the percentage of wounded able to return to their fighting units from 30–50 per cent. early in the war up to 60–80 per cent., or even more, at the present time.

THE PROBLEM OF AFTER-CARE

The enormous number of sick and wounded necessarily leaves a large number of men partially or wholly incapacitated from injury or disease. The care of these cases has become a national problem in the combating nations. This problem is partly a medical problem and partly a sociological and industrial problem. The medical problem includes hospital provision for patients with surgical injuries, needing prolonged treatment for correction of deformities, for preparing stumps for artificial limbs, for fitting artificial limbs, for eye injuries, for the tuberculous, mental and neurological conditions, cardiac cases and other chronic ailments. Orthopædic care and provision for the blind are the two most important of the problems, for the tuberculous, the insane and other chronic disease conditions can be more readily cared for by existing hospitals. The sociological and industrial problem includes the technical training of disabled men to fit them for new positions or for their former trade if practicable and to secure new positions for them. A brief review of what has been done in Great Britain and France will be of interest in illustrating these problems. In Great Britain it has been found that from 5 to 10 per cent. of all the wounded become permanently disabled. The total number of disabled soldiers is therefore very large. Sir George Murray, in a report to the Local Government Board for England and Wales, published in 1915, estimated that there would be at least 16,000 disabled soldiers and sailors discharged from service monthly by the end of the year. The magnitude of the problem was not realized at first and existing private agencies endeavored to care for the disabled men. National institutes for the blind and deaf, polytechnic schools, societies of arts and crafts, and nearly every other agency, private or public, in both France and England, offered their services to care for the blind and deaf, to re-educate the crippled, and to secure employment for those who were able to work.

In 1915, France bore the heaviest brunt of the fighting for the Allies, and in consequence had a far greater number of wounded. The enormous increase of cripples placed a heavier burden on the various private institutions than they could carry. The French Government then appointed an Interministerial Commission to study the problem, and this commission recommended that subventions be granted to certain existing institutions, that new institutions be established, that disabled soldiers be given the opportunity to learn a new trade when it was not possible for them to pursue their previous vocations, and that facilities be provided for maintaining the soldier while he was learning a new occupation. The War Department established special hospitals known as "Centres of Apparatus" in a number of the eighteen Army regions in France which were outside of the fighting zone, to which soldiers could be sent while still under treatment at the existing military hospitals and where they could secure an artificial limb or the necessary orthopædic apparatus. Many soldiers were provided with artificial limbs, but it was learned that in many instances the soldier discarded his artificial limb in an endeavor to work without it. Many French surgeons doubted the usefulness of providing artificial limbs for the soldiers, stating that they were too cumbersome and not suitable for the ordinary working man. Other physicians realized that the real reason for the artificial limbs not being used was that the stump had not been properly prepared to receive an artificial limb, that the limb had not been properly fitted, and that the wearer had not been sufficiently educated in its use. This latter opinion prevailed, and about a year ago the centres of apparatus were abolished and military orthopædic hospitals created in their stead in each Army region, where stumps could be properly prepared for artificial limbs and the necessary training given. One of these military orthopædic hospitals is situated at Bordeaux and the surgical work there is under the direction of Major Gourdon. A brief description of this hospital will illustrate the purpose and usefulness of these institutions. Instructions have been issued to the Chief Medical Officer in each Army region to transfer to the military orthopædic hospital all amputation cases, all patients crippled from wounds, and all others who would require apparatus or orthopædic treatment. Upon the arrival of the patient at the orthopædic hospital a complete physical examination is made and also a special orthopædic examination, which includes functional tests to determine the physical capacity of various muscle groups. Careful records are made of the examination, including charts and diagrams of the wounded part, an X-ray photograph, and in some instances a special plaster cast is made of the crippled limb. Appropriate treatment is then commenced, electricity and massage being quite generally used until the limb is in a suitable condition to receive an artificial leg or special apparatus. This treatment may last for one or more months, but as soon as the patient is able to be up and about he begins to receive special training in some branch of work which he has chosen for his future career, although every endeavor is made to return the soldier to his previous occupation and varied facilities for training are provided so that he can nearly always work at his former trade.

The vocational school for this region is also in Bordeaux and situated but a short distance from the hospital. Soldiers who live in the city receive their discharge from the hospital but continue at the school. This school provides a complete commercial course including stenography, typewriting, commercial arithmetic, correspondence, bookkeeping, and also special courses in French and English. There are also opportunities for learning tailoring, shoe-repairing, bookbinding, tinsmithing, forge and metal work, toy manufacture, drawing, industrial design, pottery, and the manufacture and repair of artificial limbs. Courses are also offered in the repair and operation of automobiles and for training assistants in the use of plaster-of-Paris and photography. The work is under the direction of competent instructors who have had wide experience in these fields. Major Gourdon lays great stress upon the functional re-education of impaired muscles. Each patient is carefully studied in order to ascertain how much power remains in his wounded limb and appropriate exercises are prescribed in order to increase its usefulness.

Professor Amar, of the Society of Arts and Crafts, has for years studied the efficiency of the workingman and has suggested a method for re-educating a disabled limb. Professor Amar prescribes a complete physical and functional examination of the crippled limb, the functional training of the limb without any apparatus in order to increase the muscular efficiency or to increase the sensitiveness of the stump if an amputation has been performed, and finally to re-educate the affected arm or leg with the artificial limb or apparatus attached. Major Gourdon firmly believes in Professor Amar's teaching and has carried out this plan with remarkable success. He also believes that it is of great importance to secure as teachers men who have learned a trade after having lost a limb. Major Gourdon has been ably assisted in the re-educational training of the armless men by a young woman whom he found begging in front of the Cathedral at Bordeaux. The girl had lost both her hands in an explosion at a munitions factory, and Major Gourdon offered to teach her how to use her arms and artificial hands. After a number of months of training she was able to dress herself, to sew, embroider, weave baskets, and do many other useful occupations without the artificial hands as well as with them. The sensitiveness of her stumps had been so increased that blindfolded she could distinguish small weights which varied only one or two grams. She became so proficient in her work that Major Gourdon employed her as instructor for the men who had lost an arm.

When the soldier is ready to leave the school, employment is secured for him, either through a central employment bureau which has been established in Paris or through a local employment bureau established in this region, and he is given a certificate on discharge stating that he has completed so many days of training. He may also return to the school for additional training at any time when he so desires, and he may also come back to the hospital as frequently as may be necessary to have his artificial apparatus kept in repair and receive such adjustment as may be necessary.

As soon as a soldier is discharged from the hospital he receives his pension and all expenses for his re-education are paid by the Government and the apparatus is furnished him also without expense. Institutions similar to this now exist in every section of France so that any soldier who has been crippled may receive the proper treatment and apparatus, re-education, pension, and appointment. Unfortunately nearly every soldier is strongly tempted to return home at the earliest possible moment, and if he can work at all at almost any occupation, he is needed at home, for France sorely needs workmen on her farms and in her factories and the soldier must consider the immediate necessity as well as the future welfare of his family. Many soldiers, therefore, do not receive the re-education which would be of inestimable value to them, to their families, and to their country. This is a situation which cannot be wholly obviated with the existing conditions in France.

The present efficient organization for the care of disabled soldiers and sailors in England has been the outgrowth of work originated through efforts of private philanthropy. One of the earliest efforts made was to provide artificial limbs and for this purpose a special hospital was established at Roehampton, in the outskirts of London, through the efforts of Lady Falmouth, Lady Harcourt and Lady Kenderdine, and the hospital was designated as the Queen Mary and Alexandria Hospital. Difficulties at once arose, for it was found that it was not feasible to secure the manufacture of a sufficient number of artificial limbs in England, and American manufacturers were called upon to furnish an additional number of these limbs. This is a sad commentary on the United States, for it brings home the fact that the production and manufacture of artificial limbs was far greater in the United States than in England to meet the demands created by industrial accidents. It was very shortly realized that the artificial limbs were not giving satisfaction to their wearers and for the same reason that existed in France. The British War Department then established a special hospital at Brighton to treat the stumps and to prepare them for receiving the artificial limbs. While undergoing this treatment at Brighton and having a new leg fitted at Roehampton, time hung heavy on the hands of the British soldiers and it was appreciated that habits of idleness would be inculcated in the soldiers, which would seriously impair their future ability to gain a livelihood. Treatment workshops were then established at Roehampton entirely at the expense of Lady Wantage. During the month, while the soldier was being fitted for his limb, he was given opportunity to receive work for treatment which would increase the suppleness of his muscles, and an opportunity was given to try himself out in some occupation.

Roehampton accommodates about four hundred patients, but as the number of patients waiting admission increased, there was delay at Brighton, and although additional accommodations were provided at Brighton, yet the length of stay was prolonged. Appeals were then made by the surgeon at Brighton for occupation of the soldiers and training workshops were established there by Queen Mary.

The steady growth of this work and the intense specialization of it required the services of the best orthopædic surgeons in Great Britain, and Colonel Robert Jones, an orthopædic surgeon of Liverpool of international reputation, was placed in charge of all the orthopædic work in Great Britain. There were many other soldiers disabled from wounds who had not lost a limb, yet who were in great need of special orthopædic treatment. Wounds which had left behind them a stiffened joint, a misshapen limb, or a paralyzed hand or foot from an injured nerve, required the services of these special surgeons.

A military orthopædic hospital was then established in Liverpool under the direction of Colonel Jones and shortly afterward a similar hospital was established at Hammersmith in London. At these hospitals special facilities were provided for electro-diagnosis to test the functional efficiency of injured limbs, also for giving massage, and some time later a plant for hydrotherapeutic treatment was installed to give douches and baths, which are so helpful in relieving stiff joints. Before these hospitals were opened the necessity for maintaining treatment workshops in connection with the hospital was fully appreciated and when the hospitals commenced their work, facilities were provided for carpentry work, tailoring, shoe-repairing, painting, fret-saw work, grinding of surgical instruments, electrical work, plumbing, bricklaying, cigarmaking, leather work, and repairing and manufacturing of splints and orthopædic apparatus.

The prime object of these workshops is to provide natural exercises for functionally impaired joints and muscles, rather than to give this exercise by means of highly specialized apparatus such as is given by the Zander method of physical training, which is so tedious and uninteresting to the average individual. These training workshops also keep the man from acquiring an idle disposition and teach him practically that he still has a sphere of usefulness. The success of these two institutions which have been in operation for nearly eight months, and the insufficient accommodation provided by them, have demonstrated the necessity of establishing new institutions in the large urban centres and new hospitals will be opened shortly in Dublin, Cardiff, Birmingham and Glasgow. A similar institution near Edinburgh will be enlarged.

In order to secure the satisfactory use of an artificial limb it has been found necessary to manufacture artificial limbs on the grounds of the Roehampton Hospital and to train the men in the use of their newly acquired member before giving them their discharge. By this method the artificial limb can be properly fitted, suitable adjustments made, and the soldier trained in its use before he leaves the hospital. It has been found most efficacious to have the men trained by discharged non-commissioned officers who have lost a limb and who are successfully using an artificial one. The men with artificial legs are trained by a man who is wearing an artificial leg and the men who are wearing an artificial arm are likewise trained by a man who is wearing an artificial arm. It is astonishing to see what satisfactory results are obtained by the use of these artificial limbs. A man with an artificial leg can readily learn to hop, jump or dance quite gracefully and to be apparently as active on his feet as he was before. The men who have lost an arm have been very much assisted by a very ingenious man who is working at the hospital who had lost an arm in an industrial accident some time prior to the war. This man has been able to devise a number of ingenious and simple devices which are attached to an artificial arm, so that a man with one of these appliances can readily learn to perform a large number of special tasks. Some of the soldiers have been taught by this man to wield a sledge hammer, ride a bicycle, play golf, hold a book and to acquire many other similar accomplishments. By means of a universal pincer attachment any small object can be readily picked up, the pincers being opened by shrugging the shoulders to which a strap is attached, which runs down to the pincers, and the pincers are closed by means of a spring. Upon the discharge of a soldier from Roehampton or from a military orthopædic hospital, he has an opportunity to continue his training in a polytechnic or vocational school, many of which exist in Great Britain, and all have been opened to the work of re-educating the disabled soldier for civil life. These technical schools offer courses in a wide variety of subjects, commercial work, stenography and typewriting, arts and crafts and mechanical and industrial trades in their branches. At the Regent Street Polytechnic Institute one can readily see the results of this system. Men who had previously been unskilled laborers have been taught to become efficient mechanics, carpenters, tinsmiths or electricians, in from three to six months. Employment has been secured for them and they are able to earn two to three times as much as they could prior to the war. So many men have shown such marked aptitude for learning a new trade and have become skilled in so short a time that the country has realized that it does not take an apprentice from three to seven years to become a skilled mechanic and has also learned the astonishing fact that the only highly technical skilled trade is that of farming. It has not been found possible to teach a man to become a farmer in any reasonable period of time.

It is only natural that a soldier will ask many questions before commencing a period of re-education which may last three months or sometimes even a year, and so many questions of a similar character have been asked that each soldier is now given a copy of a number of questions and their answers so that he can be reassured about the financial condition of his family. Every soldier of Great Britain who has a wife or other dependents has a separate allowance granted to his wife or other dependents during his absence. This separation allowance is continued while the soldier is in the hospital and also during the period of his vocational training. Many soldiers naturally desire to return to their homes as soon as they are discharged from the hospital, but every soldier is urged to take a special course of training unless it is possible for him to return to his former employment, which is ascertained by special agents by communication with his former employer. A further stimulus is given to the soldier by automatically beginning his pension on the day of his discharge from hospital, by organizing special hospitals for housing and boarding the soldier during his period of re-education and by granting him a pension of 5s. a week during this period. A soldier, then, will receive during his re-education period his pension, board and lodging, vocational instruction and an extra pension of 5s. a week from the Government. In addition to this his wife, children or other dependents also have their separation allowance continued. If a soldier is wounded in France he is treated at various hospitals until he reaches a base hospital. If he has a serious injury which will require a long treatment, he is transferred to a general hospital in England as soon as possible. If, on the other hand, his injury is not very severe and requires only short treatment, he is quickly returned to his unit, or if a longer period is required he is transferred to a general hospital in Great Britain and then to a special orthopædic hospital, or if he has lost a limb, to the hospital at Brighton. From Brighton he is ultimately transferred to Roehampton, and whether in the military orthopædic hospital or at Roehampton application is made for his discharge and pension three weeks before he is expected to leave this hospital. Upon his discharge from the hospital the pension commences, which is granted in two forms: If his disability be functional and a complete cure is anticipated, he may receive a gratuity or an allowance which may be increased or diminished, depending upon the extent of his disability, and if he has served for a considerable period of time in the Army he also receives a supplementary service pension. Pensions for functional disability may only be temporary and may be increased or diminished, but pensions for permanent disability, if once allowed, remain fixed at the amount originally granted.

The pensions ministry has created a large number of local committees in various parts of Great Britain, and prior to the discharge of a disabled soldier from a hospital, he is visited by an agent of the Local Pensions Committee of the district in which the hospital is located. If the soldier returns to his home situated in the district of another committee, all the facts relating to his case are transferred to the local committee. The discharged soldier may then carry on his vocational training, either in the district in which the hospital was situated or he may be transferred to his own home and receive his vocational training in that district. In either event he remains under the supervision of the local Pensions Committee. This supervision has the following functions: First, to see that appropriate outdoor treatment is provided for the soldier if he is in need of it, the adjustment and repair of artificial limbs or other apparatus, and maintaining the soldier in continuous employment, if that be possible.

The principle laid down by Sir Henry Norman, reporting to the Prime Minister on the result of his investigations on the after-care and re-education of disabled soldiers and sailors in

France, was that hospitals and re-education centres should be, "few and good, rather than poor and many," and this principle has been firmly adhered to. The concentration of a large group of disabled soldiers makes it possible to give a larger variety of courses of training and applies not only to those with disabled limbs but also to those who have been blinded in battle. The re-education work for the blind in England has been carried on entirely by private agencies, particularly by the National Institute for the Blind. The successful re-education of the blind soldiers would perhaps not have been possible were it not for the fact that the most energetic and efficient member of the Board of Directors of the National Institute was Sir Arthur Pearson, who became blind shortly prior to the war. Largely due to Sir Arthur's efforts a large school, known at St. Dunstan's School for the Blind, was established in Regent Park, and to this school all blinded soldiers are urged to come. This is made easier because all the blind soldiers receive hospital treatment at the Chelsea Hospital for the Blind in London, and while in the hospital they are visited by agents of St. Dunstan's School, some of whom are blind themselves and can readily explain to the blinded soldiers the advantages of the institution. There are now nearly five hundred pupils at St. Dunstan's, which is supported by grants from the Prince of Wales' Fund and by volunteer contributions. Accommodation for officers has been provided by Sir Arthur Pearson in houses near his own home in London, and he also has as guests in his own house a certain number of these blinded officers.

Sir Arthur has laid down three cardinal principles for the re-education of the blind. First, no sympathy shall be expressed for any blinded soldier. He must be told that he has a life of usefulness before him, that he must learn to be blind, and that he can be taught to learn a trade which will make him self-supporting. Second, instruction must be given by blinded persons, particularly by those who have become blind in adult life. And, finally, blind pupils must be given short periods of work. This last principle Sir Arthur realizes well himself, for although he has been over the grounds of St. Dunstan's many times and readily notices any unevenness or turn in the path, yet when he showed the grounds to the Prince of Wales he could not explain the work to him while walking, as each of these tasks required complete concentration for the blinded person.

At St. Dunstan's every soldier is required to learn typewriting and is given a typewriter on his discharge. He is also required to learn to read Braille so that on his discharge he can surely be able to read books and to write his own letters. The vocational training given to the blind soldiers includes a variety of special trades, and the proficiency attained by some of the blind soldiers is truly remarkable. Carpentry and joinery are taught and some of these men become very skilled in cabinet work, in making bookcases, picture frames, and other similar small and useful articles of furniture which command a ready sale. Classes are given in shoe-repairing, mat-making, basket work and poultry raising. It is hardly believable that a blind man can pick out a hen from twenty different varieties and tell immediately which variety it is, or that he can select a special type of poultry food from a large number of samples. The men, however, are not encouraged to learn poultry raising unless they have a wife or some other member of their family who can assist them in regulating the temperature of the incubators and who can also assist in marketing the products.

All of the trades taught are those which can be carried on at home and each one of which is also sufficiently lucrative to enable the soldier to be self-supporting from what he earns and from what he receives from his pension.

Pastime occupations are also taught in weaving rugs, making network bags, hammocks and other similar articles. These various courses take from four to six months and a course in massage is also given which requires one year. Many men have completed the course in massage and have passed the examination required by England before they are allowed to practice.

THE NEW PATHOLOGY OF SYPHILIS *

DR. ALDRED SCOTT WARTHIN

University of Michigan.

IN an analysis of 4880 autopsies performed at Bellevue Hospital during a period of ten years Symmers † found anatomic evidence of syphilis in only 314 cases, or 6.5 per cent. In a similar study made by myself of 750 autopsies at Ann Arbor during the last ten-year period evidence of syphilitic infection was found in 300 cases, or in 40 per cent. of the entire autopsy material. Nothing could better illustrate and emphasize the points which I hope to establish in this paper than the wide discrepancy between these two studies. This is made all the more striking when the character of the clinical material in the two hospitals is considered. In a great city hospital like Bellevue, in a great city like New York, with patients derived chiefly from the poorer classes, the incidence of syphilis would naturally be thought to be much greater than in a state hospital, like the university hospitals in Ann Arbor, in which the clinical material is drawn chiefly from the rural population of the state, representing the better elements of the middle class farmers, village storekeepers, mechanics and laborers. Is the latter rural population syphilized to a greater extent than the poorer working classes of New York? In 139 autopsies made at Ann Arbor in 1916–1917, fifty-six cases showed evidences of active syphilis, in 1915–1916 out of 79 autopsies there were 30 cases, and in 1914–1915 out of 58 autopsies there were 25 cases, and for the remaining years the incidence was 40 to 50 per cent. annually. Does this mean a greater total incidence of syphilis in Michigan than in New York?

I believe that this striking difference in findings is chiefly dependent, not upon the clinical material, but upon the *different pathologic criteria employed in these two studies.* If we turn

* Delivered December 8, 1917.

† Journal of the American Medical Association, 1916, lxvi, 1457.

to Symmers' paper we find that the criteria employed by him were chiefly anatomic. His diagnoses were based upon the following lesions: Aortitis in 55.7 per cent. of cases, aneurism in 25.6, chronic interstitial orchitis in 39, lesions of the nervous system in 35.6, of the liver in 33.4, of the skin in 33.4, indurative atrophy of the base of the tongue in 25, osseous lesions in 14.9, of the respiratory tract in 10.5, of the lymph-nodes in 6, and of the gastro-intestinal tract in 2.2 per cent. It is very evident from Symmers' paper that many of the findings not classed as gummata were in reality gummatous processes and should have been classed as such. For example, hepar lobatum always means healed gummata of the liver. He takes no note of syphilis of the heart muscle, the pancreas or adrenals, or of the occurrence in the most varied tissues of small inflammatory infiltrations associated with the presence of the Spirochæte pallida. In short, his diagnoses have nothing to do with the spirochæte and the most common lesions produced by this organism; but are based chiefly upon the gross pathologic anatomy of pre-spirochæte days.

The pathologic anatomy of syphilis is still ruled by the dicta of the gross pathologic anatomists of the latter half of the last century. The statements in our textbooks concerning the pathology of this infection in its latter stages *are based almost without exception upon the occurrence of the gumma, and syphilis of an organ is said to be frequent or rare according to the frequency of gumma of that organ.* The gumma was practically the only anatomic lesion of syphilis recognizable by the early pathologic anatomists. Morgagni's knowledge of the gross pathology of syphilis (*lues venera*) consisted almost wholly of observations upon gummatous lesion of the bones, aneurism of the aorta, and changes in the lungs and kidney. He speaks particularly of never finding changes in the liver in bodies affected with the lues venera. As it was not until the years 1831–1837 that syphilis was separated from gonorrhœa and soft chancre by Ricord, there was no advance made in the pathology of syphilis in the first thirty years of the nineteenth century.

It is a very strange fact that Rokitansky, the father of modern gross pathologic anatomy, in the thirty thousand autopsies said to have been performed by him, should have added nothing to the knowledge of the pathology of syphilis. With a pathologic material drawn from a highly infected population his observations upon the gross pathologic anatomy of syphilis are amazingly few. Ulcers near the nails, necrosis and hyperostoses in bones, and inflammations of fibrous structures, and possibly gummata, constitute his apparent knowledge of this disease, as shown by his great work on gross pathologic anatomy. Virchow, likewise, in his "Cellular Pathology," 1858–1860, barely mentions syphilis and, at that, not in connection with any essential pathologic feature of the disease. Nevertheless, in 1858 * he clearly distinguished the simple inflammatory (irritative) and the gummatous lesions of syphilis, and showed for the first time the part played by this disease in producing inflammatory conditions of the most varied organs and tissues. This article really laid the foundation for the modern knowledge of the pathology of syphilis obtained since the spirochæte was discovered. But his separation of syphilitic lesions into the two types made little impression upon the syphilology of the next forty years. In Wagner's "Textbook of Pathology" (1862–1876), emphasis of the *syphiloma* (tuberculum s. gumma syphiliticum, tumor gummosus, gummy tumor) as the essential pathologic lesion of syphilis ruled completely the minds of both clinicians and pathologists up to nearly the close of the century, and still remains the chief part of the pathology of syphilis in our textbooks. This narrowing of the conception of the pathology of this disease was largely due to the very valuable and comprehensive article by Baümler on syphilis in the von Ziemssen's Handbook (1874). The chapter on the general pathologic anatomy of syphilis in this article concerns itself chiefly with Wagner's conception of the syphiloma; and Baümler's monograph has been the fount of inspiration for the majority of textbook articles on syphilis written since 1875.

As the relationship of tabes and paresis to syphilis became more evident during the next two decades the conception of "postsyphilitic," "metasyphilitic," and "parasyphilitic" proc-

* Ueber die Natur der constitutionell-syphilitischen Affectionen, Arch. f. Path. Anat. u. Phys., xv, 217.

esses arose in explanation of this relationship. Fournier (*Les affections parasyphilitiques*, Paris, 1894) was chiefly responsible for the use of this term and for the view that a large number of pathologic conditions bore a definite relationship to syphilis, but were not syphilis and were not necessarily caused by it. Paresis, tabes, aortic aneurism, arteriosclerosis, a variety of conditions of the nervous system, leucoderma, leucoplakia, and many other affections were regarded as parasyphilitic affections. The association of a typical form of aortitis with aneurism, paresis, tabes, and other parasyphilitic conditions gradually led to an acceptance of its syphilitic origin and nature. Nevertheless, up to the discovery in 1905, of the Spirochæte pallida, the gumma remained the one specific histopathologic lesion of syphilis.

With the discovery of the etiologic agent of syphilis it was to be expected that a change would be wrought in our concepts of the pathology of the disease, and that expectation was soon fulfilled. Parasyphilis has disappeared as the various parasyphilitic affections have been shown to be active syphilis with living spirochætes still present in the affected tissues. The term is now a misnomer. To the pathologic criteria of the disease there have been definitely added during the last decade the characteristic lesions of the central nervous system and syphilitic mesaortitis. The Harvey lecture by Fordyce, in 1915, on "Some Problems in the Pathology of Syphilis," expresses very fully the generally accepted knowledge of the pathology of syphilis of the present day. He recognizes that "in all stages and in all organs the lesion begins in the perivascular lymph-spaces as a lymphocytic and plasma-cell infiltration;" but he still says that "the type of lesion of the tertiary period is the gumma." He advances the pathology of syphilis only by the full recognition of the syphilitic nature of the nervous lesions and mesaortitis. Of the pathology of latent syphilis in other organs and tissues he has this to say: "Aside from gummatous involvement of the viscera, little is known of the effects of the infection on the various organs." My investigations and their results begin here in the demonstration that the gumma is not the type of lesion of late or latent syphilis, and that the viscera are involved in all cases of latent syphilis, not by gummatous processes, but by specific inflammatory processes, eventually fibrosis, usually mild in character, but acquiring pathologic importance because of their progressive character.

As soon as the Levaditi method of demonstrating the Spirochæte pallida in sections was published, I began investigations as to its occurrence and distribution in the tissues, and my attention was first drawn to congenital syphilis because of the greater ease of demonstrating the spirochætes in the tissues of such cases. As a result of such studies important facts concerning the incidence of Spirochæte pallida in the heart muscle of congenital syphilitics have been added to our knowledge, as, for example, the constant presence of spirochætes in the hearts of cases of congenital syphilis dying before or at birth, the occurrence of focal fatty changes in the myocardium due to the colonization of the organism, and of a specific type of interstitial myocarditis due to the same cause. The essential lesion in congenital syphilitic myocarditis was shown to be œdema of the interstitial tissues, often giving reactions for mucin, infiltration with lymphocytes and plasma cells, and fibroblastic and angioblastic proliferations. Spirochætes were found to be constantly present in such lesions, often in enormous numbers. That spirochætes could be present in great numbers in the tissues of congenital syphilis without producing tissue changes was also shown.

From the study of the lesions of congenital syphilis it was a natural step to that of the pathology of acquired syphilis. Similar lymphocyte and plasma-cell infiltrations, associated with spirochæte localization, were found in the tissues, and organs of known cases of acquired syphilis, aortic aneurism, tabes, paresis, etc., as well as in cases not recognized clinically as syphilis, but it was not possible to demonstrate the presence of spirochætes so readily or in such a large proportion of cases, owing to their smaller numbers and widely scattered distribution. Nevertheless, the demonstration of the organism was successful in such a large number of cases (75 of the 300 cases), as to make the specific syphilitic nature of these lesions certain. In the progress of these studies the specific inflammatory lesions of spirochæte localization have been found in the myo-, endo-, and pericardium, the aorta, pulmonary and other large arteries, nervous system, liver, pancreas, adrenals, testis, prostate, prevertebral and mesenteric tissues. These lesions vary greatly in size, from minute collections of few cells to larger infiltrations just visible to the naked eye. Every stage of development, from the early active lesions to complete healing and fibrosis, was observed; but no cases were found in which there were no active lesions. Complete healing throughout the body was never observed. The marked tendency of the lesions to undergo fibrosis and healing with the formation of dense hyaline scar tissue was a striking feature and regarded as evidence of the relatively avirulent character of the organisms. Spirochætes may be found in all stages up to nearly complete healing, but were never found in the dense fibroid areas. A detailed description of these lesions of latent syphilis will now be given.

THE MICROSCOPIC PATHOLOGY OF LATENT SYPHILIS

Nervous System.—The central nervous system was examined in only a small percentage of the material, the head much more frequently being opened at autopsy than the spinal column. No especial study was made of either brain or cord, and the changes noted in these were only those found in the ordinary routine of microscopic examination accorded all tissues and organs obtained at autopsy. The most constant changes were those found in the *meninges*. In practically every case of latent or clinical syphilis autopsied some degree of thickening of the meninges was noted. The dura was constantly more adherent and thickened. No active syphilitic foci were, however, ever found in this membrane. Focal thickenings of the leptomeninges were found in practically every case. These varied in all possible degrees. They were most common over the parietal convolutions, and along the median surfaces, being most easily seen over the sulci. They more frequently involved the arachnoid than the pia; but the focal thickenings very frequently represented fibroid areas involving both pia and arachnoid. Thickening of the wall and more or less obliteration of the meningeal vessels were usually found associated with the localized fibrosis. In the great majority of the brains examined these meningeal focal thickenings were small, usually pinhead in size, and sharply circumscribed. Only in clinical cases of paresis, tabes, cerebral syphilis, cerebral gumma and "toxic psychosis" were they larger, more diffuse and more marked. Transition stages from these small focal lesions to the larger ones were found. The great majority of these focal fibroses of the leptomeninges were healed inactive areas, plasma-cell infiltrations and fibroblastic infiltrations being found only in the more active cases of syphilis. They appear in the latent cases to represent old and early lesions in the history of the individual infection. The occurrence of active lymphocyte and plasma-cell infiltrations in the meninges in old latent cases of syphilis seemed, however, to parallel the degree of activity of the lesions found in the heart, aorta and other tissues. Precisely the same lesions in the meninges occurred in the non-paretic and non-tabetic cases of syphilis as in those showing a clinical paresis or tabes, the only difference being one of degree. Active meningeal lesions have been found more frequently in young adults with congenital syphilis than in the old cases. Similar lesions occur in the meninges of the cord; and, as in the case of the cerebral meninges, the degree of these meningeal changes usually corresponded to the severity of the lesions in other organs and tissues. The meninges of the cord usually showed the most marked changes in cases of tabes and paresis, but a few exceptions to this were found in latent cases. The meningeal changes noted by me associated with syphilis, both latent and clinical, correspond in general with those described by LeCount and other writers as characteristic of meningeal syphilis. The focal chronic leptomeningitis regarded by some writers as the result of chronic alcoholism, would appear from my experience to be the result of syphilitic infection rather than of alcoholism. It is true, that some of my most marked cases of meningeal fibrosis were both alcoholic and syphilitic; but precisely the same meningeal changes occur in those cases without a history of alcoholism.

Focal infiltrations of lymphocytes and plasma cells were found in both *brain* and *cord* in cases not regarded clinically as paresis or tabes. These infiltrations were perivascular and were sometimes associated with proliferative changes in the vessel, at other times not. The character of these minute scattered lesions is precisely identical with those found in the brain and cord, in paresis and tabes, the differences being only those of number and degree. In two cases diagnosed clinically as "toxic psychosis" these lesions in the brain were so numerous as to suggest a pathologic diagnosis of early paresis. Two other cases without nervous symptoms gave similar microscopic findings. In one case of secondary syphilis dying from salvarsan poisoning the brain showed scattered perivascular plasma-cell infiltrations.

The question is raised by these findings as to their frequency in syphilis and their relation to the symptoms of paresis and tabes. Is every case of syphilis, to a slight degree, at least, a paretic or tabetic? There can be no doubt that pathologically there are borderland cases just as there are clinically such; and my experience would lead me to believe that probably every case of old syphilis will present in the brain and cord the same scattered perivascular infiltrations of lymphocytes and plasma cells found in all other organs and tissues. Such infiltrations represent simply the local reaction to the presence of spirochætes; and their relation to paresis and tabes may be simply one of degree, with reference to the number of infecting organisms, the degree of intoxication produced, and the resulting destruction of nerve tissue and functional disturbance produced.

Minute infiltrations of lymphocytes and plasma cells are of frequent occurrence in and about the *spinal ganglia*, the *spinal nerves* and the large peripheral nerves. No spirochæte studies have been made of these, and their syphilitic etiology is assumed because of their identity with known syphilitic lesions in other organs and tissues, and their constant association with such.

Similar infiltrations are also very common in and about the *sympathetic nerves* and *ganglia*, particularly in the solar plexus and periadrenal plexus. Fibrosis, atrophy, and pigmentation of these ganglia have been observed in connection with such infiltrations. In three cases of Addison's disease due to syphilitic fibrosis and atrophy of the adrenals, the adrenal and solar plexus showed especially marked syphilitic infiltrations.

The tendency of the nervous system to spirochæte localization and to focal reactions of lymphocytes and plasma-cell infiltrations would appear from our material to be less than that of the heart, aorta, and other tissues, but this impression may be due entirely to the smaller number of cases in which the central nervous system was examined, and to the more superficial study accorded it. The routine examinations reveal, at least one very important fact, that such minute lesions as occur in other organs in syphilis are found also in the nervous system when no clinical symptoms of its involvement are present.

Heart.—The heart in every case showed microscopic lesions characteristic of spirochæte localization; and in this organ more frequently than in any other has the spirochæte itself been demonstrated by the Levaditi method. The cardiac lesions in the cases in which syphilitic infection was known to exist, and in those in which it was not suspected are identical. They vary greatly in degree. To the naked eye the hearts of the cases included in this autopsy material showed as a rule dilatation, hypertrophy, atrophy, and fibroid patches in the wall of the left ventricle. In many cases no fibroid changes were visible to the naked eye, and the occurrence of fibrosis and active infiltrations was determined only by the microscopic examination. The portion of the heart most frequently involved was the anterior wall of the left ventricle near the apex, the adjacent portion of the septum and the posterior left ventricular wall near the mitral ring. In cases of congenital infection the right ventricular wall may be chiefly affected. It must be emphasized that the determination of cardiac syphilis is essentially microscopic; when no myocardial changes can be seen by the eye the microscopic examination may reveal the most extensive lesions. This is especially true of the more acute and active cases.

The essential lesion of cardiac syphilis is an interstitial myocarditis characterized by infiltrations of lymphocytes and plasma cells along the vessels between the muscle fibres. These infiltrations are usually patchy or diffuse, very rarely focal or circumscribed, thus differing from streptococcus myocarditis. The infiltrations vary in degree, but usually are slight, the cells often being arranged in close single file between the fibres. To a superficial glance there appears to be only a slight increase of the interstitial nuclei. Polynuclears are few in the infiltrations, and eosinophiles are not present. The cells of the infiltrations are probably chiefly histogenetic lymphocytes and young formative cells. Large epithelioid fibroblasts are very common, especially in the older, healing areas. Giant cells are rare. (See Figs. 1, 2 and 3.)

The entire heart wall from epicardium to endocardium, including the papillary muscles, may be involved in the infiltrations; but in the average case they lie nearer to the endocardium, often just beneath it, or in the middle layer of the myocardium. In acquired syphilis they rarely begin on the epicardial side, as they frequently do in congenital syphilis. In the most severe cases larger areas of infiltrations are grouped around the coronary arterioles. These may reach such a size as to suggest miliary gummata (see Fig. 4). Caseation, however, does not occur in these larger infiltrations. In two cases only were true gummata found in the myocardium. These were associated with the diffuse plasma-cell infiltrations.

In the more acute, severe and active cases the stroma of the infiltrated areas in the myocardium is œdematous, often giving a slight reaction for mucin with specific dyes. In the older healed areas the stroma becomes fibroid and hyaline. In the great majority of cases the myocardium shows healed fibroid areas in association with the active infiltrations (Figs. 5 to 8). In many cases the fibroid areas predominate, and search may be necessary to show the presence of active infiltrations. This is true especially of the older unrecognized cases. In every case, however, such active areas have been found, and no completely healed cases have been seen. A progressive fibrosis of the myocardium always takes place. In acquired syphilis the fibroid areas are always larger on the endocardial side; but in some cases they have extended completely through the myocardium. When this is the case, both endocardium and pericardium are thickened, and the latter usually shows a localized adhesion. These marked changes practically always occur just above the apex, in the anterior wall of the left ventricle; aneurismal dilatation of the weakened wall at this point is not uncommon; rupture of the wall may take place as in two of our cases. More frequently, however, thrombosis occurs on the thickened endocardium overlying the fibroid patch, and death usually results from the progressive thrombosis of the left ventricle, or from embolism. In thirty of our cases thrombosis of the left ventricle over an area of syphilitic infiltration or fibrosis of the ventricular wall was the cause of death. In the great majority of the cases of latent syphilis the left ventricle was dilated, and such dilatation was either the chief or an accessory cause of death. The ''fibroid'' heart is the ultimate outcome of all cases of latent syphilis. (See Figs. 7 to 11.)

In the congenital and active acquired cases spirochætes are fairly easily demonstrated between the heart muscle fibres. In the older cases, with fibrosis more or less well advanced, the demonstration of the spirochæte becomes a task requiring patience and determination, spread often over days or weeks. They are, nevertheless, more easily found in the heart than in any other organ or tissue, so far as our experience goes. (See Figs. 12 to 15.)

The parietal and mitral endocardium appears resistant to the spirochæte to a much greater degree than that of the aortic valves. In no case have I been able to demonstrate the occurrence of syphilitic changes in the mitral valves. Secondary streptococcus or staphylococcus endocarditis with mitral stenosis or insufficiency was in a number of cases, particularly those of congenital syphilis, the immediate cause of death. The heart of congenital syphilis seems to give a local predisposition to secondary infections. Sclerosis of the coronaries may or may not be associated with syphilitic myocarditis. In my material marked coronary sclerosis was rather a rare finding; the coronary involvement was perivascular rather than primarily vascular. Even in a number of the angina pectoris cases the coronary sclerosis, as far as the larger branches were concerned, was not marked, although these cases all showed marked fibrosis of the myocardium. Thrombosis of the coronaries was not observed in any case. The smaller terminal arterioles and capillaries are obliterated and destroyed by the perivascular infiltrations and proliferations, while the larger coronary branches rarely show much sclerosis, except in the cases showing a general arteriosclerosis. A striking feature of the fibroid areas is the dilatation of preëxisting capillaries or veins or a new formation of such in the fibroid areas. Often such areas appear cavernous or sinusoidal, because of the large blood spaces present having practically no wall but that of the lining endothelium. These appearances are probably the result of a compensating circulation in newly formed capillaries. In younger scars the new formation of capillaries is very striking, and this vascular proliferation appears to be one of the distinct features of syphilitic myocarditis.

The heart muscle itself in all of the cases presented varying degrees of hypertrophy with simple and brown atrophy, fatty degeneration, and necrosis, all of these changes usually being present in the same heart. In the immediate neighborhood or periphery of the infiltrations the heart muscle fibres often showed no changes at all; in other cases fibres extending through the lesions showed only hypertrophy. I have previously shown that colonies of spirochætes may be found in heart muscle appearing perfectly normal. While this is most common in cases of congenital syphilis, it is also found in late acquired syphilis. It is evident that the toxic action of such spirochætes upon the muscle fibres must be very slight indeed. The intensive study of these cardiac lesions tends to emphasize more and more the mild and slowly progressive nature of the latent syphilitic infection.

The clinical features of these heart lesions can not be presented in detail here, and for the present only generalizations can be given. While a history of symptoms is wanting in some cases, the great majority of the cases included in this material presented symptoms of cardiac weakness, and circulatory disturbances. A very large number of the cases were frankly those presenting the cardio-vascular-renal complex. The termination of the case was frequently cardiac dilatation. Shortness of breath, palpitation, precardial pains, anginal attacks, irregularity of pulse, swelling of ankles, dizziness, general weakness, ringing in ears, etc., were the most common subjective symptoms. All of our cases of angina pectoris were syphilitic. The blood-pressure may be high or low; the cases are about evenly divided in this respect. The disturbances of rhythm are very prominent and of every variety; the most interesting cases studied in the Clinic of Internal Medicine coming to autopsy belong to this material. "Functional" murmurs were common. The final clinical picture in all was that of an insufficient heart—a heart that could not do its work properly. The majority died a cardiac death; as shown by the hypertrophy and dilatation of the heart, and the chronic passive congestion of lungs and other organs. The chief pathologic findings at autopsy were those of a myocardial insufficiency ("fibroid heart") without (in the great majority of cases) accompanying valvular lesions.

Aorta.—The aorta, when examined microscopically, showed in every case of old syphilis characteristic syphilitic infiltrations in its media and adventitia. To the naked eye the changes may be very slight or marked. The gross appearances may be those of so-called senile atherosclerosis or of the type now generally recognized as syphilitic aortitis, or the two gross pictures were frequently combined in the same case, particularly in older patients. While the lesions in the majority of cases are most often seen in the beginning of the aorta and in its arch, they are often most marked in the abdominal aorta; and, in a few cases, were confined to this portion, so far as the gross appearances were concerned. The process is very common about the mouths of the aortic branches.

It is certain, from my experience, that the *gross appearances are no absolute criterion of the aortic condition. When the gross appearances of syphilitic aortitis are present the pathologic diagnosis of syphilis may be given at the autopsy table without hesitation; but when the picture is that of atherosclerosis, no positive exclusion of syphilis can be made without a microscopic examination.* The aorta may present no changes, or very slight ones, to the naked eye, but the microscopic investigation may show characteristic plasma cells along the vasa vasorum of the media and adventitia. This is true of all the early stages of the diseases.

In the few cases of secondary syphilis examined at autopsy the aorta showed slight changes ("fatty degeneration of the intima"), or none at all, yet microscopic study showed extensive infiltrations along the vasa vasorum and around the small vessels in the prevertebral tissues. This is the early active stage when the demonstration of spirochætes can be most easily carried out. *The cases recognizable by the naked eye as syphilitic aortitis are old cases;* and the demonstration of the spirochætes in these becomes increasingly difficult. This is particularly true when to the syphilitic aortitis there are added the changes of atherosclerosis due to age or other etiologic factors. *In the great majority of old cases the gross appearances of atherosclerosis are combined with, and conceal those of syphilitic aortitis.* For this reason a negative gross diagnosis of syphilis of the aorta is of no value, in the absence of a thorough microscopic study.

The microscopic features of this form of aortitis are now so well known that they will be but briefly discussed here. Small infiltrations of lymphocytes and plasma cells are found along the vasa vasorum of the media and adventitia, usually most marked around the vessels of the latter, and diminishing in degree as the vessel passes up into the media. Perivascular proliferation, fibrosis and obliteration of the small vessel then follows. (See Figs. 16 and 17.) The resulting disturbances of nutrition of the vessel wall are first seen in the intima and the inner portion of the media, in the form of fatty degeneration, atrophy and necrosis of the cells of this portion of the vessel, with weakening and thinning of the wall, followed later by fibrosis and hyaline change. The involvement of the media progresses steadily outwards, and because of the greater involvement of the media locally there results local thinning of the vessel wall and microscopic ruptures of the elastic fibres. Such changes naturally predispose to the development of aneurisms. In simple uncomplicated syphilitic aortitis the fibrosis of the intima is less than in atherosclerosis, and there is less tendency to secondary atheroma and calcification. The two forms of aortic disease are, however, combined in the majority of cases, and the microscopic picture presents the characteristics of both processes. In some cases the changes in

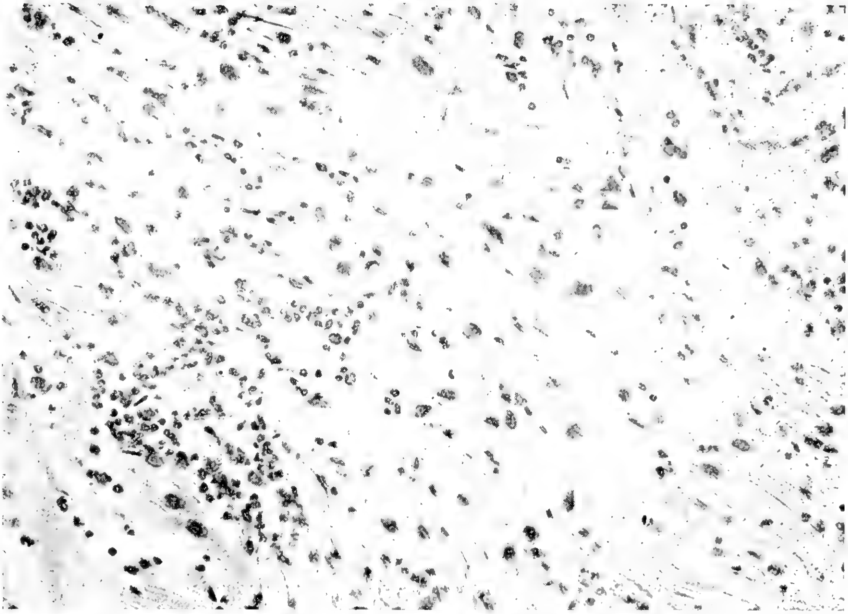


Fig. 1.—Chronic syphilitic myocarditis. Unsuspected latent syphilis. Sudden death. Male, aged 52 years. Dilatation of left ventricle. Wall of ventricle showed diffuse plasma-cell infiltrations. Spirochætes present throughout these infiltrations.

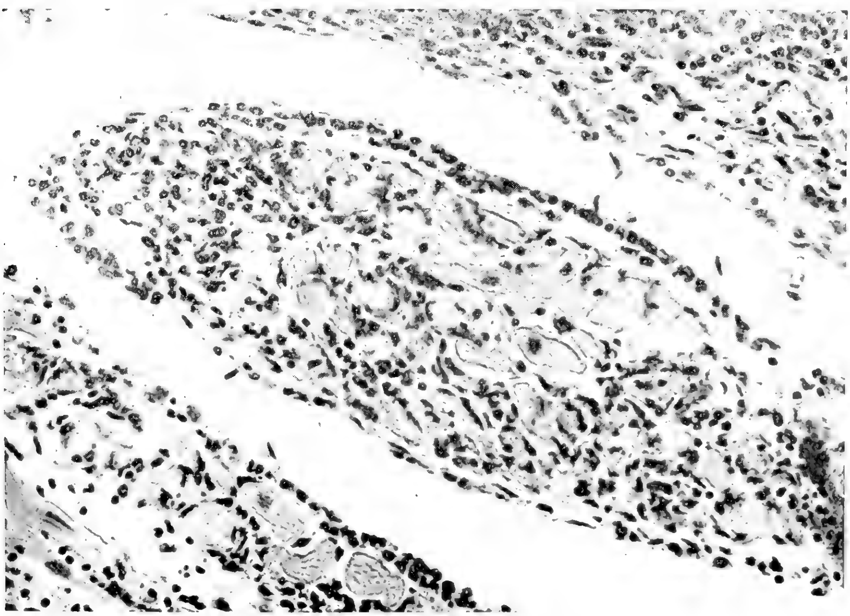


Fig. 2.—Chronic syphilitic myocarditis. Male, 45 years of age. Sudden death. Syphilis not suspected by clinicians; aneurysmal dilatation of left ventricle at apex. Diffuse plasma-cell infiltration of papillary muscles and wall of left ventricle at apex. Spirochætes present.

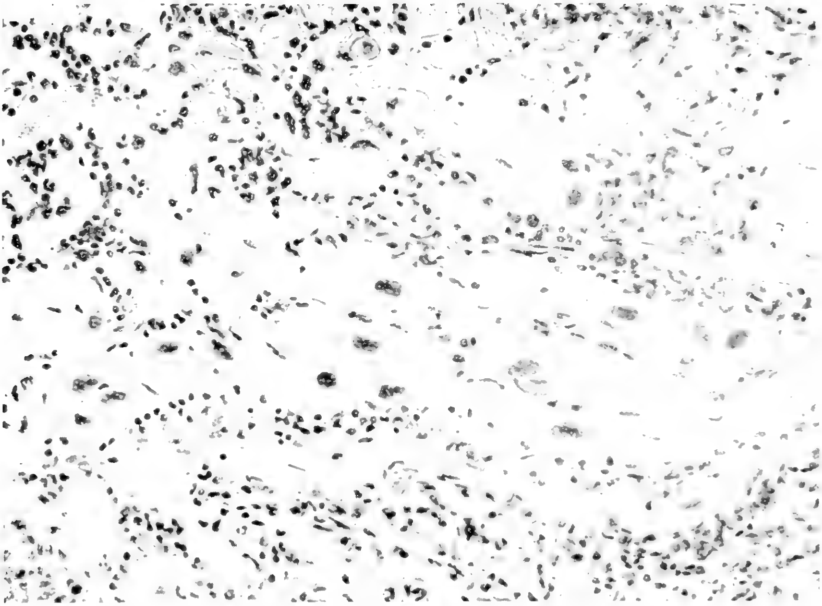


Fig. 3.—Chronic syphilitic myocarditis. Unsuspected latent syphilis in middle-aged man. Sudden death. More severe process than in preceding. More marked plasma-cell infiltrations of left ventricle wall above apex. Spirochætes.

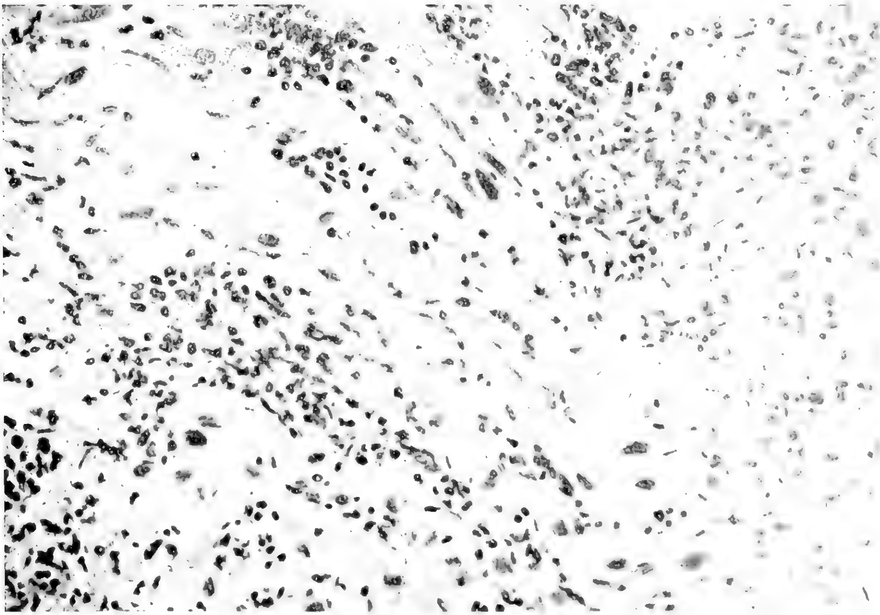


Fig. 4.—Chronic syphilitic myocarditis. Sudden death in middle-aged male with history of "cured" syphilis. More active process; plasma-cell infiltrations more diffuse with larger focal infiltrations approaching miliary gummata. Abundant spirochætes.

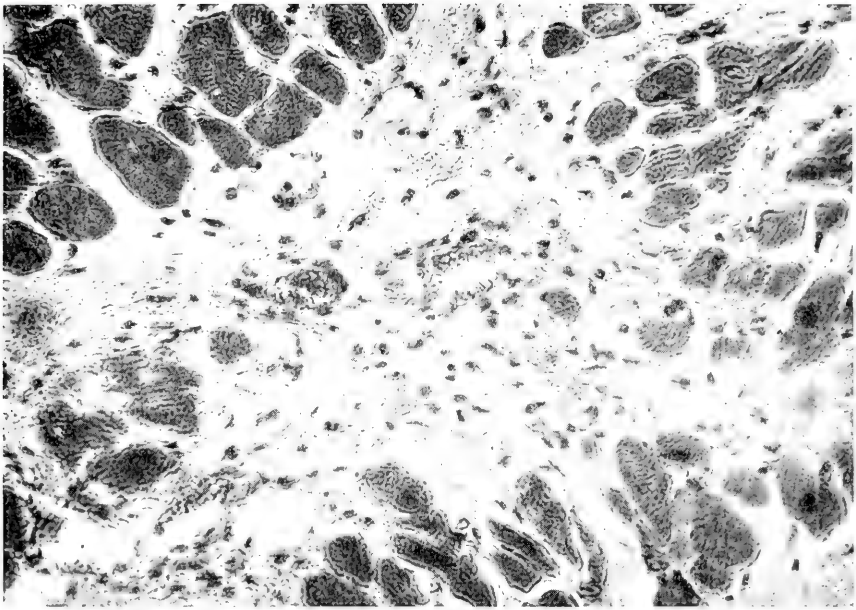


Fig. 5.—Chronic syphilitic myocarditis. Older process. Fibroid heart. Case of diabetes; unsuspected latent syphilis. Small active area in left ventricle wall in healing stage. Few spirochætes.

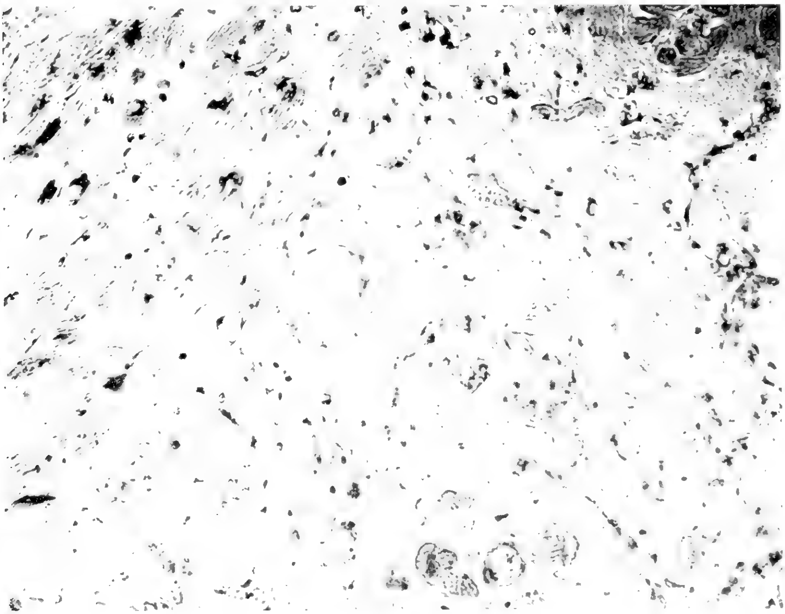


Fig. 6.—Chronic syphilitic myocarditis. Left ventricle wall from case of syphilis contracted 14 years previously. Suicide. Fibroid areas in heart with active plasma-cell infiltrations. Few spirochætes.

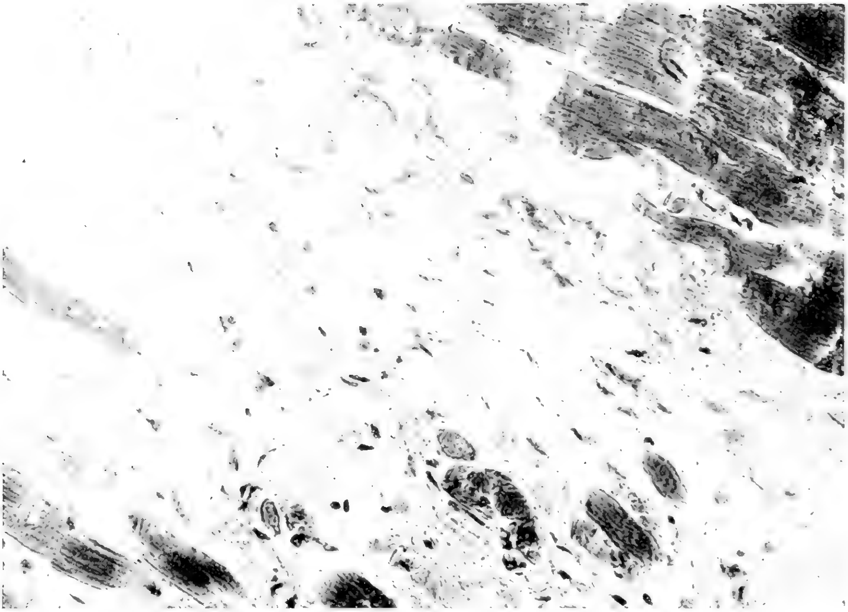


Fig. 7.—Chronic syphilitic myocarditis. Old "cured syphilis"; negative Wassermann; cardio-vascular-renal symptom-complex; dilated, fibroid heart. In areas showing no more active plasma-cell infiltration than in photographic spirochætes found in small colonies.

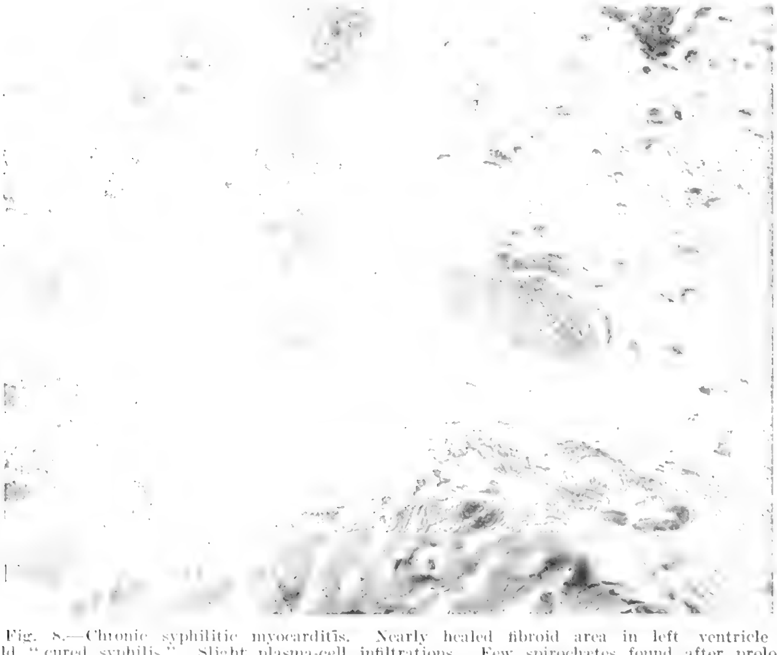


Fig. 8.—Chronic syphilitic myocarditis. Nearly healed fibroid area in left ventricle wall of old "cured syphilis." Slight plasma-cell infiltrations. Few spirochætes found after prolonged search.

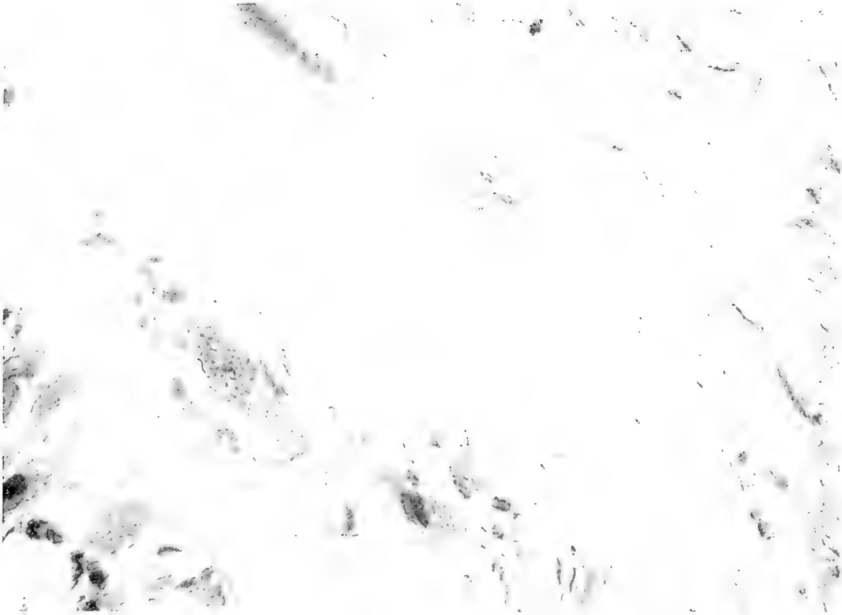


Fig. 9.—Chronic syphilitic myocarditis. Completely healed fibroid area. In such hyaline connective tissue without plasma-cell infiltration spirochætes have never been found.

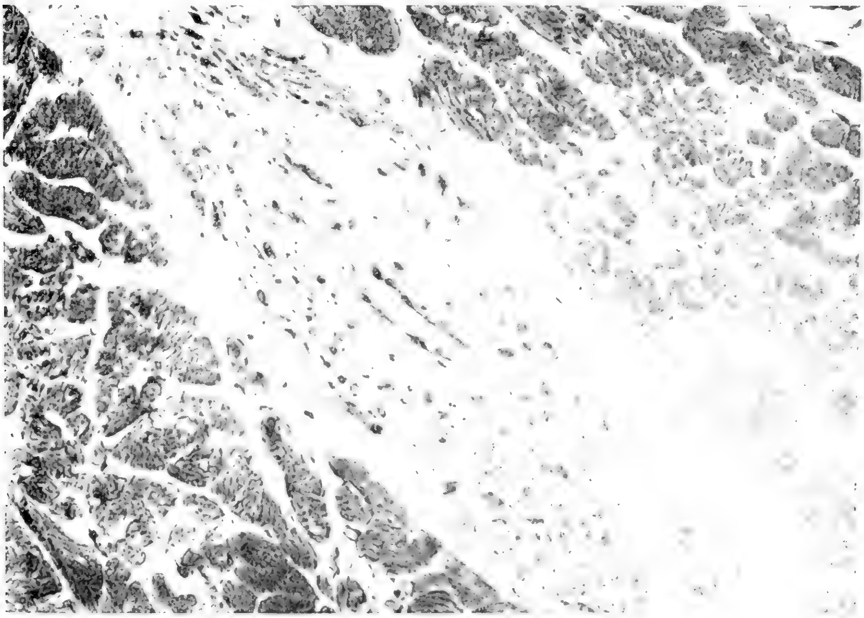


Fig. 10.—Tangential section of coronary vessel showing slight active syphilitic infiltration.

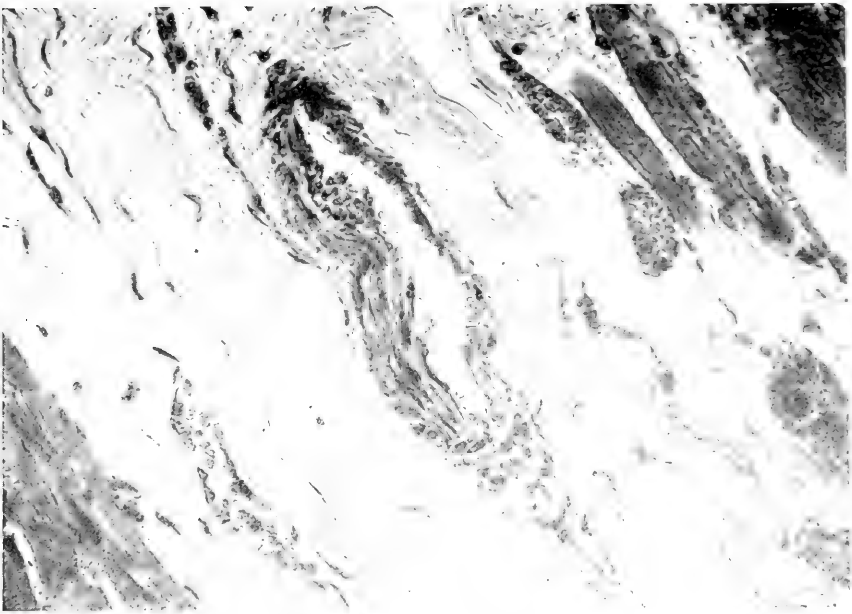


Fig. 11.—Similar section, from same case, showing complete healing; fibrosis without plasma cells.

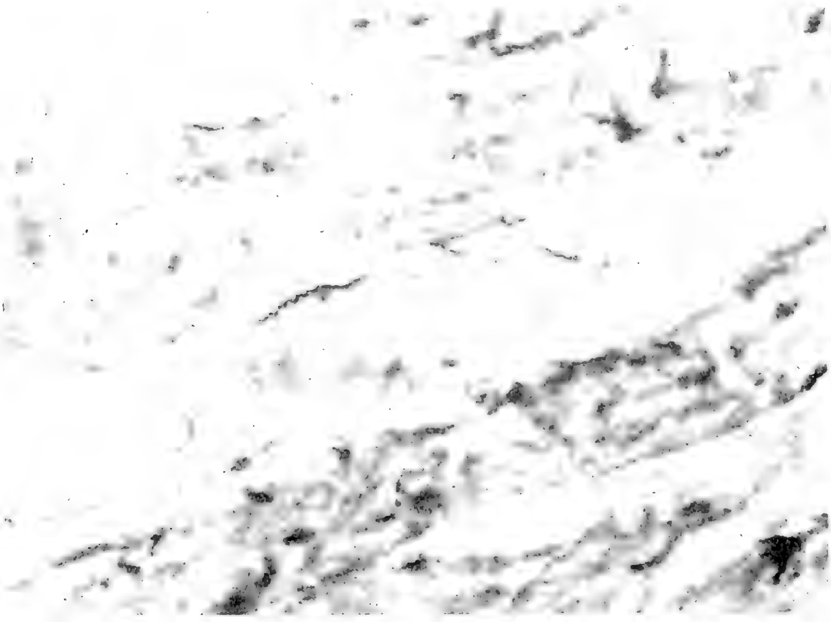


Fig. 12.- Levaditi preparation of active latent, unsuspected syphilis of left ventricle wall. Many spirochætes between muscle fibres.

Fig. 13.—Levaditi preparation of chronic syphilitic myocarditis from case of unsuspected syphilis. Spirochætes at border of fibroid patch.

Fig. 14.—Levaditi preparation of chronic syphilitic myocarditis. Case of diabetes, syphilis not suspected, negative Wassermann. After prolonged search small colony of spirochætes found in small area of plasma cells at border of fibroid patch.

Fig. 15.—Levaditi preparation of fibroid heart from case of diabetes, with unsuspected syphilis, negative Wassermann. After six weeks' search of blocks from left ventricle wall this colony of spirochætes was found at border of fibroid patch.

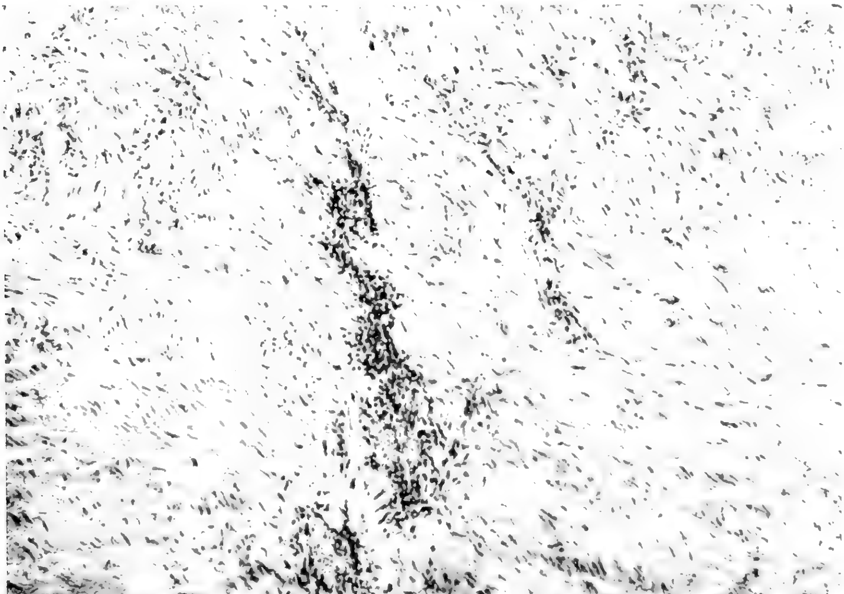


Fig. 16.—Typical syphilitic mesaortitis. All cases of latent syphilis show this lesion in this aorta wall; it is a practically constant sign of syphilis. Small plasma-cell infiltrations along the vasa vasorum, through the media of the aorta.

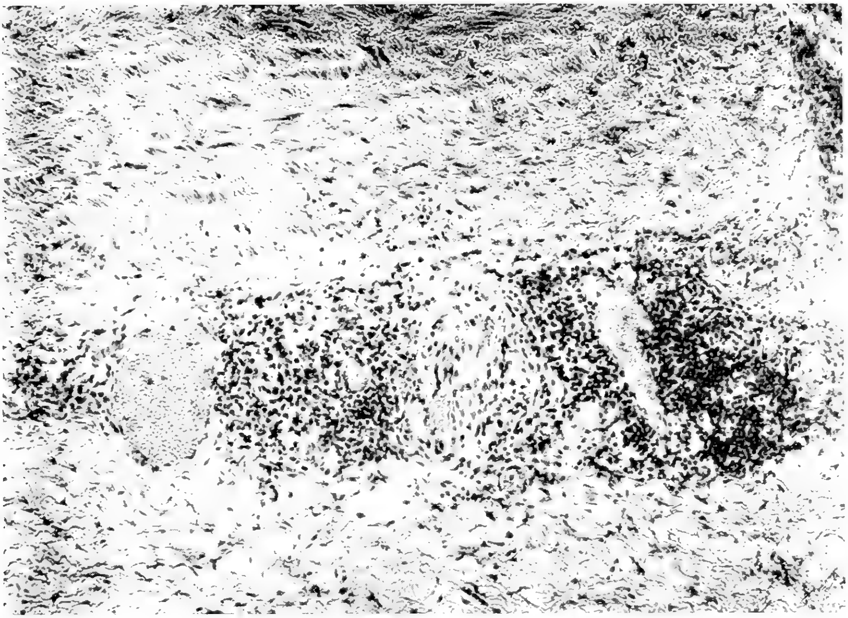


Fig. 17.—Portion of media and adventitia of aorta from case of latent, unsuspected syphilis. Characteristic plasma-cell infiltrations around the vasa vasorum, with obliteration of the small artery. One of the most constant and characteristic lesions of latent syphilis. Spirochætes are usually in small numbers and found only in these active foci.

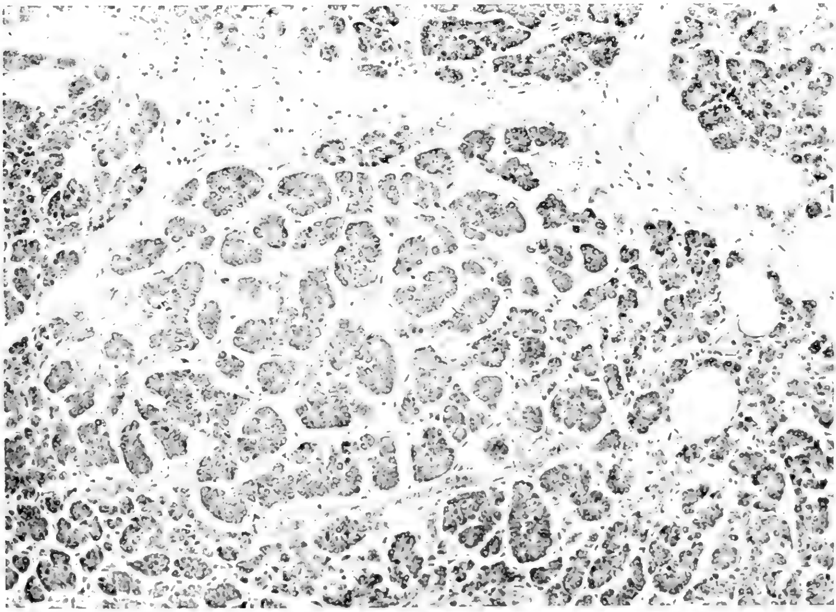


Fig. 18.—Pancreas from case of diabetes, with unsuspected syphilis and negative Wassermann. Diffuse chronic interstitial pancreatitis. Very small active areas, in which small groups of spirochætes were found.

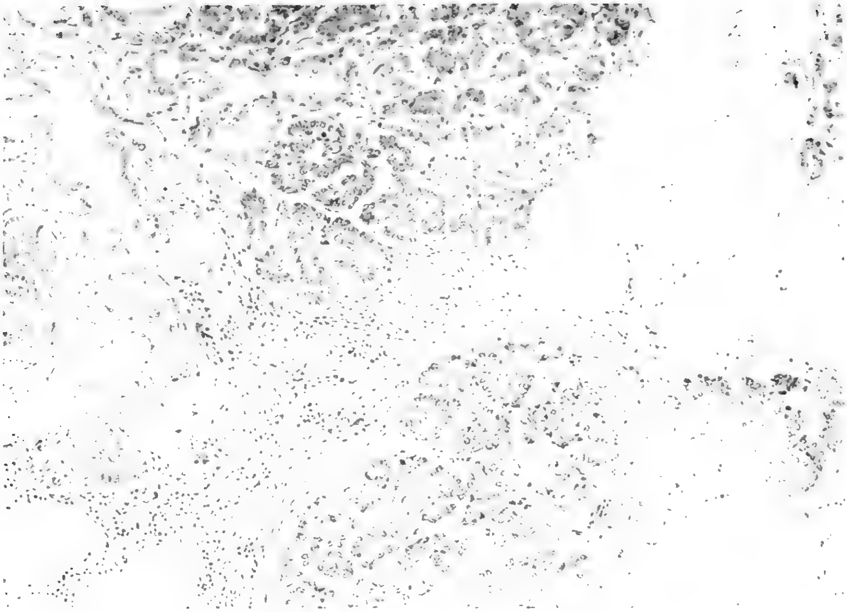


Fig. 19. Chronic syphilitic pancreatitis, with active areas, from case of diabetes, unsuspected syphilis and negative Wassermann reaction. Spirochætes found in heart and pancreas.

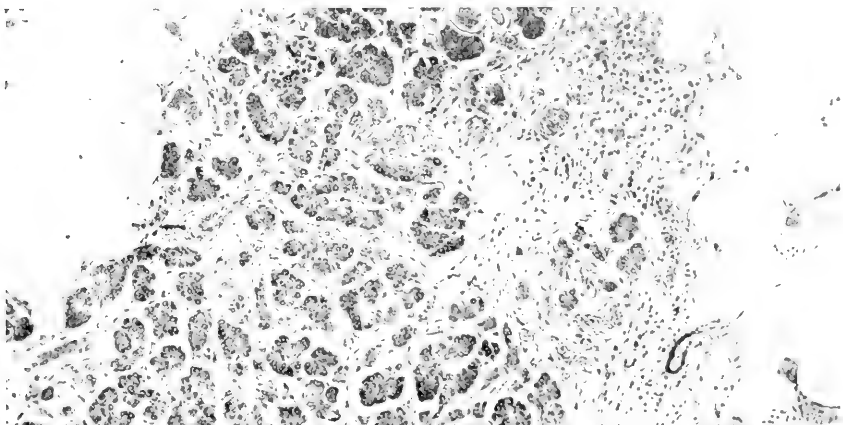


Fig. 20.—Chronic syphilitic pancreatitis. From tail of pancreas; same case as preceding.

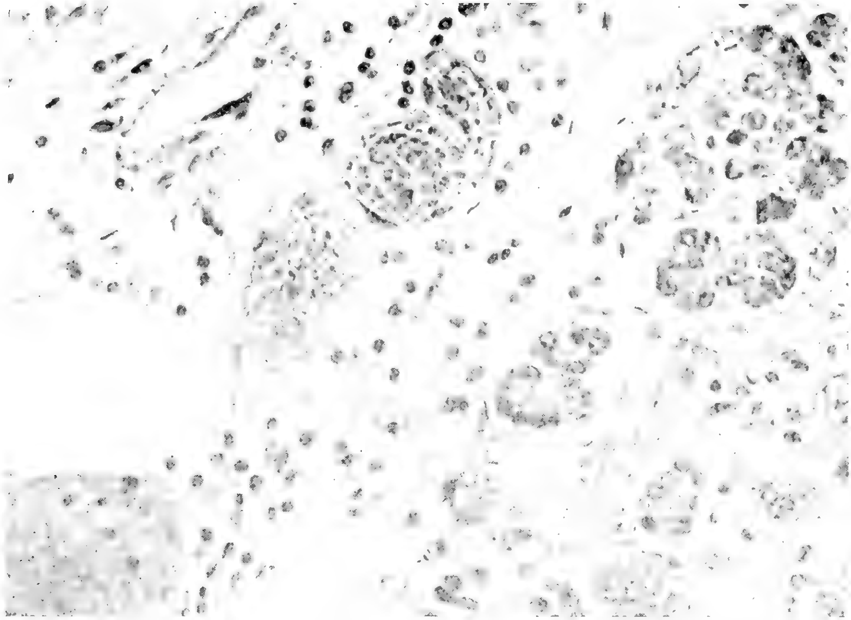


Fig. 21.—Chronic syphilitic pancreatitis. Higher power. Same case as preceding, plasma-cell infiltration; increase of stroma, and atrophy of acini.

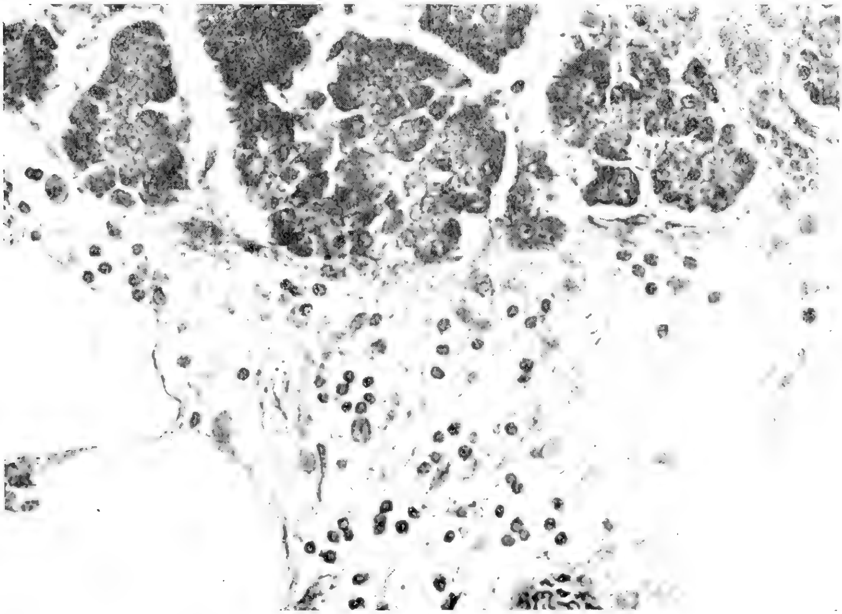


Fig. 22.—Chronic syphilitic pancreatitis. Same case as in Fig. 18. Small area of active plasma-cell infiltration and edema, in which spirochætes were found.

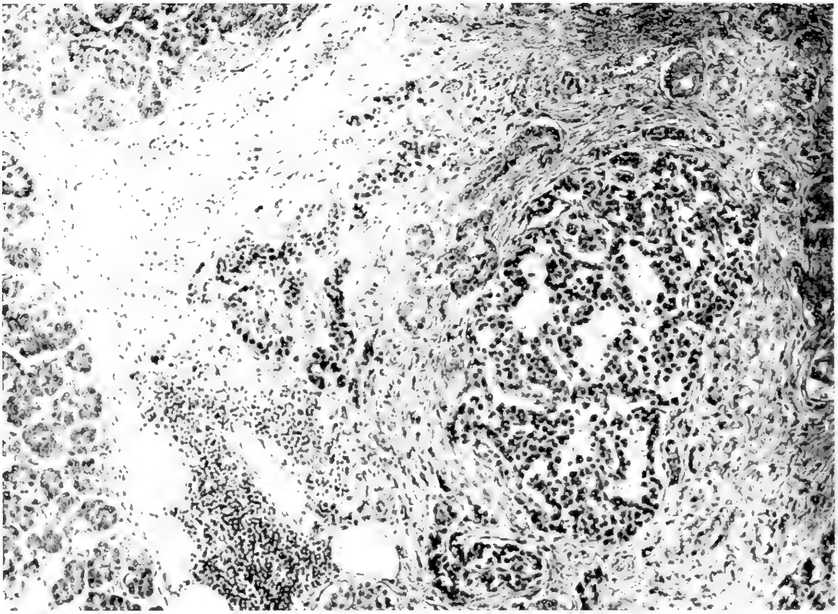


Fig. 23.—Chronic syphilitic pancreatitis. Same case, as in Figs. 19-21. Area of active syphilitic inflammation; new formation of pancreatic acini.

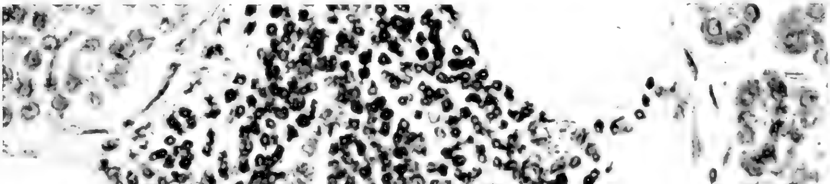


Fig. 24. Chronic syphilitic pancreatitis. High power view of active area of plasma-cell infiltration seen in preceding.

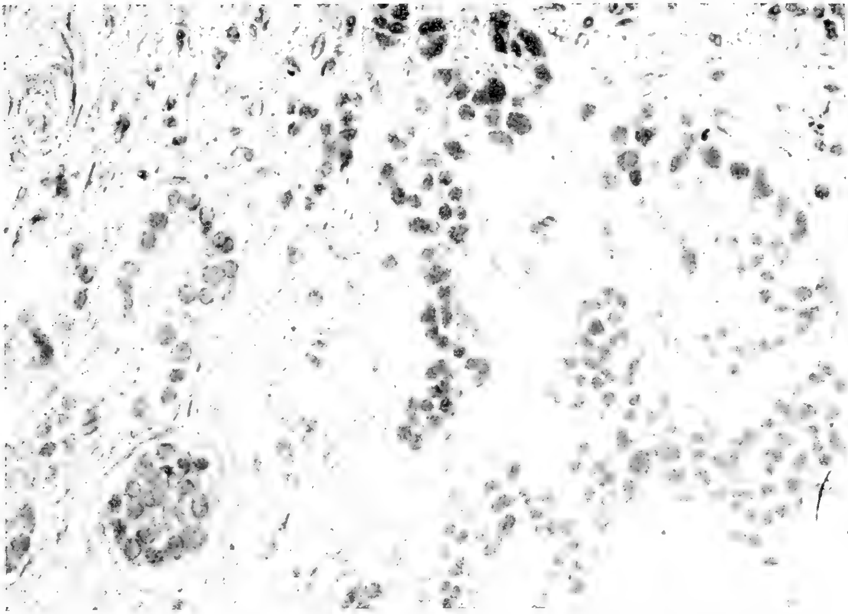


Fig. 25.—Chronic syphilitic pancreatitis. High power, showing fibroid stroma and atrophy of acini. Healed, inactive area.

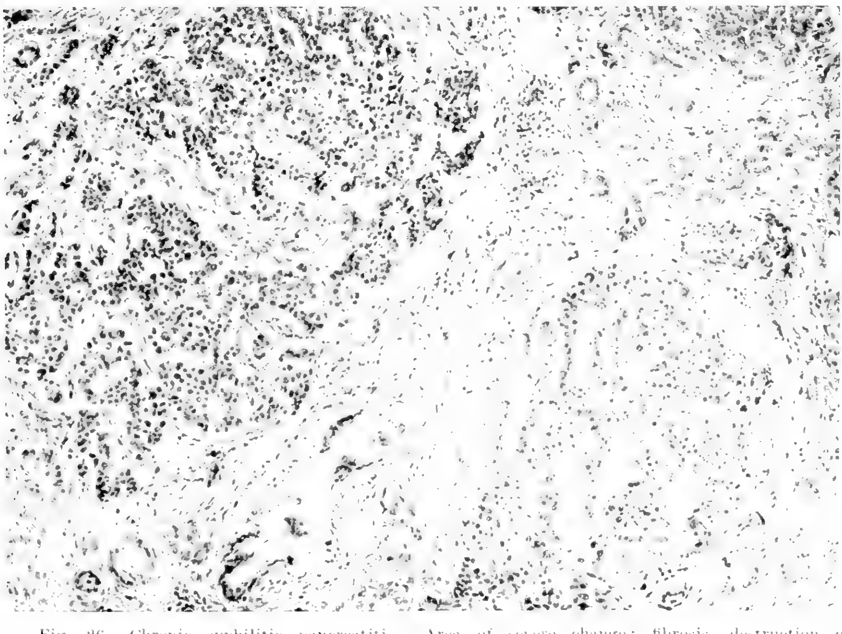


Fig. 26.—Chronic syphilitic pancreatitis. Area of severe change; fibrosis, destruction of pancreatic tissue and atypical regeneration of acini from pancreatic ducts. Such newly formed acini are usually mistaken for new islands of Langerhans.

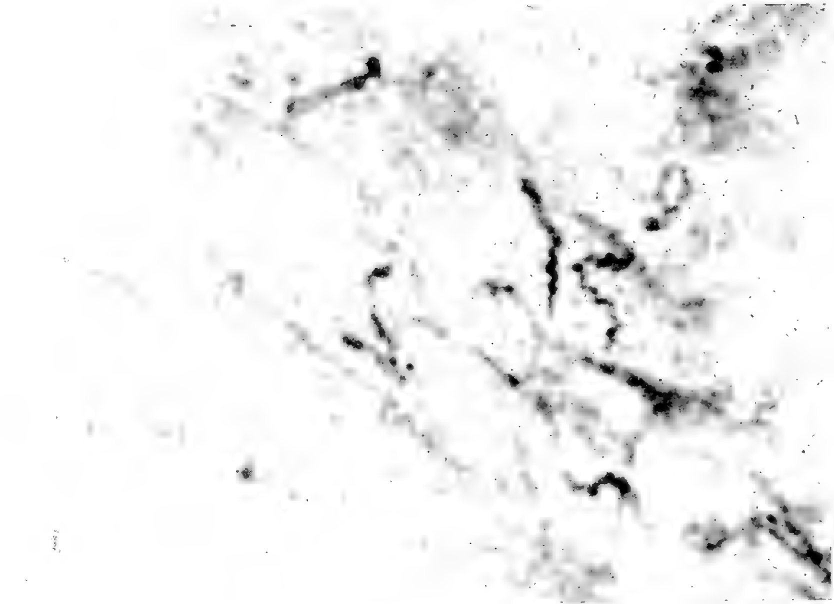


Fig. 27. Colony of spirochætes in œdematous, infiltrated area between lobules.

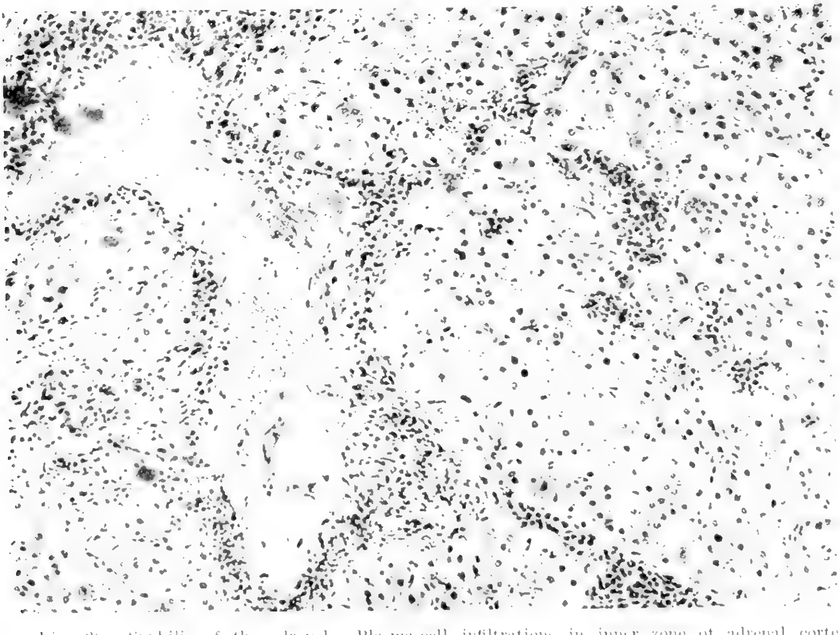


Fig. 28.—Syphilis of the adrenal. Plasma-cell infiltrations in inner zone of adrenal cortex and in medulla. One of the most constant findings in latent syphilis. These infiltrations are usually much less marked than in this case.

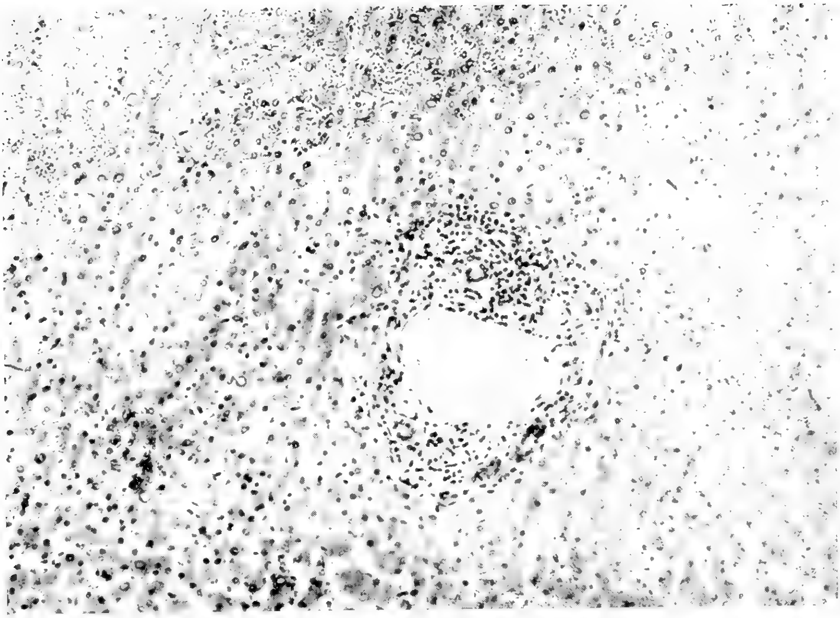


Fig. 29.—Liver from case of latent syphilis. The most constant and the mildest syphilitic lesion of this organ. Slight plasma-cell infiltration of periportal tissues. Every degree from this very slight lesion, up to the most severe grades of cirrhosis presents itself in syphilis.

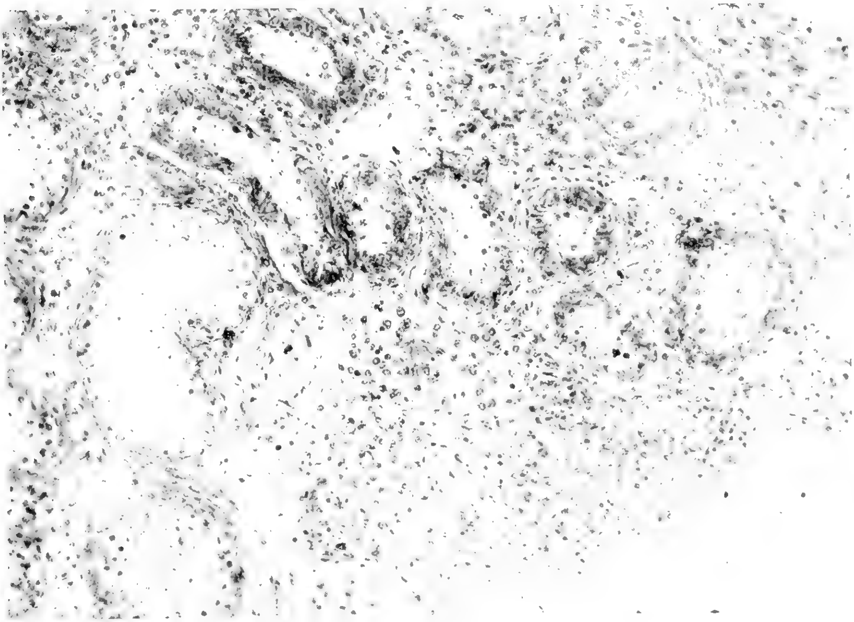


Fig. 30.—Active syphilitic orchitis. A constant lesion in all old cases of latent syphilis. Varies greatly in degree and extent. Spirochætes found only in active areas, as in this case.

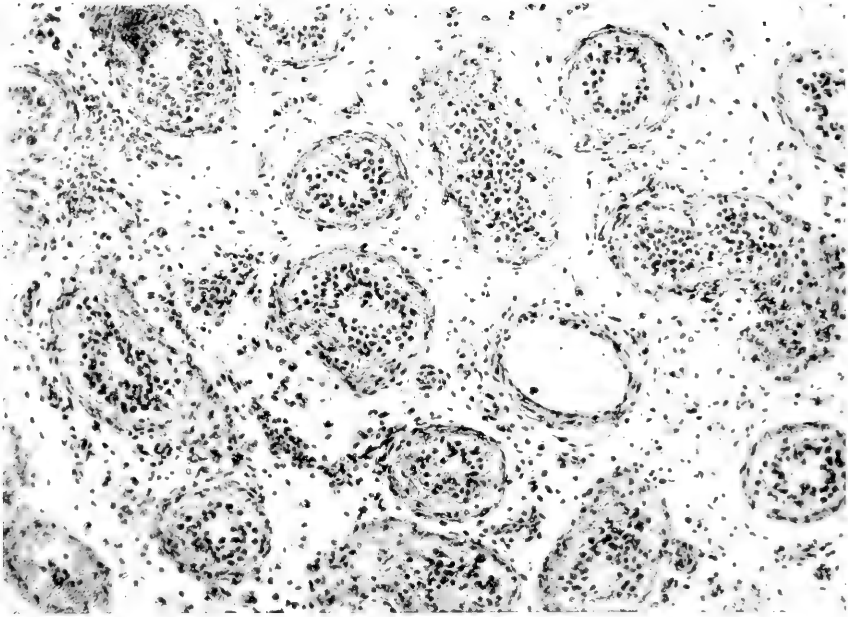


Fig. 31.—Subacute syphilitic orchitis. Increase of stroma; atrophy of germ cells; hyaline thickening of basement membrane of tubules; active syphilitic infiltrations. From case of congenital syphilis. Patient, aged 19 years.

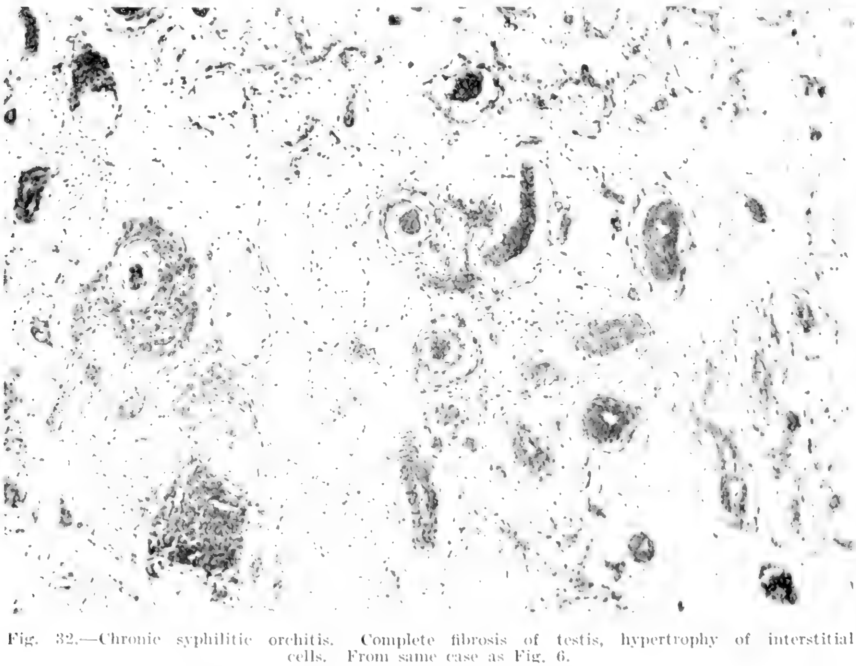


Fig. 32.—Chronic syphilitic orchitis. Complete fibrosis of testis, hypertrophy of interstitial cells. From same case as Fig. 6.

the intima and media really represent a slow anæmic infarction due to the shutting off of the blood supply as the result of the obliterative endarteritis in the arteries of the vasa vasorum in the adventitia. The obliterated arterioles often appear as concentric formations resembling tubercles, miliary gummata or even suggesting epithelial formations. The lymphocytic and plasma-cell infiltrations are in the early stages most marked in the perivascular lymph-spaces of the arterioles; but later these infiltrations often become very marked around the greatly dilated veins. A new formation of capillaries is often seen in the adventitia and outer portion of the media. These infiltrations often are large enough to be regarded as miliary gummata, but the development of well-defined gummatous nodules with caseating centres and giant cells is rare. When these do occur they are usually multiple.

The demonstration of spirochætes requires much time and patient search. I have found them in the aorta of acquired cases of syphilis only in the perivascular infiltrations of the adventitia. They occur usually in small colonies. In congenital syphilis, however, the intima of the aorta may show localized proliferations and infiltrations containing great numbers of spirochætes. In such congenital infections the syphilitic lesions of the intima may later heal and present the appearances of atherosclerosis. They then can not be distinguished from the local lesions of the intima found in typhoid fever and other infections.

Pulmonary Artery.—I have studied and reported a case of syphilitic aneurism of the pulmonary artery with marked and characteristic syphilitic arteritis of this vessel and its branches. The presence of the spirochæte was demonstrated in the aneurismal sac, with blood-clot in the wall. The organisms were found in very small numbers, possibly owing to the previous salvarsan treatment. The microscopic changes in the wall of the pulmonary artery were identical with those of syphilitic aortitis. How frequently such changes have occurred in the pulmonary artery in my cases I am unable to say, as no especial attention was paid to this vessel. In the microscopic notes on the lungs of these cases, there is frequent mention of thickened and hyaline pulmonary

6

vessels; these changes were usually referred to the chronic passive congestion of the lung present in practically all cases. In but two other cases were there changes in the pulmonary artery so marked as to attract attention. One of these cases was that of a male who had had for some years a well-marked case of chronic cyanosis and polycythemia (Vaquez's disease). At autopsy his pulmonary arteries showed marked dilatation and atherosclerotic changes in the main branches with hyaline fibrosis and complete obstruction of many capillaries. The microscopic examination showed the presence of a typical syphilitic mesarteritis of the pulmonary arteries; and the polycythemia is explained as compensatory to the circulatory changes in the lung. This case undoubtedly falls into the group, of which a number have been reported from South America and India, of syphilis of the pulmonary arteries associated with polycythemia and cyanosis ("Ayerza's disease"). The other case of unusual atherosclerosis of the pulmonary artery showed microscopic changes of syphilitic arteritis without other complications.

Syphilis of Peripheral Arteries.—In several cases syphilitic arteritis of the femoral artery and its large branches, the popliteal and the tibial arteries was noted. In one case, a colored woman, the entire systemic arterial trunks and their smaller branches showed severe syphilitic arteritis with multiple thromboses. The abdominal aorta from the level of the diaphragm down and all of its branches contained organizing thrombi; globular thrombi were present in all four chambers of the heart. This case presented a condition not described in the literature—a very active generalized syphilis of the entire arterial system and heart. In all of these cases of syphilis of the larger arteries, the microscopic picture is identical with that seen in syphilis of the aorta and pulmonary arteries. There is the same lymphocytic and plasma-cell infiltration along the vaso vasorum of the media and adventitia with localized degeneration and fibrosis of the intima and inner portion of the media. In the smaller branches the entire vessel wall is involved and the process takes on the character of a proliferative endarteritis, as in the case of the arterial vasa vasorum. The clinical importance of these arterial changes in this autopsy material has been chiefly that of aneurism, thrombosis, embolism, infarction and gangrene, in about 5 per cent. of the total number of autopsies; in the remaining cases no definite clinical symptoms could be ascribed to the aortic changes beyond the general circulatory disturbances common to all of the syphilitic cases, and which have been interpreted as chiefly cardiac in origin.

Pancreas.—The pancreas in all of the old cases of syphilis showed a greater or less degree of atrophy and interstitial fibrosis. In the majority of cases the changes were irregularly scattered throughout the organ, the body and the tail portions showing an especial tendency to involvement. Lobules showing marked change may be surrounded by those showing no change. In other cases the entire pancreas showed a diffuse fibrosis, varying from slight to the most marked degree. The connective-tissue increase is both inter- and intralobular. In the majority of cases it was old, containing few cells; but in two cases of diabetes it was more fibroblastic in character and contained many cells of lymphocyte and plasma-cell type. Careful search has revealed, however, in every case active areas of plasma-cell infiltration. These areas often show an œdematous or myxomatous connective tissue, the plasma-cells and lymphocytes may be few or many. Such inflammatory areas are most often found at the border of a lobule, and the latter are invaded by new connective tissue from the periphery usually, although occasionally the process appears to begin within the lobule. Fibrosis of the islands in varying degrees is often associated with the interstitial inflammation. In all of the cases of diabetes but two, island fibrosis was very marked, and presented characteristic features, the chief of these being the thick crowding of large hyperchromatic cells around the border of the hyaline fibroid islands. These cells were interpreted as regenerative or hypertrophic. In several non-diabetic cases the chronic pancreatitis and fibrosis of the islands was as marked, or even more so, than in the diabetic cases.

The pancreatic acini show varying degrees of atrophy in the affected areas. As the acini disappear fat is deposited in the connective-tissue cells; in many cases such fatty infiltration following the atrophy of the pancreatic parenchyma is very marked. Islands completely surrounded by fat tissue are often seen in the tail portion of the organ. Regenerative formations may be found in practically every case; they often reach such a degree as to appear neoplastic, resembling adenomata or cystadenomata. The newly formed acini resemble islands and are undoubtedly often mistaken for newly formed ones. They arise from the epithelium of the lobular ducts and also from that of the larger ducts. Newly formed acini may even be found within dilated larger ducts. In every one of the cases of syphilis the pancreas showed evidences of progressive destruction and repair. No evidence of the new formation of islands, however, was ever seen. Sclerosis of the blood-vessels of the organ may or may not be associated with the pancreatitis. Some degree of it was often found in the lobules showing marked interstitial change; but only in a relatively small number of cases was the inflammatory process associated with a general sclerosis of the pancreatic arteries. (See Figs. 18 to 26.)

As to the syphilitic nature of these lesions, they are identical with those produced by the spirochæte in other tissues and organs. The localized plasma-cell infiltrations, slight fibroblastic proliferation, œdematous or mucoid stroma, eventually fibrosis, are histologically specific characteristics, I believe; and in further proof of this view, spirochætes were demonstrated in these areas in the pancreas of two cases of diabetes.

So far as the clinical significance of these pancreatic changes is concerned the only fact of importance shown is their association with diabetes. In eleven out of twelve cases of diabetes coming to autopsy, the heart, aorta, pancreas, adrenals (testes, in the males), and other tissues showed the characteristic plasma-cell infiltrations and fibrosis of latent syphilis. In five cases Spirochæte pallida was demonstrated in the myocardium, and in two cases (Fig. 27) in the pancreas itself. In the pancreas they occurred in small colonies in the areas of cell infiltrations. That diabetes is the result of syphilis I do not venture to assert. If it is true that a chronic interstitial pancreatitis is the most common pathologic finding in the pancreas in diabetes, it seems very likely that syphilis is the most common cause of interstitial pancreatitis, but not necessarily, of course, the only cause. Syphilitic pancreatitis may be a common cause of diabetes, if it can be shown that interstitial pancreatitis is the essential pathology of diabetes.

Adrenals.—Small infiltrations of plasma cells and lymphocytes are of constant occurrence in the adrenals of cases having known syphilis and unsuspected latent syphilis. In the great majority of cases these infiltrations are slight. They occur usually in the medullary portion or in the inner portion of the reticular zone of the cortex. (See Fig. 28.) They are usually perivascular. Fibroblastic proliferation of the stroma or fibrosis may or may not be present; the capsule of the organ is usually thickened, and perivascular infiltrations of small size occur in the surrounding tissues. The walls of the blood-vessels usually are thickened. Very rarely the infiltrations are so marked as to assume the characters of miliary gummata. Caseating gummata with giant cells have not been seen. In three cases the syphilitic infiltrations and fibrosis were so marked as to have caused nearly complete atrophy of the greater part of the organ. All three of these cases presented the symptom complex of Addison's disease. In one of these cases marked syphilitic infiltrations occurred also in the adrenal and semilunar ganglia. With the exception of these three cases no symptoms were observed that could be directly ascribed to the syphilitic changes in the adrenals. Whether in the less severe cases disturbances of adrenal function may be responsible for the low blood-pressure seen in some of the cases it is, of course, impossible to say. Another striking feature of the adrenals in chronic syphilis is the marked lipoidosis of the cortex seen in so many cases. This lipoidosis may be patchy involving certain circumscribed areas in the cortex, or it may involve the entire cortex. The cells are filled with numerous, large doubly refracting droplets that stain a brownish red with Sudan III and Scharlach R; with osmic acid many of the droplets take no stain, while others are grayish brown. The significance of this lipoidosis is not apparent, nor is its relation to syphilis. It is probably to be interpreted as an expression of a cholesterolemia or cholesterol retention, as a feature of a general disturbance of metabolism.

Liver.—The liver showed chronic passive congestion and atrophy (brown atrophy chiefly) in every case. Gummata were found in five cases, hepar lobatum in eight, atrophic cirrhosis in ten and an intralobular cirrhosis in one, Glissonian cirrhosis in three cases, while localized fibrosis was very common. The inflammatory lesions varied from slight plasma-cell infiltrations of the periportal tissue to the most marked cirrhotic changes. The relationship of these latter changes to syphilis has not been absolutely determined except in a few cases in which spirochætes were found in such infiltrations. It is worthy of note that in a case of secondary syphilis dying of salvarsan poisoning focal necroses containing spirochætes were present throughout the liver. (See Fig. 29.)

Testis.—In all of the male cases the testes showed varying degrees of atrophy and fibrosis. In the more active cases plasma-cell and lymphocyte infiltration between the tubules, fibroblastic proliferation of the stroma, thickening of the basement membrane and diminished spermatogenesis are the chief changes. (See Fig. 30.) These changes may involve the entire organ, or occur in small scattered patches. In the older cases the germinal epithelium of the tubules may be entirely lost, the tubules collapsed, and represented entirely by the hyaline thickened basement membrane which still keeps the shape of the tubule. The interstitial cells remain preserved, and in many cases appear hypertrophic. The stroma between the tubules is thickened and hyaline. (See Figs. 31 and 32.) In severe cases the entire testis becomes fibroid. Spirochætes can be demonstrated only in the active cellular infiltrations. So far as size, shape, and consistency are concerned, the gross appearances of the affected organs may seem to be normal. The clinical significance of these changes is a progressive loss of spermatogenesis and virility. Many of the patients had complained of premature loss of sexual desire.

Other Lesions.—Throughout the *prevertebral tissues, root of mesentery,* along the *radicles of the portal vein,* and in the *pelvic tissues* there constantly occur in the bodies of old syphilitics minute perivascular infiltrations of lymphocytes and plasma cells, associated with fibroblastic and angioblastic proliferations, eventually fibrosis, of a more or less marked degree. That the spirochæte is associated with these minute lesions has been definitely proved. Therefore, in all cases in which these occur the possibility of spirochæte localization must be considered. Such minute syphilitic inflammations may be widespread; they may be found in any tissue or organ.

Lungs.—The occurrence of syphilitic localization in the lungs was positively determined in three cases only, in which there were vascularized granulomatous areas, gummatous in character. No especial study has been made of this organ. In nearly every case the lungs showed chronic passive congestion and more or less marked induration or fibrosis. This has usually been interpreted as the result of the chronic passive congestion. As other writers have already pointed out, this fibrosis of the lungs may be directly the result of syphilis; but to what extent this has been true in this autopsy material I have not had time to determine. The question should, however, be taken up by investigators, as our knowledge of syphilis of the lung is very fragmentary and vague.

Spleen.—Chronic passive congestion, atrophy, and sclerosis of the splenic arterioles are the almost constant findings in the spleens of old syphilitics. Gummata were found in three cases; and these were the only positively determined instances of spirochæte localization in this organ. This is also a field requiring investigation. I have been unable to extend my studies to this organ.

Kidneys.—Changes in the kidneys—chronic passive congestion, atrophy, infarctions, local and diffuse inflammations—were found in practically all kidneys coming from these cases. The proportion of cases of chronic parenchymatous nephritis is very striking. Out of the first forty-one cases of this material studied there were seventeen cases of acute, subacute and chronic parenchymatous nephritis, and three cases of interstitial nephritis. The relation of these conditions to the syphilitic infection is not apparent. I have never found spirochætes in the kidney, but they have been looked for in only a few cases. This is also a field demanding investigation.

Genital Apparatus.—Outside of the testes spirochætes have been found in the sexual apparatus of the cases in this material once only, and that in the prostate of a young man with early tertiary syphilis clinically latent. Diffuse plasma-cell infiltrations occurred throughout the stroma of the organ, and not around the gland spaces as in chronic gonorrhœa. The infiltrations were perivascular, interstitial, and not periglandular or subepithelial. Fibroblastic and angioblastic proliferations were prominent, and numerous giant cells occurred in the larger infiltrations, giving them the characters of miliary gummata without caseation. Groups of spirochætes were found in these. This case was the first one in which syphilitic lesions of the prostate were positively demonstrated. No spirochæte study has been made of other portions of the internal reproductive tract in either sex.

Lymph-nodes.—The lymph-nodes of the older cases of syphilis (even in young individuals) were atrophic and presented lymphoid atrophy, chronic sinus catarrh and hyaline formations (scars) in the germ centres and lymphoid tissue. In younger cases the nodes are frequently hyperplastic, but the germ centres, while enlarged, show a marked lymphocyte exhaustion. These appearances indicate a continuous demand made upon these organs against a persistent infection.

Bone-marrow.—Premature and excessive osteoporosis of the bones, and fatty atrophy of the marrow characterized the majority of cases. In a small number of cases the lymphoid-marrow was found to be increased.

Hemal-nodes.—These were atrophic, in the great majority of cases. In association with marked anæmia, and syphilis of the portal vein with Banti's disease complex, a marked hyperplasia of these nodes was seen, with great numbers of hemophages blocking the sinuses.

SUMMARY

The pathologic lesions, as described above, are common to all cases of old syphilis (secondary stage onwards). They were found in known active cases of late syphilis (aortic aneurism, gumma of brain and liver, tabes, paresis, etc.), in cases with history of syphilis treated and regarded as cured, in cases with negative and cases with positive Wassermann reaction; and, in

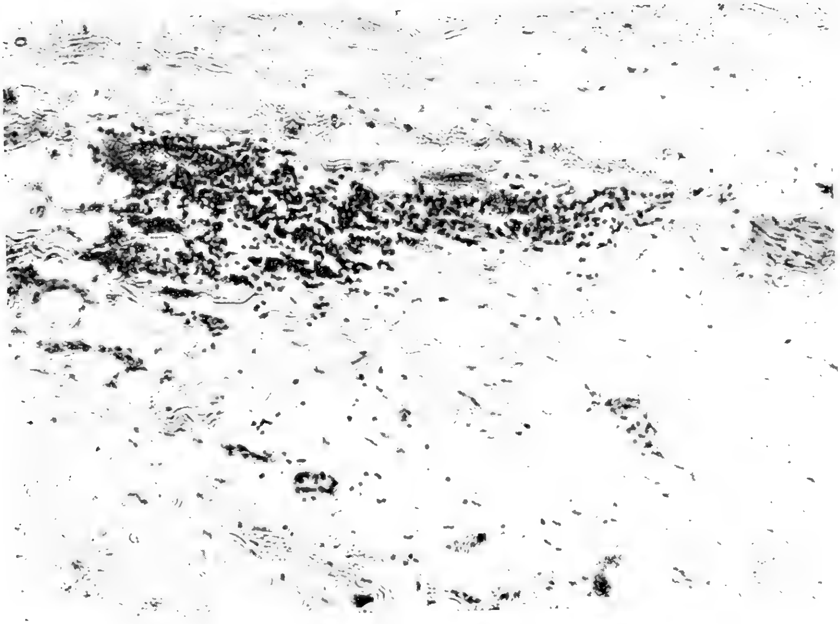


Fig. 33.—Syphilitic infiltrations in prevertebral tissues. Common findings in all old latent cases.

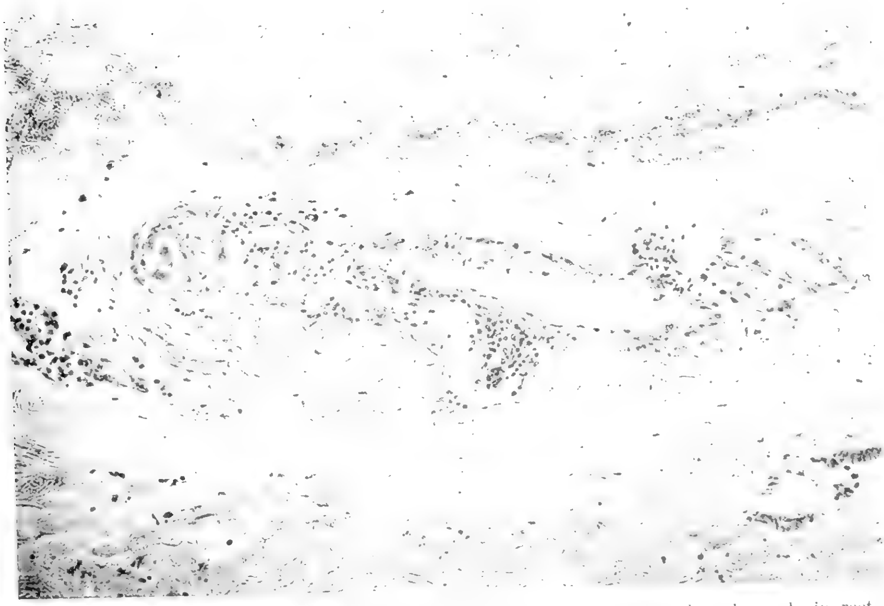


Fig. 34.—Small syphilitic infiltrations of plasma-cells around nerve trunk and vessels in root of mesentery. These are common in all old cases of active latent syphilis and are found particularly near the abdominal aorta and solar plexus.

the great majority of autopsies, in the bodies of those who gave no history of syphilis and no clinical signs or symptoms interpreted by the clinicians as indicating syphilis. It is probable that many of these patients never knew that they had syphilis; the infection in some cases is probably congenital, in others accidental. In other patients the previous infection may have been entirely forgotten or supposed to have been entirely cured. As syphilis is a "skin disease" to the average mind, both lay and medical, the symptoms predominating in this class of patients were not likely to arouse any suspicion of any relationship to the old infection, unless excited to such suspicions by direct and intensive questionings along this line, which they failed to receive.

It is, therefore, evident that syphilis as a latent infection is very much commoner than is generally supposed; and that the proportion of syphilitics in our ailing class is very high. It is, perhaps, idle to estimate the number of cases of syphilis in our population. To my mind the estimates of 5 to 15 per cent. given by various writers are all too low; we would place the incidence of syphilitic infection in this country as nearer 30 per cent. An analysis of our vital statistics will easily show that at a very low estimate about one-tenth of all the deaths occurring in the United States can be attributed to syphilis. Osler has recently made a similar estimate for Great Britain. Syphilis is the leading infection and the chief cause of death, even when estimates are based upon our incomplete and imperfect knowledge of the pathology and symptomatology of the disease after the chancre and skin-symptom stages have been passed through. Death is rare in the first two years after infection with syphilis; the incidence of syphilitic death increases progressively with the years after the infection. Syphilis is particularly the cause of death in males between forty and sixty years of age; and as its symptomatology at this stage is in the great majority of cases either myocardial, vascular, renal, hepatic, etc., it is not recognized clinically as syphilis.

It is, further, very evident that infection with syphilis means *spirochæte-carrying* in many, if not in all cases. The cases in the material analyzed in this study represent "*spirochæte carriers,*" and the pathology given above is the pathology of a mild latent infection in which there is but little antagonism between the infecting organism and its host. Syphilis after a preliminary invasion and disturbance of the body tends in the great majority of cases probably to become an infection not much more active or injurious than the streptococci of the mouth cavity. The very slight lesions found in so many cases prove this point beyond dispute. In women, particularly, does the infection often become so mild as to be practically non-existent, except when pregnancy occurs and there is born a syphilitic child, or a syphilitic abortion or stillbirth occurs, with spirochætes in placenta, fetus, or child. *The spirochæte carrier is immune to new infection only as long as he carries spirochætes.* This axiom we accept to-day, but we are yet far from understanding the reactions between the host body and the parasitic spirochæte. The individual tissue immunities and susceptibilities that undoubtedly exist, the reawakening of virulence on the part of the quiescent organism, its relationship to the Wassermann reaction, the question of positive cure, etc., are chief among the unsolved problems connected with this most important of all infections.

As to curability, I have never seen pathologically a cured case of syphilis. In all cases examined at autopsy active areas of specific inflammation are always seen, and such areas mean always the persistence of the spirochæte. Perhaps these intra-tissue parasites should in cases without symptoms and negative Wassermann reaction be regarded in the same light as that in which we look upon the streptococci of the mouth cavity. Does the spirochæte cease to be a cause of disease, and the body become a carrier of relatively or even quite completely harmless organisms? That some progressive injury is being caused is demonstrated conclusively by these studies. Immunity to the Spirochæte pallida, and probably to all other organisms that enter the body tissues or, perhaps, even its passages and cavities, is paid for with a price—the price of defense. The infiltrations of lymphocytes and plasma cells in themselves may cause damage—infinitesimal, perhaps—but when persistent over a period of years may finally produce functional disturbances. The persistent slight damage and necessary repair by fibroblastic proliferation and the eventual fibrosis explains the latent period of syphilis and the final outcome in such terminal conditions as aortitis, myocarditis, pancreatitis, etc. The majority of cases of syphilitic infection die from the results of these slow mild inflammatory processes in the viscera and blood-vessels rather than from paresis or tabes. I am convinced that the great majority of all cases infected with syphilis die of *chronic myocarditis.*

The syphilitic is pathologically "damaged goods;" and the damage is a progressive one. He wears out sooner, his viscera more quickly reach their histogenetic limits, he actually becomes prematurely old, and there is a constant strain upon his defensive powers. All of these are arguments for the prevention of syphilitic infection rather than for its cure. No man can acquire syphilis, become clinically cured, which as far as we know means latency of the infection, that is, spirochæte carrying, and have the same potential body-value and expectancy of life as before the infection.

This pathologic conception of the syphilitic, as probably always a spirochæte carrier once the infection is acquired, should influence the therapeutic management of this chronic infection. The syphilitic, even when apparently perfectly well, should have his life laid out for him along lines tending to prevent the reawakening of the virulence of the organism or an increased susceptibility of the body tissues and organs. This is done for the patient who has once had clinical tuberculosis; when properly treated his future life is planned to prevent the reawakening of his infection, because he, too, is usually, if not always, still a carrier of the infective agent. But in the case of the syphilitic such hygienic measures are not applied, implicit reliance is usually placed upon a certain amount of salvarsan or mercurial treatment, while the infected individual is permitted to take up his life again as if he were an ordinary individual, and, as a rule, he succumbs prematurely to the stress and strains incident even to ordinary living. The treatment of syphilis, as it is ordinarily carried out, looks only to the present moment; it should look to the whole future life of the infected individual.

Syphilis in the woman presents peculiar problems. In the great majority of women infected with this disease it runs an absolutely latent course; the lesions at autopsy in the heart and aorta are always, except in rare cases, much milder than in man. Such women die of secondary infections or other conditions, rather than of myocarditis or aortitis. The pancreas and adrenals are, however, affected to the same degree as in man, the adrenals perhaps more so. A syphilitic woman may, however, pass her entire life without any clinical manifestations of syphilis, except the production of syphilitic progeny. I have come into touch with numerous examples of this kind, of which a few may be cited here.

1. Wife of a school teacher gave birth to a dead child. Autopsy of the infant revealed syphilis of the liver, and spirochætes. Both father and mother were above suspicion, absolutely negative histories, no signs, repeated Wassermanns of both negative. Pathologic diagnosis of syphilis not accepted by clinicians. Woman without treatment was allowed to become pregnant again and in a little over a year was again delivered of a dead and macerated fetus showing syphilis of liver and heart, and spirochætes. Repeated Wassermanns of both father and mother were negative. The only explanation of this case that could be obtained was in the fact that the father of the mother had been a chronic drunkard since youth.

2. Case similar to above. Two syphilitic children from father and mother, both apparently healthy, no history and no signs of syphilis, negative Wassermann in both. Father of mother a chronic drunkard since early manhood.

3. Father and mother apparently healthy, no signs and no history of infection, negative Wassermann in both, repeated abortions, one living child dying a few months after birth of congenital syphilis of liver, spleen and heart. The history of this case brought out the fact that the mother's father had been a chronic drunkard, "a beast," and diseased. Mother as a very young child had been rescued from the family conditions and brought up by a relative. A sister left behind became a keeper of a house of ill fame.

4. Grandfather on both sides a chronic drunkard. Father and mother apparently well, no signs of syphilis, negative Wassermann in both. Three apparently healthy children, although minute examination reveals certain stigmata in bone development, then a child dying of active syphilis, then two more children apparently well, than a dead dropsical fetus showing a marked syphilitic placenta.

5. Father a preacher, no history or signs of syphilis, negative Wassermann; mother's father has "blood poisoning," mother herself apparently well, negative Wassermanns repeatedly. Three syphilitic miscarriages.

It is very probable that in each of these cases the mother had congenital syphilis from her father. When there is a history of chronic alcoholism, syphilis is almost invariably present, too. I believe that congenital syphilis in the woman is particularly likely to run a mild latent course without clinical manifestations, but that during the early months of pregnancy the spirochætes gaining entrance to the fetal circulation may regain their virulency and cause abortion, miscarriage, stillbirth, or give rise to active clinical syphilis in children born alive. Such children may show the infection at birth or later.

It is very difficult to demonstrate spirochætes in the placentas of syphilitic children born at or near full term. In the fibroid villi they can not be found. In the young, myxomatous hyperplastic villi of the syphilitic abortion occurring in the early months of pregnancy they are demonstrated more easily. I have found syphilitic lesions and spirochætes in placenta and tissues of a dead macerated fetus coming from a mother thoroughly treated with salvarsan according to modern methods, said by an expert in syphilology to be cured, and told that she might have healthy children. The first child was a syphilitic. It is also of interest to note the apparent fact that the tissues of the macerated fetus appear to be a good culture medium for the spirochæte.

The constant occurrence of syphilitic lesions in the testes of latent syphilitics throws light upon the clinical facts, already known, that such cases may transmit the disease, and show spirochætes in their semen. The pathologic findings warrant the assertion that any individual who has had syphilis is particularly likely to pass out spirochætes in the semen and cause a seminal infection of woman or child. The localization of the spirochætes in the basement membrane of the seminiferous tubules makes this form of transmission practically a certainty. It is very probable that the great majority of cases of congenital syphilis are seminal infections of the mother and placental infections of the fetus.

So far as the Wassermann reaction is concerned, I believe that a well-marked positive reaction indicates syphilis, with very few exceptions, such as generalized carcinomatosis, sarcomatosis, etc. In these conditions a 4-plus reaction may be found without any autopsy signs of syphilis. A negative reaction can not be taken as indicating the absence of syphilitic infection, nor can repeated negative reactions. I have repeatedly found active lesions of syphilis with spirochætes present when the reaction was negative. This is particularly true of gumma of the brain and congenital syphilis. As has been frequently noted the blood reaction is frequently negative in brain and cord syphilis when that of the spinal fluid is positive. I have had an opportunity of examining the bodies of eight cases dying from salvarsan poisoning; three of these were children with congenital syphilis, and of the five adult cases, three had syphilis of the central nervous system and had intradural treatments. In the congenital cases the treatment apparently had not in the slightest degree affected the number of spirochætes. In two of these cases the tissues throughout the body were swarming with spirochætes. In an adult case with secondary lesions the liver contained multiple focal necroses with spirochætes present in the necrotic areas. It is a question as to whether these focal necroses were due to the spirochætes primarily or to the action of the arsenic. In all cases death was apparently due to the toxic action upon the renal epithelium.

CONCLUSIONS

1. The gumma is not the essential typical lesion of old or latent syphilis. It is a relatively rare formation; and the great majority of cases of syphilis run their course without the formation of gummatous granulomata.

2. The new pathology of syphilis is based upon the demonstration that the essential tissue-lesion of either late or latent syphilis is an irritative or inflammatory process, usually mild in degree, characterized by lymphocytic and plasma-cell infiltrations in the stroma particularly about the blood-vessels and lymphatics, slight tissue proliferations, eventually fibrosis, and atrophy or degeneration of the parenchyma.

3. These mild inflammatory reactions are due to the localizations in the tissues of relatively avirulent spirochætes.

4. Syphilitic inflammations of this type occur in all tissues and organs; but are most easily recognized in the nervous system,

heart, aorta, pancreas, adrenals, and testes. They are, however, usually widely distributed throughout the entire body, although in individual cases showing especial predilection for certain organs or tissues. No explanation of these system, organ, or tissue predilections is yet evident; neither is there any explanation of those cases in which all organs and tissues show the most severe degree of these lesions.

5. The syphilitic is a spirochæte carrier. In this respect, the Spirochæte pallida is to be classed with the trypanosome, the malarial organisms, lepra and tubercle bacilli, streptococcus, etc.

6. Syphilis tends to become a mild process; but at any time the partnership between the body and the spirochæte may become disturbed, and tissue susceptibility or virulence of the spirochæte become increased so that the disease again appears above the clinical horizon.

7. Immunity in syphilis depends upon the carrying of the spirochæte. A price is paid for this immunity in the form of the defensive inflammatory lesions previously described.

8. The disastrous effects of syphilitic infection usually require a period of years for their development. The slowly progressive lesions, fibrosis and atrophy, may at last manifest themselves in paresis, tabes, myocarditis, aortitis, aneurism, diabetes, hepatitis, or in many other forms of tissue damage and functional disturbance. Lesions of the viscera are much more common and important clinically than those of the central nervous system, but they are rarely recognized as syphilitic by the clinician. Syphilitic death occurs most frequently in males between the ages of forty and sixty. Chronic myocarditis is the most common form of death due to syphilis.

9. The pathologic diagnosis of syphilis is essentially microscopic. Only in a relatively small number of cases are the gross lesions (tabes, gumma, aortitis, etc.) typical enough to be recognized by the naked eye. A negative diagnosis of syphilis can not be given with any certainty without a routine microscopic examination of all organs and tissues, but particularly of the left ventricle wall, the aorta, both its arch and abdominal portion, the testes, pancreas, and adrenals.

BIBLIOGRAPHY

Author's Publications on Syphilis

Congenital Syphilis of the Heart, Am. Jour. Med. Sc., 1911.

Congenital Syphilis Simulating Leucæmia and Splenic Anæmia (Banti's Disease). International Clinics, iv, 20.

Cardiac Syphilis, Ohio State Med. Jour., March, 1912.

Localization of Spirochæte Pallida in the Heart Muscle in Congenital Syphilis, Jour. Am. Med. Assn., 1912.

Focal Fatty Degeneration of the Myocardium Associated with Localized Colonies of Spirochæte Pallida, Jour. Am. Med. Assn., 1912.

Primary Tissue Lesions in the Heart Produced by Spirochæte Pallida, Am. Jour. Med. Sc., 1914, cxlvii.

Ibid., Trans. XVII Inter. Cong. of Med., Sect. of Pathology, Part II, p. 299.

The Coincidence of Latent Syphilis and Diabetes, Am. Jour. Med. Sc., 1916, cliii, p. 157 (with Miss Wilson).

Myxoma-like Growths in the Heart Due to Localization of Spirochæte Pallida, Jour. Infect. Dis., 1916, xix, p. 138.

The Staining of Spirochæte Pallida in Tissues, Bull. Inter. Assn. Med. Mus., No. 6.

The Persistence of Active Lesions and Spirochætes in the Tissues of Cases of Clinically Inactive or "Cured" Syphilis, Am. Jour. Med. Sc., 1916, cliii, 508.

Visceral Lesions in Latent Syphilis, Miss. Valley Med. Jour., April, 1917.

The Rôle of Syphilis in Internal Medicine, Oration in Medicine before the Illinois State Medical Society, 1917, Jour. Illinois State Med. Soc., 1917.

Syphilitic Aneurysm of the Pulmonary Artery, with Demonstration of the Spirochæte, Am. Jour. Syphilis, 1917.

FOOD CHEMISTRY IN THE SERVICE OF HUMAN NUTRITION*

DR. HENRY C. SHERMAN
Columbia University.

AT the suggestion of the President of the Society, I propose to speak this evening of the application of food chemistry to problems of human nutrition, with special reference to the economic aspects of our present food situation. Let us then consider how in the light of our present knowledge we can best combine adequacy of nutrition with economic use of food, remembering that economic in this connection and at this time should mean not only the wisest expenditure of money for food from the standpoint of the individual consumer, but also such conservation of the food resources of the entire country as shall enable us to furnish our Allies and our armies abroad with the largest possible share of those foods which are adapted to their needs and suitable for exportation.

Briefly and somewhat crudely, the material requisites of an adequate diet may be summarized under five heads. It must: (1) Provide sufficient amounts of digestible organic nutrients to yield the necessary number of calories of energy; (2) furnish proteins in ample amount and of suitable sorts; (3) supply adequate amounts and proper proportions of the ash constituents, salts or inorganic foodstuffs; (4) furnish enough of those as yet unidentified substances, the food hormones or so-called vitamines; (5) it must include a sufficient amount of material of such physical character as to ensure the proper handling of the food mass and its residue in the digestive tract. Since we are here to deal with the chemical rather than physical aspects, discussion may be limited to the first four of these requisites. Logically each of these four categories calls for subdivision.

---

* Delivered January 12, 1918.

As sources of energy the carbohydrates, fats, and proteins function interchangeably to a very large but not to an unlimited extent. If our understanding of the relation of the energy value of food to the energy requirement of the body is to be complete, we must study the intermediary metabolism of each of the organic foodstuffs and its relation to the energy exchange, including the problem of its specific dynamic action.

Similarly the problem of protein requirement divides itself into a group of problems having to do with the requirements of the body for each of 15 or 16 amino acids which constitute the building stones of the body tissues, and which are less widely interchangeable than are the energy values of the different foodstuffs.

The ash or mineral matter comprises at least ten chemical elements not contained in simple proteins, fats, and carbohydrates and which are not only not interchangeable, but are in some cases actually antagonistic in function. Under ordinary conditions and with our usual ample use of table salt the only mineral elements which now appear to require special consideration, from the standpoint of adequacy of nutrition, are phosphorus, calcium and iron.

The vitamine or hormone value of foods is due to at least two substances distinguished as fat-soluble and water-soluble vitamines or as Fat-soluble A and Water-soluble B. To these it now appears that a third, the antiscorbutic vitamine, Water-soluble C, is to be added.

It cannot be denied that the rapid progress of our knowledge of nutrition during the past few years has tended to complicate rather than simplify our conceptions of food values and nutritive requirements. But while the problem has become more complex, it also has become clearer, because we now for the first time have reason to believe that all of the substances needed for normal nutrition have been apprehended and can be reckoned with, even though the chemical identification is in some cases not yet accomplished.

It is most fortunate that the recent progress of research in nutrition, so largely the work of our own countrymen, has brought us to this stage in our knowledge of nutritive requirements in time for us to apply it to the problem (now for the first time really urgent in this country) of making a more economical use of our national food resources.

The efficiency with which economy in the use of food and conservation of the food supply can be combined with entire adequacy of nutrition is chiefly dependent upon the extent to which we can state the various essentials of an adequate diet in quantitative terms.

The quantitative study of the energy requirement has been so recently summarized and so fully discussed before this Society by the very men [1, 2, 3] to whom we are chiefly indebted for its progress in recent years that to review the subject here would involve unnecessary repetition. Suffice it to say that all authorities are now in substantial agreement as to the principles of the energy metabolism and the fundamental facts regarding the energy requirement of the body, particularly of the normal adult. So well do different investigators agree in their estimates of the basal metabolism of normal men, that it seems safe not only to accept their average results as expressing the basal energy requirement with a satisfactory approach to exactness, but also to tabulate together the measurements made in different laboratories upon the energy output under various conditions of work and rest so as to furnish a table of "hourly factors" from which the day's energy metabolism and therefore the day's food requirement, so far as it is measured in terms of energy, may be computed. Reduced to a common basis of 70 kilograms (154 pounds) of body weight and averaged in round numbers, the data thus compiled are as follows:

Table I.—Hourly expenditure of energy by an average-sized man (70 kilograms; 154 pounds without clothing) under different conditions of activity. (Approximate averages only.)

Sleeping	60– 70 calories
Awake, lying still	70– 85 calories
Sitting at rest	100 calories
Standing at rest	115 calories
Tailoring	135 calories

Typewriting rapidly	140 calories
Bookbinding	170 calories
"Light exercise" (bicycle ergometer)....	170 calories
Shoemaking	180 calories
Walking slowly (about 2⅔ miles per hour)	200 calories
Carpentry	240 calories
Metal working	240 calories
Industrial painting	240 calories
"Active exercise" (bicycle ergometer) ..	290 calories
Walking actively (about 3¾ miles per hour)	300 calories
Stoneworking	400 calories
"Severe exercise" (bicycle ergometer)...	450 calories
Sawing wood	480 calories
Running (about 5¼ miles per hour).....	500 calories
"Very severe exercise" (bicycle ergometer)	600 calories

For a healthy man or woman of normal physique the energy requirement for twenty-four hours can be calculated from the number of hours spent in each degree of muscular activity, using the hourly rates of energy expenditure indicated in the table and reducing or increasing the total, according as the body weight is less or more than 70 kilograms.

If the degree or intensity of muscular activity is consistently interpreted, the results thus calculated will be found to be in satisfactory agreement with the generally accepted estimates of the food requirements of people of different occupations, as illustrated in the charts recently published by Lusk.[1]

The available data on the energy requirements of growing children vary over a somewhat wider range so that average figures are more difficult to give and less accurate to use. DuBois [3] has constructed a curve of basal metabolism per square metre of body surface at different ages. But the condition predicated for the measurement of basal metabolism—complete quiescence on an empty stomach—is so remote from the usual status of a healthy growing child, that it is necessary to make large assumptions in arguing from the rate of the basal metabolism to the total requirement for a day of normal activity. Estimates of the energy requirements of healthy children must therefore allow for considerable individual variations.

The published data regarding energy metabolism and total food consumption of children have been carefully compiled by Miss Gillett [4] under the auspices of the New York Association for Improving the Condition of the Poor. This study led to the system of food allowances shown in Table II.

TABLE II.—FOOD ALLOWANCES FOR HEALTHY CHILDREN (Gillett)

Age—Years	Calories per Day	
	Boys	Girls
Under 2	900–1200	900–1200
From 2–3	1000–1300	980–1280
" 3–4	1100–1400	1060–1360
" 4–5	1200–1500	1140–1440
" 5–6	1300–1600	1220–1520
" 6–7	1400–1700	1300–1600
" 7–8	1500–1800	1380–1680
" 8–9	1600–1900	1460–1760
" 9–10	1700–2000	1550–1850
" 10–11	1900–2200	1650–1950
" 11–12	2100–2400	1750–2050
" 12–13	2300–2700	1850–2150
" 13–14	2500–2900	1950–2250
" 14–15	2600–3100	2050–2350
" 15–16	2700–3300	2150–2450
" 16–17	2700–3400	2250–2550

These allowances are for average cases. That very active boys may utilize larger quantities of food has been pointed out by Gephart and emphasized by Lusk; and Miss Roberts has recently shown that the same may also be true of younger children of either sex.

Food allowances for children may well be made liberal enough to cover any reasonable doubt. In general, if the age should seem to indicate a different food requirement from that indicated by the size, the more liberal of the two should be followed. In the case of a child which is under weight with reference either to age or height, or both, the allowance of food, as calculated in calories, should be high enough to support not only a normal but an accelerated growth, or to support continued growth and at the same time fatten the tissues already formed, until a normal size and fatness, as shown by the relation of weight to height and age, is attained.

With adults as well as with children the maintenance of an optimum body weight * is usually the best evidence that the energy value of the diet is well adjusted to the needs of the individual. "Counting the calories" in the food eaten is not necessary as a means of establishing the adequacy of the customary food intake if this is already obvious from the condition of nutrition of the individual concerned, but if there be any question of prescribing the food—of rationing either an individual or a community—then adequate energy value of the ration is the first thing which should be considered, for only when the energy supply is adequate can the "tissue-building" constituents of the body and of the food be conserved to the best advantage.

The protein requirement has not been so accurately and conclusively measured as has the energy requirement. Chittenden's well-known investigation of over a decade ago[5] remains the largest single contribution to this subject and the criticisms evoked at the time by his advocacy of a standard for protein consumption only a little higher than the rate of catabolism shown by his observations—corresponding to 44 to 53 grams of protein per man of 70 kilograms per day—are perhaps as suggestive as any which have been offered. Notable among these criticisms were Meltzer's argument[6] that the usual high rate of protein consumption constitutes an important factor of safety which it would be a mistake to forego by reducing the protein content of the ration to a figure near the minimum requirement, and Benedict's criticism[7] of the low protein diets as likely to be accompanied by a less complete digestive utilization of the non-protein food. In connection with the latter point it is interesting to note that Mills[8] found a better utilization of subcutaneously injected fat when the experimental animals (cats) were fed a high protein diet than

* For discussion of optimum body weights at different ages, see "Standard Mortality Ratios Incident to Variations in Height and Weight Among Men," a report of the Joint Committee of the Actuarial Society of America and the Association of Life Insurance Medical Directors (New York, 1918).

when they were fed on low protein or fasted. Mills suggested that this might be because the high protein diet furnished more lipase in the body, and Falk and Siguira [9] found that their (castor bean) lipase preparations were composed essentially of protein material, as had already been shown in the case of purified preparations of pancreatic and malt amylases.[10, 11] (See Table III.) Since the criteria of purity ordinarily used in

TABLE III.—FORMS OF NITROGEN IN PROTEIN MATERIALS AND ENZYME PREPARATIONS

(Expressed in Percentage of the Total Nitrogen in the Material)

Form of Nitrogen	Casein [1]	Edestin [1]	Hæmoglobin [1]	Hair [1]	Pancreatic Amylase [2]	Malt Amylase [2]	Castor bean Lipose [3]
Arginine N	7.4	27.0	7.7	15.3	14.6	14.2	24.7
Histidine N	6.2	5.8	12.7	3.5	6.0	5.4	6.2
Lysine N	10.3	3.9	10.9	5.4	7.4	5.5	4.3
Cystine N	0.2	1.5	?	6.6	2.5	4.9	3.1
Amino N of filtrate	55.8	47.5	57.0	47.5	50.4	52.4	49.4
Non-Amino N of Filtrate	7.1	1.7	2.9	3.1	4.6	4.5	....
Ammonia N	10.3	10.0	5.2	10.0	8.1	7.9	12.1
Melanine N	1.3	2.0	3.6	7.4	5.3	5.6	3.3

[1] Van Slyke (1910).
[2] Sherman and Gettler (1913).
[3] Falk and Siguria (1915).

chemical research are not applicable to unstable colloidal substances like the digestive enzymes, it is easy to say that such preparations as were here analyzed may be far from pure. It has even been suggested that the protein matter of which these enzyme preparations chiefly consist may be only an impurity or a "carrier," while the "real enzyme" is something of wholly unknown chemical nature. There is, however, no positive evidence in support of this latter suggestion. On the other hand, there is much evidence which, while not conclusive, is direct and positive in character, tending to show that the common hydrolytic enzymes, such as those concerned in the utilization of foodstuffs, either are proteins or contain protein matter as an essential constituent. Probably, therefore, the food protein must furnish material for body enzymes as well as for body tissue.

Both this consideration and the more familiar one that individual amino acids furnished by the food proteins may serve as precursors of body hormones,[12, 13] naturally tend toward caution in the acceptance of a low protein standard, especially since the proteins have been shown to vary widely in their amino-acid make-up and in their nutritive value when fed singly, especially in experiments upon growing animals.[14, 15]

These differences in nutritive value among proteins, especially as correlated with chemical structure by Osborne and Mendel, are of the greatest importance, but we should be careful not to mistake them as justifying a reactionary attitude or even a needless degree of timidity in accepting and applying the results of experiments upon the amount of protein required for normal human nutrition. Rather they furnish the information necessary to enable us to plan economical use of protein wisely and with confidence. Probably the best guide to the amount of protein actually needed in the food of the human adult is to be found in the average daily rate of nitrogen output when the intake is restricted to an amount barely sufficient or not quite sufficient to maintain nitrogen equilibrium.

The nitrogen output on a diet markedly deficient in protein and involving a large loss of body nitrogen may be less than the nitrogen requirement, since a large nitrogen loss from the body might not be convertible to equilibrium by the addition of an equal amount of food nitrogen to the intake; but where there is nitrogen equilibrium on a low protein diet, it seems safe to conclude that such diet is meeting all the demands of the normal nutrition so far as protein is concerned. Also, when the nitrogen output is only very slightly greater than the intake, it seems permissible to regard the output as approximating the actual requirement. It might perhaps be argued that even a small loss of nitrogen from the body might, if long continued, be serious, possibly on the ground that the extra nitrogen of the output over that of the intake may conceivably represent the catabolism of some particular amino acid which the food does not supply in sufficient amount and whose continued loss would be detrimental. The experimental evidence, however, does not seem to support this latter view. In experiments, for example, in which gelatin is the sole protein, we do not find a merely small loss of body nitrogen which might be mistaken for approximate equilibrium, but a loss large enough to indicate plainly that the food protein in that case is inadequate. Similarly, in the well-known experiments of Osborne and Mendel, in which rations containing a single protein are fed to experimental animals, the feeding of zein rations results in prompt and considerable losses of body nitrogen and body weight.

It is, therefore, very unlikely that a diet which maintains approximate nitrogen equilibrium is so deficient, either in the kind or amount of protein which it contains, as to make it a source of danger, even if long continued. On the contrary, a small negative balance usually means simply that the body has not yet completed the adjustment of the rate of output to the rate of intake. In most such cases it is altogether probable that the continuance of the low protein diet would soon lead to nitrogen equilibrium, and that in taking the output as a measure of the requirement, we are probably overestimating the real minimum requirement for protein.

It has, therefore, been thought worth while to bring together the data of all available experiments in which the dietary conditions and the nitrogen balance were such as to indicate that the output of nitrogen might be reasonably construed as approximating the actual nutritive requirement. In order to minimize the personal equation in interpretation, we have uniformly excluded all experiments showing a loss of nitrogen greater than 1 gram per day. There remain 107 experiments upon adults showing no abnormality of digestion or health, in which the diet was sufficiently well adjusted to the probable requirement and the nitrogen balance showed sufficient approach to equilibrium to make it appear that the total output of nitrogen might be taken as an indication of the protein requirement. These experiments are taken from 22 independent investigations in which 36 different individuals (28 men and 8 women) served as subjects. For purposes of comparison, the daily output of total nitrogen in each experiment was calculated to protein and this to a basis of 70 kilograms of body weight. Reckoned in this way, the apparent protein requirement as indicated, by the data of individual experiments, ranged between the extremes of 21 and 65 grams, averaging 45 grams of protein per man of 70 kilograms per day. Thus the average falls well within the range of Chittenden's estimate of the amount of protein required for normal nutrition when the energy value of the diet is adequate.

Examination of the data recorded in the original papers indicates that the wide differences in amounts of protein catabolized in the different experiments can not in these cases be attributed primarily to the kind of protein consumed nor to the use of diets of fuel values widely different from the energy requirements. Apparently the most influential factor was the extent to which the subject had become accustomed to a low protein diet.

In view of the fact that individual proteins when fed singly, especially to growing animals, have shown striking differences in nutritive efficiency, it may seem strange that in the experiments hitherto made to determine the protein requirement of man, the kind of protein fed has not had more influence upon the amount required. There is, however, no real discrepancy between the two sets of findings. Experiments like those of Osborne and Mendel, for example, were for the object of comparing individual proteins isolated even from the other proteins which always accompany them in natural or commercial food materials, and were conducted largely upon rapidly growing young animals in which there is an active synthesis and retention of protein so that a deficiency in the supply of any amino acid which is required in the construction of body protein is apt to be quickly and plainly reflected in a diminution or cessation of growth. On the other hand, in experiments, the purpose of which is not to compare proteins but to measure the normal protein requirement, the diet is naturally made up, not of isolated proteins or even of single or unusual foods, but (ordinarily at least) of such combinations of staple foods as are believed to represent a normal diet, so that even a relatively simple ration arranged for the purpose of such an experiment would probably contain a number of different proteins among which any peculiarities of amino acid make-up would be apt to offset each other, at least to a considerable extent. Moreover, the experiments of the group now under discussion have been made entirely upon adults whose protein requirement was limited to that of maintenance. In such cases there is no longer a demand for amino acids to be built into new tissue, but only to maintain the equilibrium which already exists between amino acids and proteins in the full-grown tissues. *Any* of the amino acids whose radicles are contained in tissue proteins may be expected to contribute something to the maintenance of such an equilibrium, whereas there can be no *growth* unless *all* the necessary amino acids are present. In the protein metabolism of growing children or nursing mothers the influence of food selection would probably be much more pronounced and even in the case of adult men protein requirement will probably be found to be considerably influenced by food selection when experiments suitably planned to test the question are carried out. The inadequacy of gelatin as a sole protein food and its inferiority to meat or milk protein when substituted beyond a certain proportion is well known. A series of experiments, designed to demonstrate differences in nutritive efficiency for man of the protein supplied by different staple articles of food, was carried out by Karl Thomas,[16] in Rubner's laboratory, and the striking results reported have been widely quoted, often on Rubner's authority. These results however, have as yet failed of confirmation, and, on some important points have been so directly refuted by later workers using longer experimental periods, as to make it appear that Thomas's plan of experimenting and mode of interpretation were not suited to the solution of the question at issue.

Thomas reported that meat protein was greatly superior to bread or potato protein for the maintenance of body tissues, but Hindhede [17] finds no such difference, being able to maintain normal nutrition with either bread or potato nitrogen in relatively small amounts.

Rose and Cooper [18] have also demonstrated the high value of potato nitrogen in the maintenance of nitrogen equilibrium, and experiments in the writer's laboratory [19] have tended to confirm Hindhede's finding that nitrogen equilibrium may be maintained on a relatively low intake of protein in the form of bread alone. Of at least equal practical importance are those experiments [20] which show the maintenance of nitrogen equilibrium on low protein diets in which bread or other cereal product is the chief source of protein, but is supplemented by small amounts of milk.*

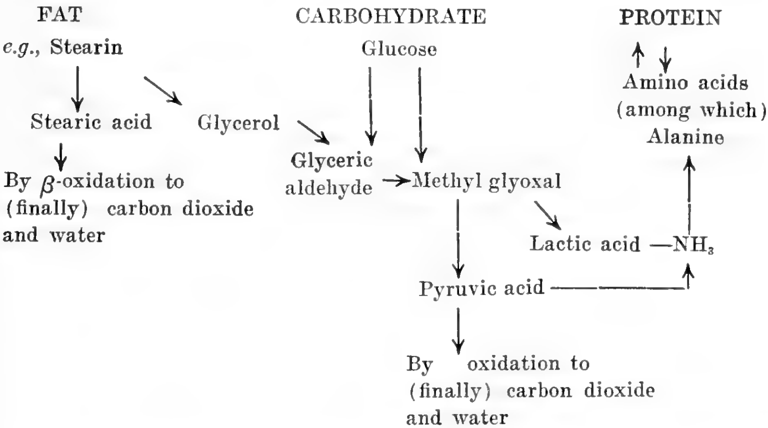
At a time when compulsory rationing is being seriously discussed and when we know that in any case economic conditions are forcing the majority of people to an increased use of the less expensive foods which may mean that a larger proportion of the protein consumed is not of the kinds having highest nutritive efficiency, it becomes important to consider somewhat more closely the question of the utility of the so-called incomplete proteins in nutrition, and the protein-sparing action of the fats and carbohydrates which may operate to conserve the protein supply by diminishing protein catabolism. In order to do this we should, I think, recognize that protein metabolism is not an affair of two distinct and separate processes—anabolism and catabolism—but is rather to be conceived as involving a series of reversible reactions or of approximate equilibria in the body. The tissues always contain protein and amino acids which in a healthy grown man are constantly in approximate equilibrium:

$$\text{Amino acids} \rightleftarrows \text{Protein}$$

The supply of amino acids in the tissues is constantly being augmented by the digestion products brought by the blood, and at the same time is constantly being depleted by deaminization. If amino acids are brought to the cell more rapidly than they are removed or deaminized, the concentration of amino acids is increased and this must tend to push the above reaction toward the right—*i.e.*, to check the rate of protein catabolism or to conserve

* Attention may also be called to the extended experiments of Osborne and Mendel, published since the above was written, showing good growth of rats on low protein diets in which wheat or wheat flour furnished most of the nitrogen but was supplemented by small amounts of milk, eggs or meat (in the latter case with butter and suitable mineral salts). Journal of Biological Chemistry 37, 557 (Apr. 1919).

the protein of body tissue, and *vice versa.* Similarly, the intake of ammonia salts under proper conditions may check the deamination of amino acids and thus indirectly take part in the maintenance of nitrogen equilibrium. But ammonia may also contribute to the actual formation of amino acids in the body, as shown by Embden and Knoop and by Dakin, and this probably furnishes us the best explanation now available of the protein-sparing action of carbohydrates and fats as illustrated in the accompanying diagram.



Since pyruvic acid appears to be regularly formed in the metabolism of carbohydrate and of the glyceryl radicle of fats, and ammonia is always being formed in protein catabolism (by deaminization of amino acids), and since the ammonium salts of α-ketonic acids, such as pyruvic acid, are convertible into amino acids which are building materials for body protein, we have here a mechanism by which an intermediary product of carbohydrate metabolism (pyruvic acid) takes up a "waste product" of protein metabolism (ammonia) and turns it back into amino acid, "protein material," again. Thus carbohydrate, in undergoing metabolism, "spares" protein, not only by serving as fuel so that protein need not be drawn upon for this purpose, but also by furnishing material, which in combination with ammonia (otherwise a waste product), can actually be converted in the body into some of the amino acids of which the body proteins are composed and with which they are in equilibrium. This explains how an increased intake of carbohydrate, with resulting increase of pyruvic acid, naturally leads to increased synthesis of amino acids and thus to a tendency toward protein storage, or, to express the same thing in somewhat different terms, tends to push the reaction, amino acids $\rightleftarrows$ protein, toward the right.

According to present theory, most, if not all, of the energy of the carbohydrate becomes available through oxidation processes which involve the intermediate production of pyruvic acid, an α-ketonic acid whose ammonium salt is capable of conversion into amino acid. Of the fat only the glyceryl radicle (about one-twentieth of the fuel value) is oxidized through pyruvic acid, while the fatty acid radicles, representing about nineteen-twentieths of the energy of the fat, are metabolized through β-oxidation processes which yield, so far as we know, no product whose ammonium salt is convertible into amino acid in the body. Hence complete withdrawal of carbohydrate, even though substituted by sufficient fat to yield an equal number of calories, must be expected to result in increased excretion of nitrogen.

Under war conditions, while we may have to economize in the use of sugar, there will probably be at least an equal pressure for economy in the use of fat so that the energy requirement will tend to be met largely by the use of starchy foods. Hence there should be at least as high a proportion of carbohydrate in the war diet as in that of peace and the full protein-sparing effect should be realized.

Now that we have a chemical explanation of the protein-sparing action of carbohydrates and fats which is based on reactions which have been definitely demonstrated to take place in the organism, we see that only a few of the simplest amino acids can be conceived as synthesized by this mechanism, and yet we know from the results of many feeding experiments that the "sparing action" of carbohydrates and fats is a large factor in conserving the protein of the body or of the intake. In harmony with this we find that "incomplete" proteins, furnishing some, but not all, of the amino acids of which body proteins are composed, may still play a very important part in the protein metabolism of maintenance.

McCollum, in 1911,[21] called attention to the rather surprising nutritive efficiency of zein in cases in which only maintenance was involved, and offered the suggestion that "repair" processes may not involve the disruption and reconstruction of entire protein molecules. The same idea may be expressed from a slightly different point of view by saying that having in the cell under conditions of maintenance an equilibrium, amino acids $\rightleftarrows$ protein, between protein and a whole group of amino acids the catabolism of protein will be diminished by increasing the concentration of any (even though not all) of the amino acids into which the protein molecule tends to be resolved.

Thus food proteins which do not furnish all of the amino acids needed for the construction of body tissue and which therefore could not properly be made the chief reliance in the feeding of growing children, or of women during pregnancy or lactation, may still be depended upon to a very large extent for the ordinary maintenance of adults.

Nor does it seem necessary to assume that because of the differences in nutritive value among proteins, a very large margin for safety must be allowed above the average amount found in the 107 experiments cited above. This would be true only if the diets in these experiments had been selected from among materials whose proteins are of more than average value, which in general was not the case. In fact, in the low protein diets used in these experiments there was often, if not usually, a more than average proportion of bread or other grain protein so that, if anything, the experiments tend to overstate the amount of protein which an ordinary mixed diet must furnish in order to cover the requirements of normal protein metabolism in the adult. Under these conditions it seems abundantly liberal to allow when planning for an economical use of food, a protein "standard" 50 per cent. higher than the average estimate of the actual requirement (which as already shown is probably an overestimate). Such a 50 per cent. margin for safety would lead to a tentative standard allowance of about 70 grams of protein per man, or 1 gram per kilogram of body weight, per day. The requirements of children for protein, as well as other tissue-building material, will be considered as proportional to their energy requirements, and therefore much higher per unit of weight than in the case of adults.

The phosphorus and calcium requirements have in the past been much less studied than the protein requirement, although in principle they are equally well adapted to investigation by the method of quantitative comparison of intake and output. Until recently the results of such experiments were not sufficiently numerous or concordant to give us much confidence in the validity of the average; and as a basis for general conclusions regarding phosphorus and calcium requirement in human nutrition, they were open to the further criticism of having been made almost exclusively upon male subjects. Experiments upon women were therefore plainly needed and since the effects of the monthly cycle upon phosphorus and calcium metabolism had not been studied, it was especially desirable that the determination of intake and output should continue for an entire month without intermission. Four young women, graduate students and research workers in the writer's laboratory, have served as subjects in such experiments, taking diets uniform from day to day for 28 or 30 days consecutively with quantitative determinations of intake and output of nitrogen, phosphorus and calcium balanced in experimental periods of three or four days each. Three of the four subjects have each made two such series of experiments.[22] From the data of all these experiments there does not appear to be any distinct monthly cycle in the total quantitative metabolism of either phosphorus or calcium; nor was the output of either of these elements in the menstrual flow large enough to materially affect the average daily metabolism for the entire month. From this standpoint the material lost in menstruation is essentially blood, and as such is important to the estimate of the average daily requirement for iron, but is of minor consequence in the nitrogen, phosphorus and calcium metabolism.

The determination of phosphorus and calcium balance in three- or four-day periods for twenty-eight or thirty days without intermission gave, therefore, in each case a series of seven to ten experiments of unusual value for the purpose of studying the normal nutritive requirement, since the diets were so arranged as to furnish the desired amounts of energy and protein with quantities of phosphorus and calcium small enough to test the ability of the body to establish equilibrium on the amounts furnished, and to show to how low a level of phosphorus or of calcium metabolism the body could adjust itself.

The minimum requirements thus found, computed, for convenience of comparison and application, to a basis of 70 kilograms body weight, corresponded respectively to 0.91, 0.72, 0.83, 0.89 gram phosphorus, and 0.49, 0.38, 0.44 gram calcium "per man per day."

Averaging these results with those of several other experiments made in this laboratory upon both men and women and with all comparable data found in the literature, indicates a mean requirement per 70 kilograms of body weight of 0.88 gram phosphorus and 0.45 gram calcium per day.

Considering both the number of experiments contributing to the average and the range of results in each case, it would seem that our present knowledge of the quantities required for normal nutrition is probably about equally accurate as regards protein, phosphorus, and calcium. This being so, we have as much reason to set phosphorus and calcium "standards" as to set a "standard" for protein, and it seems logical to allow as much margin for safety in the one case as the other. The accompanying table summarizes the data on which these estimates of "requirements" and "standards" are based and shows also the relative frequency of American dietaries which fall below the standard or even the bare minimum requirement in each case.

TABLE IV.—NUTRITIVE REQUIREMENTS AND ACTUAL INTAKE.
"Per Man Per Day."

	Protein	Phosphorus	Calcium
Number of experiments.	107	95	63
"Requirement" grams			
Range	21–65	0.52–1.20	0.27–0.78
Average	45	0.88	0.45
"Standard" (50% above "requirement")	70 grams	1.32 grams	0.68 gram
Actual amounts in 246 dietaries (avg.) ...	106 grams	1.60 grams	0.74 gram
Percentage of cases below "Standard" ..	6 %	29 %	52. %
Percentage of cases below "Requirement"	none	4 %	16. %
Percentage of cases below "Requirement" if dietaries below 3000 calories per man per day were brought up to that amount..	none	Less than 1%	8. %

It must be stated with all possible emphasis that the words "requirement" and "standard" are used here only for lack of better terms and that they have not and cannot have the unconditional significance which is apt to be attached to them. McCollum's recent work [23] emphasizes the fact, which earlier work on the metabolism of calcium and iron,[24, 25] had illustrated, that the amount of any one nutrient required will depend to a considerable extent upon the amounts of other nutrients furnished. In taking the average of supposed minima found in various investigations as an estimate of the "requirement," we do not mean that just this amount would be literally required in each case. The very experiments from which this average is derived are sufficient to show that the actual requirement varies with the subject and the diet if not with other conditions. Similarly, in taking an amount 50 per cent. above the average requirement as a "standard," it is by no means intended to imply that this amount will be always the most desirable. On the contrary, a larger amount might easily be advantageous, especially in the case of calcium as a safeguard against failure of completely normal absorption in the digestive tract.

Thus the quantitative statements of what are here called "requirement" and tentative "standard" must not be literally interpreted nor rigidly applied. They are, however, directly useful as a concrete basis for classifying the results of dietary studies as to whether they contain liberal or scanty amounts of the element in question. An intake less than the so-called requirement does not necessarily mean a continuing deficit leading finally to disaster in every individual case, but does mean that there is this danger wherever such low intakes are habitual.

In individual cases in which intake and output are quantitatively determined and the inability of the subject to establish equilibrium is demonstrated, there can be no doubt that the intake is inadequate for the subject and conditions of the experiment and the fact of such a deficiency with reference to any particular element (calcium, for instance) may be established with entire certainty by the laboratory evidence without awaiting the development of any pathological symptoms.

Of the 246 dietary studies referred to in Table IV, 144 were originally recorded by the United States Department of Agriculture and have recently been subjected to more detailed analysis and computation, especially as regards the mineral elements, in connection with the investigations upon mineral metabolism at Columbia University; 102 were collected and studied in detail by Miss Gillett, working under the joint auspices of the University and the New York Association for Improving the Condition of the Poor. Nearly all of the latter were from New York City. Of the 144 government studies, 54 were made in New York City, 46 in other large cities, 44 in small cities or towns and rural regions. In each of these groups calcium is the element most often deficient and of which the average intake shows the least margin of safety above the bare requirement. It is particularly interesting to note the agreement of this result with the emphasis laid upon calcium by Osborne and Mendel [26] in their recent discussion of the mineral elements in nutrition and with that of McCollum [27] who has found in his studies of laboratory animals that it is largely if not chiefly because of insufficient calcium that such animals do not show normal nutrition on rations derived too largely from seeds. American dietaries, both urban and rural, tend to consist too largely of the products of seeds, meats, sugar and fats, all of which are poor in calcium—and too little of milk and vegetables which should be used in larger proportion, both for their mineral constituents and for the vitamines which they furnish.

As might be expected in view of New York City's great size and the difficulty and expense of bringing in adequate supplies of perishable foods—milk, for instance, having to be brought from seven states and from distances sometimes as great as 400 miles or more—the New York City dietaries show a smaller average calcium content than those of other cities, while the small towns and rural regions show the best average.

Most of the New York City dietaries, recorded by United States Department of Agriculture, were observed in 1895–1896. By the time of the investigation by the Association for Improving the Condition of the Poor in 1914–1915 the average calcium content had improved about 14 per cent. Undoubtedly this is chiefly due to the increased per capita consumption of milk which is known to have occurred during this twenty-year period, and which in turn is no doubt largely attributable to the good influence of the public and private agencies which have been working in New York City for a better and more adequate milk supply, and to the better understanding of the importance of milk by the general public largely due to the efforts of the dietitians, visiting nurses, and other visitors of the social and relief organizations and to the teachers of domestic science in the public schools. That the calcium content of the dietary is very closely related to the amount of milk used and that the latter can be influenced by education are both well illustrated by data which have been presented elsewhere.[28] By analysis of the data of the 44 dietaries studied in small towns and rural regions it was found that here also the adequacy of calcium intake depended chiefly upon the amount of milk consumed, adequate calcium being found, on the average, only in those dietaries which contain at least one-third of a quart of milk per man per day.

The results of the dietary studies indicate very strongly that the average American dietary contains a much more liberal margin of protein than of calcium, and that while the danger of a protein deficiency is rarely serious, the danger of a deficiency of calcium is very real. So far as the actual requirements of the calcium metabolism are concerned, these (as well as other "mineral" requirements) could be met by the addition of simple mineral salts to the food, but since the foods naturally rich in calcium, notably milk, eggs, vegetables and many fruits, are so valuable for other properities as well, it seems wiser in dealing with human nutrition to encourage the more liberal use of these naturally calcium-rich foods, rather than the artificial addition of calcium salts.

Phosphorus deficiencies are probably four to five times as frequent as are deficiencies of protein, and calcium deficiencies are much more frequent still. The old assumption that adequate protein may be taken as meaning adequate supplies of all tissue-building material is found to be wholly misleading. Adequate energy intake is, in practice, more apt to ensure adequacy of mineral elements, but even if all of the 246 dietaries had been brought to a basis of 3000 calories per man per day, 8 per cent. of them would still have furnished less than the average "requirement" of calcium.

The iron requirement is much less definitely known than that for phosphorus or calcium. From the few experiments which now appear trustworthy, it would seem that the actual requirement may average about 0.010 gram, and the corresponding standard be placed at 0.015 gram, per man per day. On this basis it would appear that the danger of a deficient intake of iron on freely chosen diet is less than in the case of calcium, but much greater than is the danger of a deficiency of protein.

Standard allowances of proteïn, phosphorus, calcium and iron for children's dietaries.—It will, of course be understood that in all these statements regarding adequacy of family dietaries or of food allowances for a family or a community, the child's requirement for protein, phosphorus, calcium, or iron is reckoned as proportional to his energy requirement and therefore as much more than proportional to his weight. Starting with the food allowances for healthy children, tabulated above in terms of calories, it may be convenient to reckon the requirements of children or of families containing children as follows:

Protein	2.5*	grams	per 100 calories
Phosphorus ...	0.045	gram	per 100 calories
Calcium	0.023	gram	per 100 calories
Iron	0.0005	gram	per 100 calories

The "vitamine" requirements naturally cannot be stated in terms of actual weights of the substances involved until these are identified chemically, but the percentages of certain foods rich in the one or the other of these essentials which suffice to make an othewise satisfactory diet adequate for normal growth and reproduction have been determined experimentally for several food materials by Osborne and Mendel [29] and by McCollum and his associates,[30] so that we now know in a general way the relative richness of several of the chief types of food in each of these dietary essentials and can take account of this factor of food value in considering the prominence which should be given to each type of food in planning an adequate and economical diet.

It is both interesting and important to find how generally the types of food rich in calcium—milk, eggs, vegetables—are rich in vitamines (particularly the fat soluble vitamine) as well, so that in safeguarding against deficiency of the element most likely to be deficient, we at the same time secure an ample intake of the food hormones or vitamines.

To apply knowledge of nutritive requirements in the choice of food, any one of several plans may be followed.

1. The actual quantity of each essential element could be calculated for every proposed combination of staple food materials, but this method would be too cumbersome for general use.

2. Since in the past it has been customary to treat protein

* Which should be mainly in the form of milk protein in the dietaries of growing children.

as the tissue-building material of the food and since we now know that dietaries containing enough protein do not necessarily contain enough of other building materials, such as phosphorus and calcium, we might seek to remedy the situation with a minimum revision of past habits of thought by so specifying the kind of protein as well as its amount as to ensure that adequate protein supply shall really ensure (what we formerly erroneously assumed) an adequate supply of all essential elements. Thus, in specifying that the protein in the dietaries of growing children shall be mainly in the form of milk, we ensure not only a good form of protein but an adequate supply of calcium, of phosphorus, and of vitamines as well.

3. Again, since food values are commonly stated in terms of calories and the 100-calorie portion of food is becoming a more and more familiar unit, it is possible by building up a dietary of such units and specifying the number to be drawn from each type of food, to ensure that in covering the energy requirement an adequate supply of protein, of each of the inorganic elements, and of each type of vitamine shall also be ensured. This is perhaps the most satisfactory procedure in those cases in which the balancing of the diet is attained by careful planning of each meal from day to day, and its application has been greatly facilitated by the publication of the excellent series of meal plans for which we are indebted to Mrs. Rose.[31]

4. Still another method of balancing the dietary and insuring an adequate supply of each essential nutrient without undue expenditure or extravagant consumption in any one direction, is to follow a food budget, or in other words, apportion the money expended for food among the different types of food materials. This plan, while less logical from a scientific standpoint than those previously mentioned, has the merit of simplicity, of requiring no use of technical terms, and of facilitating comparison with food statistics which are as apt to be reported in money value as in weights and measures, and in any case are much more readily reducible to money than to food value when the latter is construed as broadly as we now must construe it to cover all

the constituents of food which we know to be essential to normal nutrition.

Food supplies of American families.—The results of inquiries by the United States Bureau of Labor Statistics in over two thousand families, and of very accurate records obtained by the United States Department of Agriculture and the New York Association for Improving the Condition of the Poor in over two hundred households carefully chosen as representative of different economic groups, are quite consistent in showing that of the total expenditure for food about one-third is for meats and fish, about one-tenth for milk, one-twentieth for eggs, one-tenth to one-sixth for breadstuffs and other cereal products, about one-sixth for butter and other fats, sugar and other sweets, about one-sixth for fruit and vegetables, and one-twentieth to one-tenth for all other foods and food adjuncts. This estimate of the relative prominence of different types of food is confirmed by the statistical estimates of the values of annual product of the different food industries of the United States after allowing for imports and exports.

Are the habits of food consumption which these statistics reveal the ones which we must consider the best in the light of our present knowledge of nutrition? If they are capable of modification for the better, can this be accomplished in a manner consistent with our responsibilities in the present world food situation? I think there is no doubt whatever that the average American dietary can be modified to meet all the wishes of the Food Administration and be materially improved at the same time.

We are asked by the larger use of perishable foods, including such grain products as are more perishable than wheat flour to "save," or reduce our consumption of, wheat, meat, fats and sugar. It is in fact precisely because of the free use of meat, sugar, fat and white flour in American dietaries that so many of them are deficient in one or more of the mineral elements, particularly calcium, so that the partial substitution of other foods for each or any of these four will tend directly to remedy the commonest defect in the nutritive value of our food.

That the mineral and vitamine contents of the average American dietary can and should be improved by the larger use of milk and vegetables, even if this means a decreased consumption of meat, is now well recognized by students of nutrition. Because of the economic limitations under which the food for most families must be provided, the use of so much as one-fourth to one-third of the food money for meat practically results in too great a limitation of the consumption of fruit, vegetables and milk. Even if there were no war, we should teach a lessened use of meat and sugar in order that more milk, vegetables and fruit may be purchased and consumed. Since sugars and fats are practically devoid of inorganic foodstuffs or of water-soluble vitamine, as well as of protein, a diet in which the use of purified sugars and fats is reduced and the same number of calories supplied by an increased use of other food material, is almost sure to be improved as regards its calcium, iron and phosphorus content as well as made richer in protein and vitamine. The only exception worthy of note is the richness of butter in fat-soluble vitamine.

The duty placed upon us by the present food emergency, to eat less meat and more of such perishables as milk, vegetables and fruit, is therefore precisely what the recent advances in our knowledge of food and nutrition have shown to be for our best interest in any case.

It seems a good general rule for families of any level of income or standard of living (1) to spend at least as much for milk as for meat; (2) to spend at least as much for vegetables and fruit as for meats and fish.

If it be objected that many people "simply cannot buy" milk at present prices, it should be said in reply that while every increase in the cost of milk to consumers is greatly to be regretted and should be avoided, if possible, yet milk at any price which it has yet reached, or is likely to reach, is a better investment than meat. Lusk's admonition to the housewife to "buy three quarts of milk before buying a pound of meat" is excellent advice; all the more so in view of the general rise in prices. Any family that can afford meat at all can better afford milk.

A liberal use of milk and vegetables in the diet is the best safeguard against any deficiency which might arise through restricted choice of foods, and the safest and most practical way to ensure that the consumption of enough food to maintain a normal weight for the height and age shall meet all other requirements of nutrition as well.

REFERENCES

[1] Lusk: Science of Nutrition, Third Edition (1917) and Journal American Medical Association, vol. 70, p. 821 (1918).

[2] Benedict: Metabolism During Inanition. Harvey Lectures for 1906–1907, p. 170, and Publications of the Carnegie Institution of Washington.

[3] DuBois: The Respiration Calorimeter in Clinical Medicine, Harvey Lectures for 1915–1916, p. 101, and Papers in the Archives of Internal Medicine.

[4] Gillett: Food Allowances for Healthy Children. Published by New York Association for Improving the Condition of the Poor.

[5] Chittenden: Physiological Economy in Nutrition and The Nutrition of Man.

[6] Meltzer: The Factors of Safety in Animal Structure and Animal Economy. Harvey Lectures for 1906–1907, p. 139.

[7] Benedict: The Nutritive Requirements of the Body. American Journal of Physiology, vol. 16, p. 409 (1906).

[8] Mills: Archives of Internal Medicine, vol. 7, p. 694 (1911).

[9] Falk and Siguira: Journal of the American Chemical Society, vol. 37, p. 217 (1915).

[10] Sherman and Schlesinger: Journal of the American Chemical Society, vol. 34, p. 1104 (1912); vol. 37, p. 1305 (1915).

[11] Sherman and Gettler: Ibid. vol. 35, p. 179 (1913).

[12] Willcock and Hopkins: Journal of Physiology, vol. 35, p. 88 (1906).

[13] Osborne and Mendel: Journal of Biological Chemistry, vol. 17, p. 325 (1914).

[14] Osborne and Mendel: Feeding Experiments with Isolated Food Substances. Carnegie Institution of Washington, 1911, and subsequent papers in the Journal of Biological Chemistry.

[15] Mendel: Nutrition and Growth. Harvey Lectures for 1914–1915, p. 101.

[16] Thomas (K.): Archiv. für Anatomie und Physiologie, 1909, p. 219.

[17] Hindhede: Skand. Archiv. für Physiologie, vol. 30, p. 97; vol. 31, p. 259 (1913–14).

[18] Rose and Cooper: Journal of Biological Chemistry, vol. 30, p. 201 (1917).

[19] Sherman: Journal of Biological Chemistry, vol. 41, p. 97 (1920).

[20] Sherman, Wheeler and Yates: Journal of Biological Chemistry, vol. 34, p. 383; Sherman and Winters, Ibid. vol. 35, p. 301; Sherman, Winters and Phillips, Ibid. vol. 39, p. 53 (1919).

[21] McCollum: American Journal of Physiology, vol. 29, p, 215 (1908) (1912).

[22] Sherman, Gillett and Pope: Journal of Biological Chemistry, vol. 34, p. 373. Sherman, Wheeler and Yates: Ibid. vol. 34, p. 383.

[23] McCollum and Simmonds: Journal of Biological Chemistry, *passim.*

[24] Von Wendt: Skand. Arch. Physiologie, vol. 17, p. 211 (1905).

[25] Sherman: Bulletin 185, Office of Experiment Stations, United States Department of Agriculture, p. 37.

[26] Osborne and Mendel: Journal of Biological Chemistry, *passim.*

[27] McCollum, Simmonds *et al.*: Journal of Biological Chemistry, *passim.*

[28] Sherman and Gillett: A Study of the Adequacy and Economy of Some City Dietaries. Published by New York Association for Improving the Condition of the Poor.

[29] Osborne and Mendel: Journal of Biological Chemistry, *passim.*

[30] McCollum: Supplementary Dietary Relationships Among Natural Food Materials. Harvey Lectures for 1916–1917.

[31] Rose: Feeding the Family (New York, 1917).

THE RESULTS OF HIGH EXPLOSIVES ON THE EAR*

J. GORDON WILSON, M.A., M.B., C.M. (Edin.).

THE large number of men incapacitated for military service on account of deafness, due to the concussion of high-explosive shells, is engaging the attention of military authorities in all the armies in this war. The number of men who will return to civil life with seriously impaired hearing demands the attention of otologists. I have chosen this subject for consideration, not only because it is urgent, but also because I have had considerable opportunity to observe such results in warfare, and in addition have studied in a very modified degree corresponding effects in the laboratory. It shall be my endeavor to describe my observations and the results of my investigations rather than to attempt to offer any explanation or form any hypothesis.

One word of personal explanation: On my arrival in England, I was assigned to a base hospital specially equipped by the Canadian Government for injuries and diseases of the eye and ear, and was given as my chief duty the examination of cases of injury to the internal ear, including cases designated as shell-shock deafness. In December, 1916, I was transferred to France, again to observe cases of deafness due to shell concussion, first, to a Casualty Clearing Station, situated about four miles from the first-line trenches, and later to a stationary hospital situated somewhat further behind the lines, to which were sent severe head injuries, and cases with little or no trauma suffering from a variety of nerve symptoms, due to bursting of shells and generally designated as shell-shock. In addition, by courtesy of the officers in charge, I was permitted to observe cases at neighboring Casualty Clearing Stations and near-by stationary hospitals. It has, therefore, been possible to see injuries to the ear from

* Delivered February 9, 1918.

shell explosions first a few hours after they were received, second within a few days, and third after the lapse of several months. This work could not have been carried on without the assistance of the commanding officers of the hospitals to which I was assigned. To all of these I am indebted, but specially to Colonel Courtney, of Ottawa, Canada, whose sympathetic coöperation was invaluable.

The otological cases resulting from the bursting of a shell are divided into two groups:

1. Those in which a piece of the shell has struck the ear. The trauma may have been limited to the external canal or to the mastoid, or may have involved the middle and internal ear. Injuries to the external canal or mastoid cause total or partial deafness on that side and at the same time some loss of hearing at least temporarily in the other ear. In addition we have the results of the suppuration and contractures of the external meatus so apt to follow. Injuries involving the middle and internal ear are usually immediately fatal from associated injury to the brain, and those who survive are totally deaf in that ear.

2. Those in which the damage has come from the explosion without any fragment of the shell striking the ear or its immediate neighborhood. In some there has been no objective signs of trauma, in others some fragments may have caused a trauma in a part remote from the temporal bone. It is with this second division that this paper is concerned. It includes a large number of cases in which the diagnosis is frequently very difficult and the treatment as yet unsettled and obscure.

THE EXPLOSIVE FORCE

The present conflict is preëminently the war of trenches and high explosives. Many thousands of shells of high-explosive force are in each engagement sent over to blow up trenches and prepare the way for the attack. These shells vary in weight from a few pounds to about a ton, and each consists of a thick iron case with a central cavity containing the charge which may be as much as 200 pounds of high explosives. These shells do not contain bullets. The injury comes from the explosive force, from the fragments of the shell, and from débris from adjoining structures which they have shattered. Concussion effects are no longer confined to the men who fire the big guns; far greater and more numerous are the disastrous effects produced by the burst on all classes of combatants.

The effect of the high explosive is a great compression followed by a great decompression; it is probable that the serious damage done to the ear results from the compression. I have had men under my care who have been blown considerable distances; thus, one man was blown out of the trench and then became unconscious, another was blown six yards, became dazed, and finally lost consciousness for three days.

The explosive force varies with the shell used, and its effects with the location of the burst—open ground, trench or dugout. Mott,[1] who is a recognized authority on the effects of shell explosions on the nervous system, says: "Lord Sydenham, one of the highest authorities on the dynamics of explosives, concludes that the forces generated are sufficient to cause instantaneous death, and he has informed me that in the American Medico-Military report it is stated that 'an aneroid showed that the explosion of one of these shells caused a sudden atmospheric depression of about 350 mm. of the mercury tube, corresponding to a dynamic pressure of about ten tons to the square yard.'

"M. Arnoux, a French civil engineer, has also studied this question. A pocket aneroid barometer carried by an officer had been exposed to an explosion of the kind referred to, and was put out of working order by the force of the concussion. M. Arnoux had the aneroid repaired; he then placed it under the reservoir of an air-pump and exhausted until he had produced the same effect on the aneroid as was observed before it was repaired. He calculated from observations and experiments that the dynamic pressure exerted by the surrounding air on bodies within a few yards of the exploding shells had amounted to over 10,000 kilos per square metre. Men standing close to the exploding shell would be blown into the air or dashed against the ground with great violence, but in the case of men leaning against the side of a trench wall only the static depression could affect them."

These figures, when expressed in terms of atmospheric pressure (15 pounds to the square inch, or 76 cm. Hg), are roughly equivalent to increasing by one atmosphere the pressure on one surface of the tympanic membrane. We cannot estimate the concussion effects on the ear from the presence or absence of rupture of the tympanic membrane. In men the resisting power of the healthy membrane to concussion is very great and my present opinion derived from frequent observations is that it varies greatly in different animals and is greater in man than in most animals. But that this pressure is sufficient to cause the rupture of even normal membranes is evident from the experiments of Zalewski on temporal bones obtained at autopsy. He found that there is a considerable range of variation in apparently normal membranes. With air pressure gradually raised the average bursting pressure on apparently normal drums was 120.9 cm. of mercury, though some (10.8 per cent.) burst at less than one atmosphere (76 cm. Hg). Membranes with thin spots or scars ruptured at much lower pressure than one atmosphere. But the effects produced by the instantaneous concussion of a shell will be vastly greater than that of a gradually increased pressure, so in an average group of men there are many membranes that will rupture at pressures produced by shells exploding in the neighborhood. As might be supposed concussion effects are very prone to occur should the burst occur in trench or dugout. So great, however, is the resistance of the tympanic membrane to pressure that a number are not ruptured by the shell explosion. The concussion effects are probably transmitted through the ossicles to the internal ear. Concussion deafness with no rupture of the drum have formed a large percentage of the worst cases I have seen.

PREVALENCE OF WAR DEAFNESS

It has long been known that cases of temporary deafness occur during big gunfire. In these cases, tympanic ruptures are rare. The artillery men and navy gunners are able to take precautions such as standing back of the gun, plugging the ears with the fingers or cotton, and opening the mouth when the guns are fired.

In previous wars concussion deafness was extremely rare. Gruber, who was in charge of the otological wards in the military hospital in Vienna for several years, including the war-time of 1864–1866, saw only one case of ruptured tympanic membrane and total deafness. According to Friedländer in the Franco-Prussian War there were only 12 cases of indirect injury to the hearing in the Prussian army; in the Russo-Japanese war only 101 cases were reported in the Japanese army.

I know of no available figures that can help us to form even an approximate estimate of the numbers injured in hearing, either temporarily or permanently, by shell explosions. Whatever figures I give in this paper are to be understood as of only relative value. When in France, the fronts I was stationed at were relatively quiet and cases arising from exposure to heavy bombardment were rare, so my figures only show what may be expected in times of quietness. The base hospital, at which I was stationed and which was equipped for eye and ear cases, had sent to it either for examination and report or for admission and treatment many patients with deafness of long duration, but only such as had no need for general surgical or medical care. So obviously such figures would be misleading.

In the early days of the war the large number of cases of deafness after shell explosion, the intensity of deafness, and sometimes long persistence of this symptom, gave serious ground for fearing a serious lesion comparable to that of labyrinthine hemorrhage. This is disproved by the subsequent history of cases and by the available post-mortem examinations. There have been published alarming percentages on the subject, based on conclusions from an insufficient number of cases. While total and seemingly incurable deafness is rare, yet according to Jobson [2] a large number who have been exposed to a heavy bombardment which caused severe or complete deafness for one or more days and who declare they now hear quite well, will be found on examination to have some definite signs of deafness. In a series of examinations Jobson found a large majority, more than 80 per cent., were quite unaware of being deaf.

Dr. Sohier Bryant,[3] of Boston, has recently published a statement in regard to the number of men incapacitated from injuries and diseases of the ear in the French armies, based not only on personal observations made by himself and his colleagues in the French army, but on figures given by the French war office:

"In the zone des Armées at the Front, the total sick contains 16 per cent. of ear cases in the evacuation hospitals. From the evacuation hospitals 4½ per cent. of ear cases are evacuated to the rear.

"In the rear of the zone des Armées, in the zone des Étapes, ear cases form 6¼ per cent. of total sick. These figures rise during time of inactivity at the Front and fall during military activity. Seven per cent. of these cases are evacuated from the zone des Étapes to the Interior.

"In the Interior region ear cases form 9 per cent. of total sick.

"I estimate that about 80 per cent. of the ear cases will show considerable impairment of function. This impairment will be sufficient to permanently interfere with the civil occupations of the patients. The above figures are for 1917, some of them approximate."

These figures obviously include all ear troubles, infective and traumatic, but even then they are sufficiently alarming. One recognizes that an ear damaged even slightly by the bursting of a shell is more liable to the invasion of pathogenic organisms and to suppurative processes. My experience leads me to believe that in the British forces the number permanently incapacitated from injuries and diseases of the ear is smaller than those above quoted.

Lannois and Chevanne[4] report on 1000 cases whom they had seen at Lyons up to June, 1916. These they class as follows:

1. *War-deafness in patients having auricular lesions in process of evolution, with a non-healthy auditory mechanism:*
   (*a*) Chronic suppurative otitis media .... 189 cases
   (*b*) Sclerosis of the middle ear affecting or not the internal ear .... 134 cases

2. *War-deafness in patients with healthy auditory apparatus:*
 (*a*) Simple labyrinthine concussion .... 262 cases
 (*b*) Labyrinthine concussion with rupture of the tympanum .... 82 cases
 (*c*) Labyrinthine concussion with rupture of the tympanum, followed by acute suppurative otitis media... 301 cases
3. *War-deafness or deaf-mutism from traumatic neurosis*...... 32 cases

These figures agree generally with my observations. There is one group I wish particularly to call attention to, (*b*) and (*c*) of section (2). The amount of acute suppuration following rupture is probably a fair average, but in the armies of all the combatants is in excess of what it ought to be. The fact that only 82 out of 383 escaped suppuration does not speak well for the treatment of early cases. This is no reflection on the distinguished Lyons otologists who probably saw many of the cases after suppuration had started. Otologists in the war zone are agreed that with early and appropriate treatment such a percentage can be reduced. My experience has been that in all cases invalided from the effects of shellfire the ears ought to be examined early, and the requisite treatment employed.

My observations on cases of concussion deafness near the Front are given on a subsequent page. Here it may be said that a large proportion of the men suffering from shell-concussion deafness get better very rapidly, in one ear usually more rapidly than the other; those with simple rupture of the tympanum, without suppuration, are the first to recover; about 50 per cent. of these have serviceable hearing within a month. My experience is that even those showing slight improvement at the end of one month may still improve. But the longer the delay in improvement, the less likely they are to get better. The most obstinate show clinically only signs of labyrinthine concussion.

"SHELL-SHOCK" DEAFNESS DEFINED

In considering deafness due to high explosives, one should, as far as possible, dismiss from the mind preconceived ideas. To get a fair conception of what has happened, the subject ought to be considered with an open and critical mind, and especially when one is concerned with the ear, where the intracranial connections are so extensive and so little understood.

The term shell-shock deafness has met with just condemnation from otologists. Though the term has still a fascination for the lay mind, its vagueness as a medical term must be obvious to an audience such as this and but serves to emphasize our ignorance of its pathology. Shell-shock deafness means that the patient has been made deaf by the concussion of the shell, associated, it may be, by little obvious injuries due to its bursting. In many the probability of internal injury to the nervous system must be considered. By the force of the explosion the soldier may have been blown violently against the parapet or wall of the dugout, or hurled for some distance through the air, or struck by débris from shell destruction of neighboring buildings. One man described it as a soft irresistible force pushing him up against the parapet wall, close to which he was standing when the shell burst in the trench. As a result of the explosion the men may be buried for a varying period, and as Mott pointed out, this may have an important bearing on the symptoms which follow. It must be noted that though not observable to the casual examiner a trauma to the ear is frequently present and observable to the otologist. In recent cases seen by me, minute ruptures were observed which, under ordinary conditions, would close in a week; and when no rupture was seen the congested condition of the membrane and of the middle ear indicated that the blow had been sufficient to cause considerable disturbance. In many of the cases seen some time after the concussion in which no trauma had been diagnosed at the first examination, the history of aural hemorrhage and of rotation vertigo, made it more than likely that an injury to the peripheral aural mechanism was present at the time of the explosion. But if the term "shock" is to be condemned as too indefinite, it is just as important, perhaps more so, to avoid as far as possible the terms "hysteria" and "neurasthenia." These elastic and indefinable terms are too often applied to such cases, probably less now than in the early stages of the war, and have resulted not only in an unwarranted stigma but often in disastrous effects. The cases here reviewed will be discussed in some measure to ascertain how far the psychogenic explanation can be accepted.

THE RELATION OF THE EAR TO PRESSURE

The ear is the peripheral sense organ which *a priori* we should expect to suffer greatly from concussion effects. Like all peripheral organs, it is a mechanism adapted to transform one form of external energy into nerve impulses. There are two separate and distinct mechanisms in the internal ear, one concerned with hearing, one concerned with equilibrium. Each of these mechanisms is adjusted and made sensitive to register minute pressures and transform them into nerve impulses. The nerve impulses are carried to the central nervous system there to be interpreted and utilized. In hearing, air vibrations (varying, say, from thirty-two double vibrations per second up to several thousand double vibrations per second) in various combinations are transmitted normally through the external auditory meatus to the drum membrane, which is finely swung to catch them. The vibrations are then transmitted through the ossicles and the middle ear to the cochlea, where they are transformed into nerve impulses. Nerve impulses may also be set up in the cochlea by vibrations through bone, but these so far as hearing is concerned are of secondary importance. The nerve impulses are conveyed along the cochlear nerve and acoustic path to the temporal lobe, where they enter in one definite bundle. Here they come into association with various parts of the cerebrum. The route from the periphery to the temporal lobe is not one undivided path. To put it roughly, there is not one telephone wire from the ear to the receiving and interpreting station in the cortex. The path is broken at various synapses or junctions or telephone exchanges. At these synapses connection is made with other nerve paths, and communication can be and is established with other physiological systems. What the significance of this probable interchange may be we do not know. Possibly the directing of the eyes to a source of sound and the erection of the ears in animals are among them.

The other pressure mechanism in the internal ear is a system of canals containing fluid, a manometer, designed to register and signal to the central nervous system movements of the head. This mechanism is adjusted to indicate very small varying pressures. Here also in the central path we have numerous synapses influencing other cranial pathways, somewhat better, though still very inadequately, understood. The information so obtained from the vestibular peripheral mechanism is coördinated with information received from other sources (the eyes, joints, etc.) and enables the muscular mechanism to adapt itself rapidly to varying alterations of our centre of gravity to preserve the equilibrium—for instance, to maintain the erect posture during movements of the head.

There are certain limits of pressure normal to these two mechanisms. Pressure beyond the normal produces disturbances which are pathological. Disturbances of hearing may cause hyperacusis, hypoacusis or total deafness. Disturbances of the canalicular system produce disturbances of equilibrium—for instance, vertigo and nystagmus.

PATHOLOGICAL EFFECTS OF EXPLOSIVES

Injuries to hearing due to shell explosions may be:

1. Temporary—lasting a few minutes or a few hours, and probably due to hyperæmia in the middle ear or the internal ear.

2. Persistent over long periods or permanent, due to a lesion in the hearing mechanism—to the drum membrane, or the middle ear, or the internal ear, or disturbances in the acoustic path or central mechanism from minute hemorrhages.

Our knowledge of the pathological effects of explosives on the ear has come largely from the experimental work of Witmaack,[5] Yoshii,[6] and Hoeslii,[7] who investigated the results of pistol or revolver shots near to the ear of animals, chiefly guinea-pigs. Yoshii, whose work is the most complete, experimented in two series: (1) Effects of firing a single shot and (2) effects of firing repeated shots, daily, over a definite period. Some of the animals were killed at once, others were kept alive for a varying number of days—up to sixty. His findings in the first series may be thus briefly summarized: There were very constantly rupture of the tympanic membrane and hemorrhages into the middle ear cavity. Pathological changes were present in all the coils of the organ of Corti. The hair-cells were swollen, had lost their characteristic shape and loosened from their support. Deiter's cells had lost their normal appearance and appeared as a homogeneous mass. The cells of Hensen were flattened out. The pillars of Corti were bent and the tunnel filled with a homogeneous mass probably extravasated cell contents. Nuel's space could no longer be seen.

The tectorial membrane was raised sharply up and in extreme cases its free end reached Reissner's membrane. In recent cases blood-corpuscles were seen in the Scala Tympani and in the vestibule. Immediately after the firing a change was observable in the ganglion cells of the cochlear nerve. Nissl bodies had disappeared and the chromophile substance was no longer distinguishable. In the nerve fibres changes were seen, especially in the myelin sheath.

These changes were observed immediately after the explosion and had reached their maximum in two or three days. Then a restorative process slowly set in, especially noted in the basal coil. In animals killed after eight days the pillars were straightening out, the mass in the tunnel was absorbed though the cells were not clearly outlined. Later regeneration proceeded in all the cells, but even after sixty days the hair-cells and Deiter's cells were not fully reformed in the basal coil and could not be distinguished in the other coils. At this time the ganglion cells were again nearly normal.

As a result of repeated pistol shots Yoshii found that the pillars had collapsed and all the cells had lost their characteristic shape. This was specially observable in the region at the junction of the basal coil to the second coil where a complete atrophy of Corti's organ could be seen.

Pathological observations in man as the results of high explosives are very few and this lends additional interest to the recent observations of Mott,[8] who has reported two cases of commotio cerebri ("shell-shock") without external injury. He found the veins congested throughout the brain, both in the meninges and in the gray and white matter. There were scattered subpial hemorrhages of microscopic size almost everywhere, due to rupture of the dilated congested veins, but no punctate hemorrhages such as he had described in gas poisoning. The perivascular and perineuronal spaces are seen dilated. The general appearance is similar to that observed in experimental anæmia in animals produced by ligature of both carotids and vertebrals. He thus sums up the histological changes: "There is a generalized early chromatolytic change in the cells of the central nervous system. This change varies in intensity. The cells most affected are the small cells in which the basophile substance has partly or almost totally disappeared. In the larger cells the Nissl granules are smaller and not packed so closely together as normal. The small cells of the medulla and pons are slightly swollen, and the nucleus is large and clear. This change is present in some of the large cells, but it is less evident. This change indicates a relative degree of exhaustion of the kinetoplasm, assuming that the amount of the basophile substance is an index of biochemical neuropotential. The Nissl granules are not present in the neurone during life, but they disappear altogether in a cell that (prior to death of the whole body) has been so injured as to decay and die. Granted this premise, then, it may be assumed that the cells of this man are in a state of commencing nervous exhaustion, some nuclei of cells show the changes more markedly than others—for example, the cells of the vago-accessorius nucleus. In the white matter of the corpus callosum, the internal capsule, the pons and medulla, there are seen congested veins and hemorrhage into the sheath of these vessels, with occasional extravasation of blood-corpuscles into the adjacent tissues."

HYPOTHESES ADVANCED TO EXPLAIN SHELL-CONCUSSION DEAFNESS

The pathology of nerve deafness from high explosives in the present war is still little known; complete pathological examinations have been few. The involvement of the middle ear seen in a large number of patients, with or without rupture of the tympanic membrane, will produce diminution of hearing, but will not account for the total deafness to air and to bone conduction as well as other symptoms which follow the explosion. We have, therefore, to look for some explanation in the inner ear or its central connections.

The following hypotheses have been advanced:

1. Pathological changes in the organ of Corti and the ganglion cells in the internal ear.

2. Hemorrhages into the inner ear.

3. Interruption of the central auditory path from small hemorrhages, œdema, etc.

4. Temporary interruption of the central auditory path from functional disturbance and not due to any organic lesion.

Mr. Sydney Scott, of London, has reported a case in which, after a bullet fracturing the vertex of the skull, with no paralysis, but great bilateral though not total deafness, the post-mortem examination showed intact tympanic membrane; no injury to the stapes, or annular ligament, or membrana secundaria; no hemorrhage into labyrinth; blood-clot in both middle ears, no fracture of the base.

J. S. Fraser and John Fraser,[9] of Edinburgh, have recently published the results of pathological examinations of four cases of concussion deafness. "Our findings," they say, "lend little support to the view that in 'explosion' or 'shell' deafness (1) large hemorrhages occur in the peri- or endolymphatic spaces of the labyrinth, or (2) that rupture of the delicate neuro-epithelial sacs and tubes of the membranous labyrinth takes place." The only changes of importance found in their four cases of "explosion" injury of the ear were: (1) Rupture of the drumhead in three cases, and hemorrhage into the middle-ear in all four. (In one a large plug of wax was present in the external meatus and probably for this reason the tympanic membrane was not injured. (2) Hemorrhage in the fundus of the internal meatus in three of the four cases at the points where the nerves enter the bony canals. In two cases the neuro-epithelial structures of the labyrinth appear to be normal. In one the changes are possibly of "post-mortem" origin, but they appear to us to be due rather to an early stage of "degenerative neuritis," while in Case 6 they

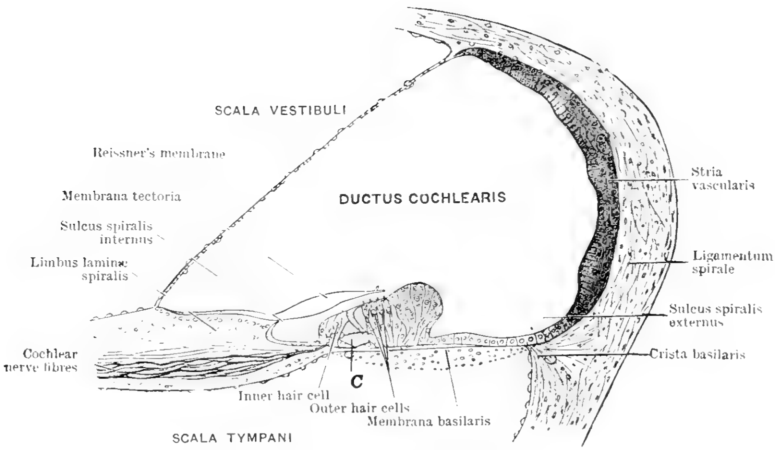


Fig. 1. Section through the ductus cochlearis (Retzius) showing the generally accepted structure of the cochlea. C = tunnel of Corti bounded by arch formed by pillars of Corti. The four rows of outer hair cells are separated by sustentacular cells (Deiters') and by Nuel space clearly seen between outer pillar and innermost of outer hair cells.

are caused by a fault in the preparation of the specimen. The vestibular apparatus, as was to be expected, showed less change than the cochlear. The neuro-epithelium of the saccule and utricle and the cells of the vestibular ganglion in the internal meatus appear to be better preserved than the corresponding parts of the cochlear apparatus. Displacement of the otolith membrane of the saccule or utricle and displacement of the cupola of one or more of the canals in two cases quite probably are artefacts. It seems quite possible that in many cases of "shell" or "explosion" deafness we have to deal with a functional affection, as suggested by Milligan and Westmacott. On the other hand, rupture of the drumhead and hemorrhage into the middle-ear spaces must cause a certain loss of hearing, while hemorrhage in the fundus of the internal meatus may give rise to deafness, tinnitus, giddiness, and other symptoms of an inner ear lesion.

I was able to secure several petrous bones while in France from patients who died shortly after injury from shells. Two have been sectioned and studied, one especially I wish to describe in detail. Very little information could be got of the case except that the man was blown up. He received abdominal injuries from which he died two days later. A piece of shrapnel penetrated the right supercilliary ridge and he was totally deaf. The right drum membrane had a small rupture in the posterior half, but there was little blood in the tympanic cavity. The petrous temporal was congested, as were also the meninges. Both petrous temporals were removed within six hours of death and the superior semicircular canals opened; the bones were placed in formalin, which was changed repeatedly. Ten days later they were placed in a tin containing formalin, hermetically sealed, and brought to Chicago, where the further examination was made.

These sections showed the following conditions:

I. The foot-plate of the stapes was uninjured (Fig. 2).

II. The ductus cochlearis showed the following important changes (Figs. 3 and 4):

1. The tectorial membrane was thrust sharply up and was attached to Reissner's membrane by serous effusion.

2. There was a small-celled exudate along Reissner's membrane, especially marked in the areas near to the attached tectorial membrane.

3. The stria vascularis was œdematous and showed hemorrhagic infiltration.

4. The basilar membrane was œdematous and showed small cell infiltration.

5. In the organ of Corti the pillars of the tunnel were unaltered. There was serous effusion and numerous small-cell infiltration which filled the tunnel and Nuel spaces. The other cells were indistinct. In some of the hair cells the hairs could be distinguished.

III. The scala vestibuli and the scala tympani had no hemorrhage.

IV. Œdema was seen, also infiltration of smalls cells throughout the area of the cochlear ganglion; in some of the ganglion cells the nuclei were well stained, but as a rule the cell contents were very indistinct. (Figs. 7 and 8.)

V. At the deeper part of the internal auditory meatus where the cochlear nerve enters the modiolus, there were dilated small veins with small hemorrhages due to rupture (by rhexis) and also hemorrhages through the interstices of the capillary walls (by diapedesis). (Figs. 7 and 8.)

VI. The vestibular mechanism was very little affected, except that there was a slight dilatation of the veins and some serous effusion and œdema. No rupture of the membranous labyrinth could be seen and there was no hemorrhage into the canals. (Figs. 5 and 6.)

These microscopic findings corroborate those of J. S. and J. Fraser, though in addition there was present the upward thrust of the tectorial membrane, so characteristic of the experimental work on guinea-pigs already referred to. These findings tend to substantiate the hypothesis that deafness from the effects of high explosives may result in distinct damage to the peripheral organ of hearing with little damage to the middle ear or the drum membrane.

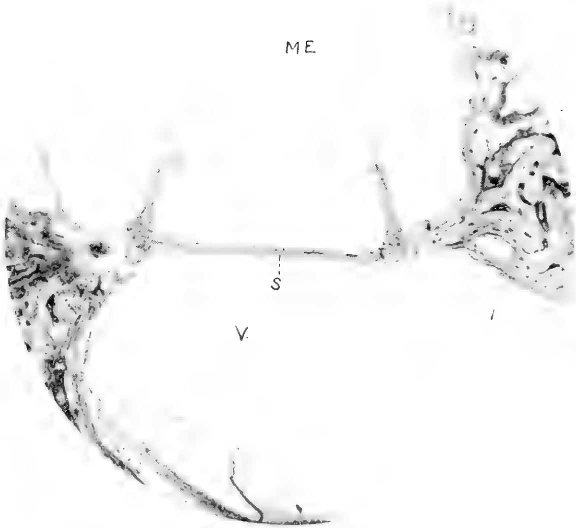


Fig. 2.—Foot-plate of Stapes (s) uninjured from case of concussion deafness. M.E. = middle ear, v = vestibule of internal ear.

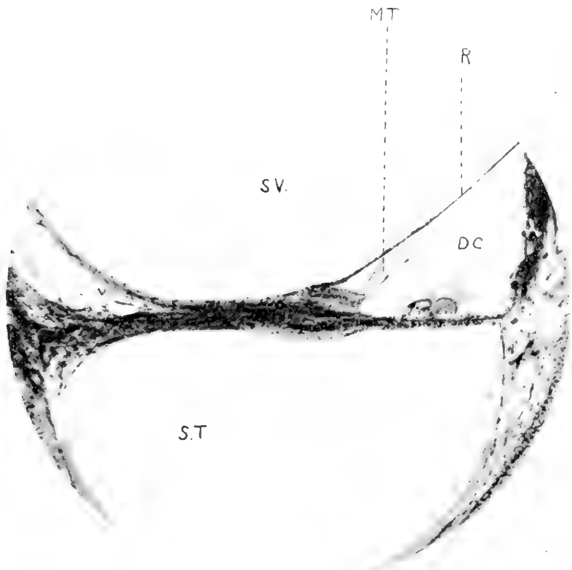


Fig. 3.—Section through cochlea from case of concussion deafness. S.V. = scala vestibuli, D.C. = ductus cochlearis, S.T. = scala tympani. M.T. = membrana tectoria, R = Reissner's membrane.

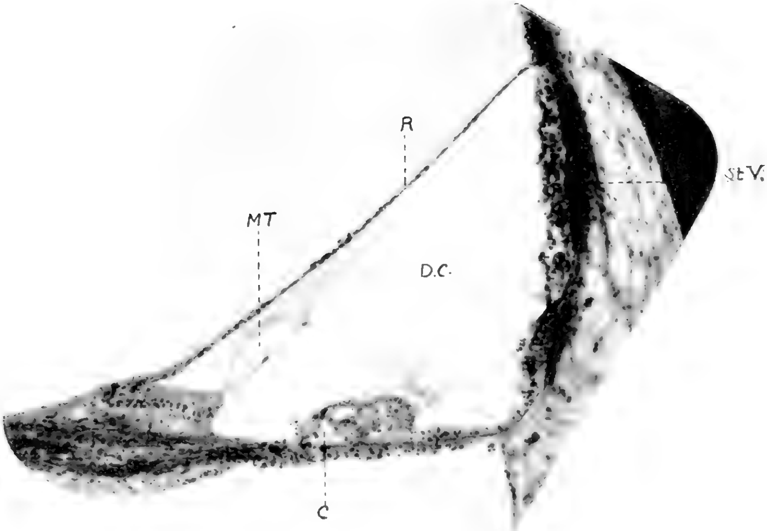


Fig. 4.—Section through ductus cochlearis, from case of concussion deafness. D.C. = ductus cochlearis, M.T. — membrana tectoria, C. = Corti's organ, St.V. = stria vascularis.

Fig. 5.—Semi-circular canal and ampulla. From case of concussion deafness. S.C. = semi-circular canal, A. = ampulla, C.A. = crista acustica with cupula.

Fig. 6.—Macula Acustica (M.A.) of utricle, from case of concussion deafness. N.U. = nerve to utricle, N.V. = nerves and vessels.

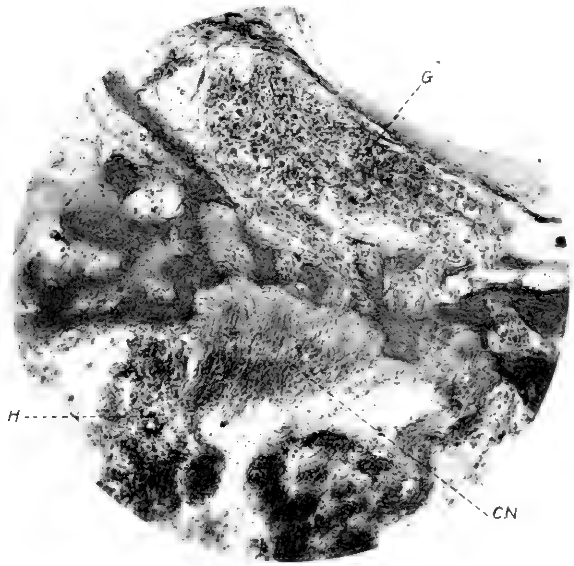


Fig. 7.—Nerves passing through lamina cribrosa at depth of internal auditory meatus. Case of concussion deafness. Small hemorrhages by rhexis and by diapedesis. (X90.)

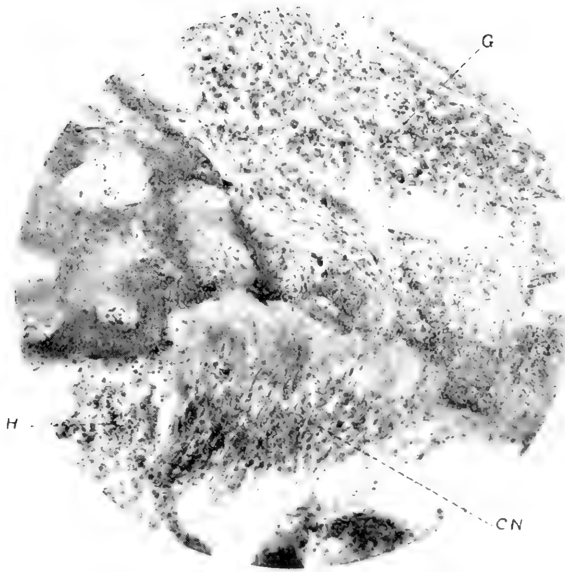


Fig. 8.– Same as Fig. 7. (X130.) C.N. = cochlear nerve, G. ganglion at base of modiolus, H. = hemorrhage.

GENERAL SYMPTOMS OF NERVE DEAFNESS FROM SHELL CONCUSSION

We are here concerned chiefly with the results of one severe concussion, followed by total or diminished loss of hearing. In some of the cases a previous concussion may have damaged the hearing, and the second made it worse, or resulted in total loss. Cases of gradual diminution of perception of sound from long exposure to gunfire do not come within this paper.

The otologist is accustomed to differentiate two types of deafness:

1. Conduction or obstructive deafness where the lesion lies in the external or middle ear.

2. Nerve deafness where the lesion lies in the internal ear or its central connections.

There are tests which enable one fairly accurately to determine which type one is dealing with. In a mixed type with both obstructive and nerve deafness, it is often very difficult to assign a relative value. In shell-concussion deafness we are, as a rule, dealing with the mixed type.

In testing cases of deafness following exposure to shell concussion, it was noted that we were dealing with a type which is not usually recognized in civil practice. The chief characteristics are:

1. That there is a diminution in the tone perception both for bone and air over the whole range of the forks.

2. When hearing is markedly diminished the diminution for the forks is marked at both ends of the scale and is least marked at about C^2 (512 dv.) and C^3 (1024 dv.).

3. When hearing is completely obliterated there may still remain a remnant to bone conduction in the region corresponding to C^2–C^3 forks.

4. With restricted tone perception, the use of a greater intensity makes it often possible to extend the area of sound perception.

In considering these findings, it is well to recall that physicists place the localization at which a minimum of energy will produce audible sounds at about 1000 dv. below rather than above this figure. Further, otologists (Bezold and Siebenmann[10]) claim that from 480 dv. to 768 dv. "is the most important part of the sound scale for hearing and understanding speech." These facts throw light on our findings that in concussion cases perception may linger for the tones C^2 (512 dv.) and C^3 (1024 dv.) while tones above and below fall below the threshold of audible sounds. It brings this area into line with the macula of the retina and its relation to vision. It makes of interest our findings that associated with concussion deafness there is frequently concentric limitation of the field of vision. In addition, since in concussion deafness increasing the intensity extends the area of sound perception, this would further strengthen the analogy; for in indirect vision the more the object is illuminated the further it can be seen at the periphery.[11] The elaboration of this subject must be left for a future paper.

NERVE SYMPTOMS ASSOCIATED WITH TOTAL LOSS OR DIMINUTION OF HEARING

The symptoms frequently associated with loss of hearing from high explosives are included by neurologists within that group of nerve diseases called traumatic neuroses. In some of our cases there is a recognizable physical trauma, in the head or elsewhere, received during a period of mental excitement. In addition to deafness, which was the chief complaint of the men who came to the otological wards, there were other symptoms varied and complex. There were present, for instance, exaggeration of tendon reflexes, tremors, vasomotor disturbances, sweatings, lethargy, sleeplessness and headaches. Vertigo with disturbances of equilibrium is commonly present and very much complained of. There was frequent concentric narrowing of the fields of vision. In many of our cases fields of anæsthesia were present. In two of our cases of total deafness there was complete anæsthesia and loss of thermal sense. In one with total loss in one ear and great diminution in the other there was anæsthesia on one-half of the body and hyperæsthesia on the other. The ear symptoms certainly accord with those which Dejerine classifies under traumatic hystero-neurasthenia. Some patients, as in neurasthenia, had hyperacusis with subjective sounds; others, as in hysteria, had the auditory acuity diminished, sometimes on both sides, sometimes on one only.

While granting that the symptoms accompanying the deafness often, but not always, fell within Dejerine's classification of traumatic hystero-neurasthenia, yet one would err if one were to insist that the nerve deafness is to be explained as due to a functional neurosis. The sudden onset of these labyrinthine symptoms and the slowly accumulating, though as yet very meagre pathological findings, make one chary of fully accepting the neurosis hypothesis in all of these cases. A study of the ear cases that have come under my observation has convinced me that in a large number the trauma has caused an organic lesion in the ear, and that, if functional symptoms be present these, so far as the ear is concerned, are secondary and subsequent to it. It is altogether possible that these functional symptoms may persist after all traces of the lesion has ceased to be capable of recognition.

CASES SEEN SOON AFTER INJURY

The cases of deafness as they present themselves soon after injury show a variety of types. All have been more or less dazed—some are admitted as stretcher cases in varying depths of stupor, in many the stupor or unconsciousness has passed off previous to admission. All have a varying amount of vertigo, but nystagmus due to labyrinthine irritation I have never seen.

I. No trauma from shell fragments and only slight injury observable in the ear.

Lance Corp. S. was knocked down and partly buried by a shell on the evening of the 22d December, 1916. He was brought into the Casualty Clearing Station early on the morning of the 23d, in a dazed condition. There is no demonstrable trauma. He lies in bed with muscles relaxed in a stupor from which he cannot be roused by pinching the skin or by loud noises. There is no nystagmus. Later in the day, while still in a state of stupor, his muscles at times are seen to be twitching, the pupils react quickly to light, the conjunctivæ are insensitive to touch. He swallows what is placed in the mouth. When disturbed he twists himself away and buries his face in the bedclothes. On the 24th he is obviously less dazed. He obeys when sharply directed by motion to put out his tongue and to turn his eyes to right or to left, during the whole time sweating freely. On the 25th he is conscious but totally deaf. He answers written questions in a whisper, though in a hesitating manner. He remembers the shell explosion and then his memory is blank until this morning. He complains of a roaring in the head and a severe frontal headache. So long as he lies still he is comfortable, but when he attempts to sit up he feels as if something were falling on him. He sweats freely. Later on in the day he was seen curled up in bed writing a letter. At this time he was able to sit up and did so without any apparent vertigo. On examination, concentric round both ears there was found a patch of anæsthesia and absence of thermal sensation. He cannot hear forks, whistle or voice. The right drum membrane is driven in and congested, is loose and freely movable, but there is no perforation and no hemorrhage. The left drum membrane is congested, not displaced, but has a small perforation near the hammer in lower half. The tubes are open. About 10 o'clock that night when he was sleeping quietly, speaking loudly to him or pinching him over anæsthetic areas did not rouse him, but when touched over the centre of forehead he awoke suddenly and in fright. He had been shocked at the Somme in June and was then totally deaf for ten days. Since then his hearing has been defective. Evacuated to base.

But the muscles are not always relaxed. Private B. admitted a few hours after being blown up by high explosive shell was in a deep stupor, from which he could not be roused. He was lying on his right side with the thighs rigidly flexed on the abdomen and the fingers clenched. The deep reflexes were very brisk and the plantar reflex was flexor in type. The pupillary reflexes were sluggish. Swallowing presented no difficulty and the attendants were able to get him to urinate. At this time the left drum membrane was normal and the right had the main vessels congested and showed through a retracted drum marked congestion over the inner wall of middle ear. Later, on recover-ing from stupor, he was found to be totally deaf. Evacuated to base.

II. A large number show signs of trauma in the drum membrane or middle ear. The damage may be slight, heal quickly, and pass unnoticed, and even where there is a considerable perforation, pain in the ear is rarely complained of and the hemorrhage may pass unnoticed. Months after a large number show defective hearing which they trace to the explosion.

H. G., 12 C. C. S.: Examined December 21, 1916. No previous ear trouble. On 15th December, 1916, a shell burst and threw him six feet. Though dazed, he was not unconscious. There was no nausea. He had rotation vertigo for three or four days and now feels as if he would pitch forward in walking. He denies hemorrhage from ears. Each tympanic membrane has a large irregular posterior perforation showing the head of the stapes. There is blood-clot in the middle ear but no suppuration is present. The left membrane has its anterior part pushed on to the internal wall of the middle ear, leaving the hammer projecting forward and apparently undisturbed. In both ears C (128 dv.) is not heard by air but is heard by bone. C^2 (512 dv.) is heard but diminished—90 seconds by air and 30 seconds by bone. C^3 and C^4 are not heard. The Galton Edelmann whistle is heard if blown loudly. In both ears conversation voice is heard at 20 inches. There is no Romberg; equilibrium is good, except on bending, and very little tremor.

Private E. C. B., 207 R. G. H., 2d Canadian C. C. S. Previous illness: In winter of 1915 had double otorrhœa following rhinitis from which he recovered completely.

On December 7, 1916, he was knocked over by a shell and dazed. He had no aural hemorrhage; no nausea, but was dizzy and deaf. The ear was washed out with hydrogen peroxide and he had rotation vertigo and fell over. Whenever he blew his nose he got dizzy. Seen December 13, in 2d Canadian C. C. S. Complains of deafness and hyperæsthesia of meatus. There is a constant tendency to shake ear with finger in meatus. Has severe tinnitus all the time. No nystagmus. When walking staggers (to right). If he shuts eyes, gets dizzy and sways, but to no particular side; feels as if going from left to right; with eyes open, objects appear to go back and forward. Even with eyes open cannot stand on either foot; dizzy if he bends to tie his boots. Pointing poor. Frontal headache. Right membrana tympani has small perforation. Left membrana tympani normal. Tubes open. Hears voice close to either ear, slightly better in right ear. Rinne positive in right—in left is either indifferent or negative. Weber to left. Bone conduction diminished in both ears. Can distinguish loud, sharp whistle.

Testing with the forks give:

Right ear—C(64)=O; C(128)=O. C^2(512)=heard, diminution 86 seconds by air and 25 seconds by bone; C^4 = O.

Left ear—C(64)= O; C(128)= O. C^2 = heard, diminution of 80 seconds by air and 15 seconds by bone. C^4 = O.

Sent to base.

SUMMARY

Of 22 cases examined soon after the shell explosion with nerve deafness, 18 had demonstrable lesions of the drum membrane. Four had no demonstrable lesion, and of these four, 3 had history and indication of old trouble. Only 1 had no previous ear trouble or no demonstrable trauma.

In one Stationary Hospital, to which cases of shell-shock were sent, including cases of shell-shock deafness, I saw 200 cases with little or no trauma exhibiting nerve symptoms ascribed to high explosives. Of these, 50 complained of deafness of varying degree. Of these 50, 17 showed demonstrable signs of injury to the internal ear traceable to the explosive. Of the other 33 the deafness had been temporary and no objective signs of disturbance of equilibrium could now be seen. The persisting defect of hearing in many of these was due to middle-ear involvement; in some of old standing; in others to blockage of the external canal from wax or some other cause. Of the 17 cases, 7 had symptoms of nerve deafness without perforation of the membrana tympani; 10 had deafness with signs of perforation; 6 had definite middle-ear trouble previous to the concussion; of the other 11, with no previous history of ear trouble, 6 had recent perforation; 12 complained of vertigo and had observable signs due to it; the others had, when examined, no symptoms of equilibrium disturbances.

A large proportion of the men suffering from shell-concussion deafness get better very rapidly, in one ear usually more rapidly than the other. My experience is that even those showing slight improvement at the end of a month may still improve. According to Lannois and Chavanne those with simple rupture of the tympanum without suppuration are the first to recover; 43 per cent. were cured in one month; 33 per cent. in two months; 12 per cent. in three months; the others required four, five, seven and eight months (2 cases). Simple labyrinthine concussions are the most obstinate; their figures give 24 per cent. of cures in one month; 22 per cent. in two; 19 per cent. in three; 12 per cent. in four; the others vary from five to nine months.

VERTIGO IN CASES SEEN SOON AFTER EXPLOSION

Next to deafness vertigo is the chief complaint. It is very difficult in many to estimate the amount of vertigo which is present. Vertigo is a subjective sensation and subjective sensations are difficult to describe; the average individual has a very indefinite idea of what medically we mean by dizziness and often includes in the term all variations in cerebral consciousness. But even moderately severe labyrinthine vertigo is accompanied by some objective signs such as nystagmus, pointing error, or other signs of unstable equilibrium as may be produced by shutting the eyes on standing or walking. Of eighteen men who complained of severe vertigo with deficient hearing due to recent injury from shell explosions and who were carefully examined for signs of vertigo, twelve gave a distinct history and showed signs of labyrinthine vertigo. In many the objective signs of vertigo pass away quickly. The greater number were comfortable so long as they remained quiet or moved slowly. Vertigo was experienced if the head were placed quickly in an unusual position and was especially apt to occur on bending. There did not appear to be any relation between the return of hearing and the disappearance of the vertigo. Six had no objective signs of vertigo. D. had been knocked out with slight deafness. C. had large double perforations and wounds on extremities of both sides which kept him absolutely quiet in bed. In G., though the perforation was large, the deafness was chiefly of middle-ear type. H., whose hearing had been bad before enlisting, had deafness largely due to middle-ear conditions.

My conclusions from observations made in France and forwarded to the Headquarters of the C. A. M. C. were:

1. Exposure to high explosives may produce rupture of the membrana tympani. This rupture may occur at any part of the membrane. It varies in size and two perforations are occasionally seen. Small perforations are most frequent, but there may be a large perforation. The force may be so great as to dislocate the malleus and drive it in on the promontory.

2. The rupture in the membrana tympani tends in most cases to spontaneous closure. Its non-closure is usually due to its large size, or middle-ear suppuration following the rupture. Appropriate treatment hastens healing and diminishes the risk of suppuration. Resulting adhesion of the malleus to the internal wall of the middle ear is not infrequent.

3. Concussion of the internal ear with nerve deafness and equilibrium disturbances occurs with or without rupture. In many the concussion passes off with slight damage to hearing, though equilibrium disturbances may persist for a considerable period.

4. The concussion may pass off, leaving an injured nerve mechanism demonstrable by (*a*) nerve deafness of a varying degree; (*b*) defects of equilibrium.

5. The treatment of recent perforated membrane which gives most satisfactory results aims at cleaning the external meatus and leaving the blood-clot over the perforation intact. The following has been found satisfactory: A plug of cotton is placed in the meatus and the lobe of the ear is cleaned and dried. The plug is removed and then the outer part of the external meatus is cleaned by pledgets of cotton dipped in hydrogen peroxide. The meatus is then dried and washed with pledgets dipped in alcohol and again dried. A piece of sterile cotton is then placed in the ear. The ear ought to be kept dry.

6. All the cases sufficiently severe to be sent to a Casualty Clearing Station ought to be kept in bed for at least ten days to allow the effects of the concussion to subside, thereby the man's return to his unit may frequently be hastened.

7. High explosives may cause a definite injury to the internal ear and its central connections. The diagnosis requires considerable experience. Speedy recognition of those injured by high explosives with appropriate treatment means more rapid recovery of hearing, diminution of subjective symptoms of vertigo, so apt to persist, and subsequent military usefulness. The figures given above show that in a considerable proportion of the cases of deafness following exposure to high explosives examined within three or four weeks after the exposure, no trauma in the internal ear could be demonstrated, and the deafness then present was accounted for by some other cause. In view of these facts an otologist of experience ought to be available at appropriate centres.

CASES SEEN SOME TIME AFTER INJURY

The base hospital to which I was assigned was at Folkestone, that old Kentish town where William Harvey was born in 1578. The hospital looked out on the square where the townsfolk have erected a statue to perpetuate the memory of his birth. The monument crowns the Leas, as the elevated seaside promenade is called, and overlooks one of the most beautiful stretches of the English Channel with the coast of France outlined on the distant horizon. The hospital has been especially provided by the Canadian authorities for eye and ear injuries and diseases. All the staff were specialists in the eye or ear, and at that time the commanding officer was a well-known eye and ear specialist from Ottawa.

CLASSIFICATION OF CASES

The cases of deficiency in hearing following exposure to, or injury from high explosives, seen by me at the base hospital, date their onset back anywhere from two months to eleven months. It was not judged sufficient to take the patient's statement that he had been exposed to shell-fire. It was necessary to have at the time of examination symptoms pointing to such or an official record supporting the statement. All have been under treatment since the injury, many in the care of competent otologists. In a great number the deficiency in hearing was due to conduction deafness traceable to injury to the middle ear; for instance, injury to the membrana tympani or to middle-ear suppuration following rupture. Consideration of these is not included in this paper.

The cases of nerve deafness can be divided into three groups:

1. Those with nerve deafness.

2. Those who have had nerve deafness of a varying degree, and who, with a varying amount of indefinite nerve symptoms, have still the fixed idea that they cannot hear. This group includes all cases of patients who hear without being conscious of doing so.

3. Malingerers. The majority in this group undoubtedly have had shell concussion which affected the hearing for a time. At the time of examination many still showed traces of traumatic neurosis. But the defective hearing had now been recovered from partially or entirely and they were consciously exaggerating the defects still remaining or consciously claiming its persistence.

It is a difficult matter to separate the second group from the third. Experience, the general condition of the patient, his answers to the test questions, largely aid the examiner. The following may be given as an example of Group 2:

Private De S.: Admitted October 1st because of total deafness in right ear. Severely wounded in head by bullet on May 28, 1916; unconscious for several hours; when recovered consciousness was deaf in right ear. Has a depression (5.2 cm. by 1.5 cm.) in the right parietal bone near interparietal suture through which pulsation of brain can be seen. Right membrana tympani slightly retracted, otherwise normal; tubes open; no hearing for voice or forks. Left membrana tympani normal; hearing for voice and forks normal. No paralyses, no anæsthesia, no astereognosis, no tremor, no Romberg. Eyes: Movements normal; fields normal; fundi normal; vision in both 6/9. To examine the vestibular mechanism the caloric test (cold) was applied to right ear. The normal vestibular reaction was quickly obtained and immediately after the voice of the examining officer was heard in right ear at room length (7 yards) and whisper at 20 inches. No suggestion was made in this case.

To this second group belong cases that yield to suggestion or recover hearing rapidly, often completely, after excitement or intense stimulation. To discuss the third group and how the malingerers can be detected is outside the limits of this paper.

CASES OF NERVE DEAFNESS

The cases now to be considered have been exposed to and damaged in some way by the shell explosion. It was not possible in a military hospital on the lines of communication to keep patients long—all one could hope to do was to keep as long as possible those promising improvement and to outline further treatment.

As stated above, cases are not now considered in which a trauma to the ear has come from the explosion but in which, when examined, the deafness was middle ear in type and in which little or no evidence of nerve deafness now was present. Further, there are eliminated cases of gross damage to the middle ear or the external meatus from pieces of shell or shell contents, even though accompanied by nerve deafness. My endeavor will be to consider cases showing the effects of high-explosive shells on the ear without any wounds to the temporal bone other than those due to the explosive force. In some there were present injuries from pieces of shell in parts of the body more or less remote from the ear—but in these the trauma could not have damaged the internal ear. The majority of the cases under review had vertigo in a varying degree, but this symptom I am not here considering. Many were examined in whom the nerve deafness had almost, if not entirely, disappeared, but in whom disturbance of equilibrium was still complained of and in some objectively present.

The number of cases of persisting deafness after shell explosion is still very much in doubt. This is shown by the following quotations from competent otologists:

"War deafness in patients with healthy auditory apparatus: The intensity of deafness exhibited by soldiers suffering from labyrinthine concussion, and sometimes the long persistence of this symptom, gave, at the outbreak of hostilities, serious ground for fearing a functional importance comparable to that of labyrinthine hemorrhage. Some authors, prematurely drawing conclusions from an insufficient number of cases, have published alarming percentages on the subject. Labyrinthine concussion, however, is most frequently a question of simple shock, not a definite lesion. Of 262 cases of *simple labyrinthine concussion* we have had only 5 per cent. of almost total and seemingly incurable deafness." (Lannois and Chavanne, *loc. cit.*)

A large number who have been exposed to a heavy bombardment which caused severe or complete deafness for one or more days, and who have declared they hear quite well, will be found on examination to have some diminution of hearing. According to Jobson [2] a large majority—over 80 per cent.—were quite unaware of being deaf. We have no reliable statistics. But it can be said that even at the best a large number of men are left at the end of two or three months with impairment of hearing and showing little or no tendency to improve. If left alone, they are not likely to improve. The question then arises what can be done for them to better the remnant of hearing still present. To this I will now direct your attention.

In my work it was early observed that when certain forks could not be heard by air or bone, by summation of stimuli it was possible to get the note perceived through the mastoid. To make sure that this was so, the patient was required to hum the note. It was further noted that after repeated applications of the fork the time required for the perception of the note gradually diminished and that at this period he was able to perceive the note passed into the ears by tubes attached to resonating boxes. With these observations as basis, the following treatment was adopted—varying in accordance with the degree of deafness present:

1. Tuning-forks are applied: (*a*) To the bone (the mastoid); (*b*) through resonators, attached to the ear by tube; (*c*) through the air. In our worst cases the time given to (*a*), (*b*), or (*c*) varied with the amount of deafness.

2. The voice is used: (*a*) Through resonators with tube in ear; (*b*) with speaking tubes; (*c*) without any aid. Each period of treatment is short, for fatigue is rapidly produced. If the treatment be too long, headaches, vertigo, and occasionally pain in the ear is complained of and profuse sweating is very frequently present.

3. In those complaining of total deafness, as early as possible it is ascertained if the semicircular canals are functioning, because when there is reaction to the caloric or rotation tests one feels justified in continuing treatment for some time.

4. As soon as possible carefully graduated physical exercises are given. In exercise the two essentials are short duration and no bending. The treatment (except the drill) is given twice a day in the worst cases; it ought to be given twice in all.

In the totally deaf to voice it is sometimes difficult to pass from bone to resonator; in these we found it convenient to use the resonating box of the piano. We find that at each successive stage we have to use summation of stimuli; thus, not only must the fork on the resonator be kept up for some time, but with the voice we have to repeat the word, and even then there is a marked delay before the response comes. In the later stages the delay is still present. Then it appears to be not so much that he does not hear, but that he hesitates to attach the word to the sound, for, if asked what he thinks it is he frequently answers correctly. In some cases in which an ear was totally deaf with a vestibular mechanism reacting normally, we failed to get any response. In those who had not total deafness but some perception of sound, for instance, through bone, all improved—some very considerably.

The following examples may be given:

Gunner R. Previous to enlisting, defective hearing in *left* ear sufficient to exclude him from Australian Government telephone service. On July 30, his battery was struck by a shell, and he was blown up. Does not remember anything for three days (unconscious?), then rotation vertigo, great nausea, deaf in both ears. Hearing came back gradually in *left* ear after twelve days without treatment. No return of hearing in right ear.

Admitted September 14, 1916. Right ear—membrane normal, no hearing for voice or forks. Left ear—membrane normal; hearing for conversation voice two yards; cannot hear whisper. C^1 and C^2 heard; C^3 and C^4 on increased intensity. Bone conduction diminished. Severe vertigo at times.

Treatment began 17th September. September 20—in right ear hears voice through resonator. October 3—hears voices at 12 inches in right ear. October 7—hears voice at two feet in right ear. October 12, 1916, sent to the C. C. A. C. with this report: Conversation voice, in right ear—20 inches; in left ear—5 yards. Sent to convalescent hospital.

Private H. Age, 22. Iron moulder. Complaint—partial deafness in right ear, complete deafness in left; tinnitus and headache. Vertigo not complained of. No previous ear trouble.

June 28, 1916. Blown up by shell explosion; piece of shell caused scalp wound over left parietal; unconscious for several hours; hemorrhage from left ear and ear discharge for five days.

Seen September 14, 1916. *Right ear*—conversation voice, 2 yards; loud whisper close to ear. Membrane retracted. 64 dr. and 128 not heard. C^1, C^2, C^3 heard. C^4 not heard. Bone conduction diminished; Rinne positive.

Left ear—drum congested—no perforation. No hearing for voice, forks or whistle. Hears C^2 on summation of stimuli. Both tubes open.

September 17. Right ear, 7 yards; whisper, 9 inches—all forks. Left ear, 4 yards; whisper, 2 inches. Forks, C^1 and C^4.

October 15. Right ear, normal; whisper, 24 inches. Left ear, 7 yards; whisper, 15 inches—all forks.

Private L. Dublin Fusileers. Complains of deafness and tinnitus. No previous ear trouble.

August 6, 1916. Blown up; not unconscious; no hemorrhage from ears, no otorrhœa; complete deafness. Later, left ear recovered hearing slightly.

Examined October 9, 1916. *Right*—drum membrane vessels markedly dilated, small area of relaxation. No hearing for voice or forks. Caloric in right produced marked nystagmus with four ounces of water at 65° with dissociation of eye movements.

Left ear—drum membrane normal—hears voice at 5 feet and all forks. Bone conduction diminished for all the forks.

Fields concentrically contracted within 10 mm. ring. Nose and nasopharynx normal; tubes open.

October 16. Hears all forks with right ear. Air and bone conduction diminished as follows:

	Right Ear		Left Ear	
	Air	Bone	Air	Bone
128 dv.	— 46 sec.	10 sec.	37 sec.	26 sec.
256 dv.	— 70 sec.	20 sec.	107 sec.	20 sec.
C^2	— 50 sec.	22 sec.	35 sec.	25 sec.
C^3	— 4 sec.		3 sec.	
C^4	— 7 sec.		6 sec.	

October 31. Conversation voice at 5 yards in left ear and with noise apparatus in left hears voice in right.

November 18. Left ear, 7 yards. Right ear, 3 yards.

Private H. No previous ear trouble. On June 18, 1916, after two months in France, "blown over parapet" for 10 feet and became unconscious for some hours; totally deaf in both ears.

Examined September 4, 1916. Right membrane congested; left retracted and congested. Totally deaf in both ears to voice, forks and all sounds. Can distinguish and differentiate C^1 and C^2 on right mastoid by summation of stimuli. Mentally clear and intelligent; bilateral anæsthesia; no thermal sense for heat and cold; deficient sense of position for elbow, wrist and fingers; easily fatigued; irritable; if eyes are closed frequently drops off to sleep; taste accurate but weak; concentric limitation of fields of vision. Vertigo, staggers if eyes are shut. Frequently complains of tingling and itching in the ears. (N. B.—This is a frequent complaint in these cases.)

September 14, 1916. Gets notes on the piano, note corresponding to C^2 (512), down two octaves by right ear, and all forks over right mastoid. Galton whistle at right ear not heard, but feels like a prick of a needle. (N. B.—Because of the tendency to rapid fatigue, treatment very brief and chiefly confined to right ear.)

October 4, 1916. Hears all forks over mastoid in both ears. Right ear—hears tuning-fork over resonator connected to his ear by a tube at 16 inches. While listening perspires very freely. Sings tunefully and rhythmically.

October 20. Hears in right ear short sentences with the aid of a speaking tube, and in left ear words spoken into a resonator connected to the ear with a tube. Caloric in left gives reaction with 4 ounces of water at 66° F.

On October 30 the right ear was carefully examined for tuning-fork perception, and it was found that he could not hear below C^1 (256), but could hear C^2 (512) and C^3 (1024), and on increased intensity C^4 (2048).

November 10. With a speaking tube (a glass funnel and piece of tubing) hears well and can carry on a conversation. Hears without tube if one speaks fairly loud.

Private K. Age, 23. Ranchman. Previous health good and no ear trouble.

June, 1916, blown up and partly buried; unconscious for 24 hours; hemorrhage from left ear. Complete deafness in both ears.

Examined August 21. Memory very deficient; difficult to get information of past events; has brothers, but does not know how many; not quite clear as to what he did previous to enlisting; cannot remember his movements in France. When tries to remember gets worried and irritable; not sure if he dreams, but knows that wakens with a start and often with a cry. Complains of being always dopey and of hot and cold flushes. If bends head, staggers as if drunk.

Right ear—membrana tympani normal; C^3 only fork heard on increased intensity. No hearing for voice.

Left ear—membrana tympani intact, but with adhesions to posterior wall. No perception for voice or forks.

Tubes open. Naso-pharynx normal.

August 28. Treatment only to right ear. Hears C^1 over right mastoid on prolonged contact. Hears by air C^2 and C^3 on increased intensity.

September 1. On getting up this morning had severe attack of rotation vertigo.

September 2. Range of all forks in right ear and voice at 1 foot.

September 10. Ordinary voice at 18 inches. Does not now shout but speaks in lower tone.

September 16. Got excited over quarrel with room-mate and sent to psychopathic wards of Moore barracks. Seen several weeks after and hearing showed slight improvement.

Private B. Cook. Deafness in right ear and deficient vision in right eye. No previous ear or eye trouble.

In August, 1916, was in dugout when shell hit it. Unconscious for several days, then could not see in either eye. Deaf in right ear; dulness of hearing in left and tinnitus. Marked rotation vertigo and fell when got up.

Examined November 14. Right ear—membrane has marked depression over anterior half; no hearing for voice or forks. Bone conduction diminished. Left ear—membrana tympani and hearing normal. Fields of vision: Right eye—perimeter chart shows visual field much restricted below. He is blind in lower nasal quadrant and lower temporal quadrant is markedly contracted. Left eye, normal.

November 24. All forks in right ear—voice at 4 yards. Right eye—field unaltered.

Gunner B. June, 1916. Shell exploded in pit where he was; blew up ammunition and killed 5 out of 7. Unconscious for four hours. No hemorrhage from ears but vertigo. Completely deaf.

In left ear hearing began to return in about three weeks. Right came back slower.

Examined September 17. Right drum membrane slightly retracted; hearing for voice 3/20. Left normal in appearance, but adherent to the posterior wall. Hearing 5/20.

Right ear—C_1 and C not heard; C^1 and C^2 heard; C^3 and C^4 not heard. Left ear—C_1 not heard; C and C^1 and C^2 heard; C^3 and C^4 not heard.

Duration of forks for *air* conduction diminished greatly in both ears; *e.g.,* in left ear C^1—30 to 40 seconds; C^2—25 seconds. Tubes open. Bone conduction diminished. Rinne unsatisfactory.

Fields of vision contracted. Fundi normal. Deficient sensation over body for touch and thermal sense. Marked vertigo; very slow rotation produced nausea.

October 6. Voices heard in right and left ears at 4 yards. C^3 in both ears; C^4 in left; C_1 not heard in either ear.

October 18. Voice heard at 6 yards in both ears.

Private H. Deafness and discharge from left ear. No previous ear trouble.

March 26, 1916. Blown up, buried, unconscious for one hour. Hemorrhage from nose, none from ear, deafness from which never completely recovered. Could not be trusted to get or deliver messages because of deafness. Returned to lines.

June 3, 1916. Blown up and buried. Hemorrhage from left ear, and since then otorrhœa and deafness.

Examined September 14. Right ear—membrana tympani thickened and retracted. Tubes open. Voice at 2 yards. Left ear—large perforation, mucopurulent secretion. Conversation voice—2 feet and whisper close to ear. Bone conduction diminished. In left ear forks show: 64 and 128 not heard; C^1 and C^2 heard; C^3 and C^4 not heard; whistle not heard. (Zone of tone perception in left ear clearly marked, but because of otorrhœa no stimulation of hearing with forks.)

Thirty-four cases of concussion injury, showing nerve deafness of over three months' duration *without* perforation of the tympanic membrane, were examined in October and November.

1. Of these seventeen were given the treatment above mentioned, and improved.

2. Three showed evidence of improving hearing when they first came under observation, received no treatment, and continued to improve.

3. Two had slight deafness but marked tinnitus and vertigo.

4. The other twelve showing no improvement may be thus classified:

Three had section of the VII nerve from bullet wound outside the skull. Deafness with injury to the facial nerve have shown no tendency to improve.

Two had total deafness in one ear (good hearing in the other) and gave no vestibular reaction to caloric test.

One had Ménière syndrome associated with old radical mastoid.

Two had had severe cranial concussion—S. had been struck also by bullet over frontal; L., a dispatch rider, was blown up by a shell bursting under his machine.

In four no explanation could be offered. Of these four—two totally deaf, left ear; one markedly deaf, left ear; one markedly deaf in both ears.

During that time among the men sent down for concussion deafness, eight had had concussion deafness and now were classed as malingerers or suffering from the fixed idea that they could not hear.

Many of the cases seen *had perforation* of the tympanic membrane and in these suppuration of middle ear was frequently present. In these the deafness was a combination of conduction and nerve deafness. It was impossible to assign the relative amount of deafness due to each. In these, treatment was first directed to check the otorrhœa, and acoustic stimulation was not given till the suppuration had stopped. Our records of results date from this time, and in thirty-four cases—19 showed improvement, in some markedly so. It might be urged that improved hearing may have followed cessation of the ear discharge, but the records for the forks and the bone conduction changes show that something else was at work than the middle-ear improvement.

GENERAL RESULTS

Examination of the tuning-fork records of shell-concussion cases of deafness give the following interesting results:

1. There is a lack of perception of the forks at both ends of the scale, and the perception for all forks is diminished for air conduction and for bone conduction so far as these could be tested.

2. There never were found gaps in the hearing of tones as figured by Bezold [12] in deaf mutes. It would appear that the remnant of hearing left for tone perception is best considered as the apex of the normal curve of tone perception which curve has as a result of the injury fallen as a whole below the threshold of perception. This is strengthened by the fact that in some increase of intensity will increase the limits of perception.

3. The last note to disappear is somewhere near the frequency of C^2–C^3; and the first to be perceived by air is also near this frequency. It is interesting to associate this with physiological findings that it is near this frequency that the minimum intensity gives perception.

SUMMARY

1. In deafness resulting from concussion due to high explosives, there is frequently a trauma demonstrable in the ear. The perception of sound is diminished over the whole normal range both for bone and air conduction. This diminution may be so great as to totally abolish perception of sound.

2. In the totally deaf who improve, bone conduction is perceived before air conduction. In these cases summation of stimuli plays an important part in the perception of sound. It is essential to differentiate vibrations from musical notes.

3. There is a marked diminution of the duration of hearing along the whole series of forks, both through bone and air.

4. The normal stimulus (musical notes or voice) is an adequate stimulus for the nerve and is the best stimulus. Electricity is contraindicated and likely to do harm since it so easily produces vertigo.

5. If the conducting mechanism is damaged or destroyed, it not only takes longer to get improvement, but complete recovery cannot be expected.

6. As the deafness diminishes there may persist for a long time an inability to grasp intelligently what is said or to retain the memory of it. Thus a word may have to be repeated two or three times before the patient gets it; or, if he be asked to repeat two or three numbers given consecutively, he will repeat the last one; he knows that there were others but "did not get them."

7. Pathological examinations show that the auditory mechanism may be seriously damaged while the vestibular shows little or no change. Therefore the vestibular mechanism may react to stimulation in cases where the cochlea is seriously damaged.

8. Prognosis is good, as a rule, especially in cases where there is no trauma demonstrable in the peripheral organ, no marked history of aural vertigo, and a normal caloric reaction. The most noteworthy exception met with so far is damage to the seventh nerve. In these cases, if hearing returns, it returns but slowly, and so far as we have observed very imperfectly even with a normal drum membrane, little if any signs of middle-ear inflammation, and a caloric reaction present.

9. The frequency of labyrinthine symptoms immediately following the atmospheric compression and decompression from the shell burst speaks against an exclusive view of the psychogenic explanation of the deafness. The percentage of early recovery speaks against any very serious damage to the peripheral organ of Corti. My early investigations, based on clinical observations, led me to believe that in many of the cases we were dealing with some ultra microscopic change probably at the synapses. But my recent pathological observations have led me to believe that while this is so in some, yet organic changes in the peripheral organ and its nerve offer a more satisfactory explanation for the deafness and vertigo.

The progressive recovery of hearing, so constantly observed, suggested in the light of our pathological and experimental knowledge, that we are dealing with injuries of the nature of contusions with œdema, capillary hemorrhages, changes in the myelin sheaths and molecular changes in the nerve-cells. That in the majority of concussion cases we have a marked destruction of the organ of Corti or a definite lesion of the auditory cortex appears to me doubtful, for in both of these regions we are dealing with a highly specialized structure in which regeneration would be unlikely.

REFERENCES

[1] Mott: Lettsonian Lectures. Transactions of the Medical Society of London, xxxix, 160 and 172.

[2] Jobson, T. B.: Lancet, 1917, 566.

[3] Bryant, W. S.: Journal of Laryngology, Rhinology, and Otology, 1917, Nov., 338.

[4] Lannois and Chavanne: Lyon Médical, 1916, cxxv, 35–40.

[5] Wittmaack, K.: Über Schädigung des Gehörs durch Schalleinwirkung, Ztschr. f. Ohrenh., 1907, liv, 37.

[6] Yoshii, U.: Experimentelle Untersuchungen über die Schädigung des Gehörsorgan durch Schalleinwirkung, Ztschr. f. Ohrenh., 1909, lviii, 201.

[7] Hoessli, H.: Weitere experimentelle Studien über die akustische Schädigung des Saugetierlabyrinths, Ztschr. f. Ohrenh., 1912, lxiv, 101, and 1913, lxix, 224.

[8] Mott: Brit. Med. Jour., 1917, Nov., 10.

[9] Fraser, J. S., and Fraser, John: Journal of Laryngology, Rhinology, and Otology, 1917, Nov., 340 and 369.

[10] Bezold and Siebemann: Textbook of Otology, Chicago, 1917, p. 71.

[11] Luciani: Human Physiology, London, 1917, 4, p. 339.

[12] Bezold and Siebemann: Otology, p. 53.

CERTAIN ASPECTS OF THE APPLICATION OF ANTISEPTICS IN MILITARY PRACTICE *

Dr. E. K. DUNHAM.

IT will be my endeavor in this lecture to bring together, in some sort of consecutive form, the essential facts concerning the chlorine group of antiseptics, their action and the principles underlying their successful application in surgical practice.

We may distinguish chlorine in three conditions: First, as free chlorine in the gaseous condition or compressed to liquid form; second, compounds in which the chlorine is "available" or "active;" and, third, fixed chlorine, so firmly in stable combination that it is no longer "available" or "active," and is also devoid of antiseptic potency. Of these three states, the free chlorine is, in general, the most reactive; *i.e.*, the most prone to seek combination with other elements. It may have either a direct chlorinating or an indirect oxidizing action upon substances with which it comes into contact, depending upon the nature of the substance, the absence or presence of water and various physical conditions, such as temperature, exposure to light, etc. The reactivity of free chlorine is of such a high order that its use in surgical and medical practice is extremely limited. Even in very dilute solution it is highly irritating and the mass of chlorine that can be applied is consequently very limited, too small, in fact, to be of material value for disinfection in the presence of any considerable organic matter. Its chief use is for the disinfection of potable waters, for which purpose it is admirably adapted because no objectionable end products remain in the water.

For surgical purposes, the so-called "active" chlorine compounds are the ones that have come into wise use and acquired a high reputation for efficiency. In those particular compounds that have proved most valuable, the chlorine is linked to either oxygen, as in hypochlorous acid and its salts, the hypochlorites,

* Delivered October 19, 1918.

or to nitrogen in the chloramines. These linkages mitigate the reactivity of the chlorine but do not preclude its entering into those reactions which result in still more stable compounds and which are also intimately related to the process of disinfection, including the killing of bacteria.

In the third or fixed state, the chlorine is displaced from the existing combination with such difficulty that no spontaneous antiseptic action is possible.

Before taking up the various members of the active chlorine group of antiseptics in detail, it seems important to point out the differences between these as a class and antiseptic substances not dependent upon chlorine for their action. Most of these, such as phenol, the inorganic metallic salts and probably other substances, such as alcohol and formaldehyde, appear to act as coagulants. The speed of the coagulation they effect, the firmness of the coagulum and the depth (penetration) to which it extends varies with the concentration of the agent and other conditions and also depends upon the particular agent employed. Many of these substances are used as fixative agents in histological technic to bring about a coagulation of living tissues with a minimum of undesirable distortion of structure, and this use exemplifies their mode of action. The active chlorine compounds do not occasion such fixation. They are not to be classed as coagulants, and in fact one of these compounds, sodium hypochlorite, the active ingredient of Dakin's solution, exerts a marked solvent action upon solid protein substances, a unique property of the greatest value in many infections, as will be presently emphasized.

Most compounds containing active chlorine are capable of liberating free iodine from inorganic iodides, such as potassium or sodium iodide, in the presence of water. This reaction may be regarded as an oxidation, as exemplified in the equation, $HOCl + 2HI = HCl + H_2O + I_2$, in which the hydrogen of hydriodic acid is oxidized to water by hydrochlorous acid. It will be noted that an atom of active chlorine is equivalent to two of iodine, a fact to be borne in mind when this reaction serves as the basis for the indirect determination of hypochlorite by titration with a standard solution of thiosulphate.

It is not surprising that these compounds should be in greater or less degree unstable, for their utility as antiseptics depends upon their reactivity at ordinary temperatures. The most important physical deteriorating influences are light and heat. Contact with acids and readily oxidized or chlorinated organic or inorganic substances also rapidly consumes the active chlorine, reducing or abolishing the antiseptic potency.

Sodium hypochlorite cannot be preserved in solid form and, in practice, must be prepared by chemical means in the solution destined for use. There are several methods for so preparing it, and under various conditions one or another will prove of greater convenience. The original method consisted in preparing a solution of calcium hypochlorite from bleaching powder (chlorinated lime). This was then mixed without previous filtration with a solution of sodium carbonate and well shaken to render the calcium carbonate which was formed granular and then, after standing, the supernatant fluid was siphoned off and filtered. The resulting solution, containing sodium hypochlorite, was more or less strongly alkaline, because a variable amount of calcium hydrate is always present in chlorinated lime. While this alkalinity rendered the hypochlorite solution more stable, it was objectionable because it augmented the irritation of the tissues with which the solution came in contact. To avoid the use of strong acids to obtain neutrality and provide "buffer" salts capable of adjusting the reaction of the solution to varying conditions of slight fortuitous acidity or alkalinity when in use, boric acid was employed to neutralize the hypochlorite solution, and sufficient boric acid was added to abolish the development of a pink color on the addition of solid phenolphthalein to a sample. The resulting solution, diluted to a hypochlorite concentration of 0.5 per cent. NaOcl, was the original Dakin's solution, which proved so efficacious in the treatment of septic wounds in France, when used with a proper regard to its chemical and bacteriocidal properties.

There have been several modifications of minor essential importance devised to facilitate the preparation of sodium hypochlorite solutions, but none of these can be entrusted to the inexperienced with the same confidence as can the original procedure.

One of these methods, devised by Daufresne to do away with the neutralization with boric acid, consists in the use of a mixture of sodium carbonate and bicarbonate in the preparation of the hypochlorite from chlorinated lime. The purpose of the bicarbonate was to care for the calcium hydrate in the bleach, sodium carbonate being formed in place of sodium hydrate. It is obvious that the proportion of bicarbonate used must be adjusted to the amount of calcium hydrate in the actual sample of bleach employed. This being done, the method has proved convenient and is very commonly used. A third frequently employed mode of preparation is based on the reaction between chlorine gas and sodium carbonate with the production of sodium chloride and carbonic acid as by-products. The resulting solution is rather less stable than the foregoing, owing to the absence of buffer salts, but can be to some extent stabilized, as can all the others, by the addition of small quantities of potassium permangate. A solution of sodium hypochlorite can also be prepared by electrolysis of a salt solution, and is characterized by the same sort of instability as the preceding solution prepared with chlorine.

Whatever may be the mode of preparation, it is important that the hypochlorite strength of the solution be checked before use of titration with a standard solution of sodium thiosulphate and that the presence of free alkali be avoided. The maximum permissible concentration, as shown by clinical experience, is approximately 0.5 per cent. of NaOCl. If the strength is less than 0.4 per cent., the germicidal efficiency of the solution is materially reduced.

It cannot be asserted that the complete *modus operandi* of the germicidal action of Dakin's solution is fully understood. A complete understanding is in fact, lacking with respect to all antiseptics. But the nature of the interactions of hypochlorites with protein substances in general strongly suggests that similar processes are involved in the process of disinfection. When proteins are acted upon by sodium hypochlorite, among the reactions which may take place is an interchange of chlorine and the hydrogen of the amino radicals, chloramine groups being formed on the one hand and sodium hydrate on the other. ($=N-H+NaOCl==N-Cl+NaOH$.) This change in the amino groups of the protein molecule induces an instability resulting in a more ready cleavage into complexes containing chloramino acids. In the free state, these are generally insoluble in aqueous media, but the sodium salts are more or less readily soluble. Since essentially equimolecular quantities of sodium hydrate are formed at the same time, an opportunity for the formation of such soluble salts is furnished by the sodium hypochlorite coincidently with the chlorination of the amino groups. The occurrence of this chain of events offers a reasonable explanation of the solvent action of sodium hypochlorite upon protein substances, such as fibrin and necrosed tissue, as well as its lethal action upon bacteria. That free alkali can be formed by reactions upon Dakin's solution is shown by the pink color which promptly develops when an alcoholic solution of phenol-phthalein is added to a solution not reacting alkaline to the solid indicator. This color soon vanishes. The difference is evidently due to the presence of the alcohol, which occasions the loss of chlorine on the part of the hypochlorite, thus liberating free alkali. This evanescent reaction in the presence of alcohol receives practical application to detect such an acidity in a hypochlorite solution as would neutralize the alkali as formed and the presence of which would cause not only an abnormally rapid deterioration in hypochlorite strength but also impair its solvent action upon proteins.

Dakin's solution occupies a high position among chlorine antiseptics because of its very great reactivity associated with a solvent action upon dead tissues and the solid portions of inflammatory exudates. It is, because of these properties, preeminent as an agent for the cleansing of septic wounds or cavities (*e.g.*, empyemata). Tissues with an abundant blood supply and active circulation are so largely protected by substances contained in the transuded serum which react with the hypochlorite that relatively little damage is done under such conditions to the fixed and living tissue elements. Where this circulation is absent or inadequate, an excess of Dakin's solution will exert a damaging and solvent action upon the living tissues. This is exemplified by the destruction and removal of the epidermis when the skin is bathed with quantities of the hypochlorite. "Burns" occasioned in this way frequently occur in the neighborhood of wounds when the skin is not protected from contact with full-strength Dakin's solution. The skin defect in such cases is confined to the epidermis; the underlying corium being protected from serious injury by transudation of fluid from the tissues, and ulcerations of appreciable depth do not occur. The process is a simple denudation of the corium by a dissolution of the epithelial covering. This can be obviated by a coating of vaseline which prevents the wetting of the skin by the Dakin's solution. It has been noted that people with oily skins, particularly negroes, are less prone to these burns than others, unless the natural sebum be previously removed by ether, gasoline or some other fat solvent.

When applied to septic wounds or purulent cavities, Dakin's solution comes in contact with many substances contained in the secretions with which the hypochlorite reacts. These reactions take place with great but not all with equal rapidity. Those substances which occasion foul odors are usually the first to be destroyed by the action of the hypochlorite, resulting in a sweetening of the secretions. Complete sterilization does not usually occur until the quantity of pus has become trivial and very little secretion is produced.

The hypochlorite has no specific germicidal properties. Sterilization is one of the incidents of the wide range of chemical reactions which take place and probably one of the more tardy. It is certain that where infections are overcome by applications of Dakin's solution, certain species of bacteria disappear more rapidly than others. As a rule, the putrefactive varieties are first eliminated, such forms as the bacillus pyocyaneus next, and last of all the hæmolytic streptococcus. Whether this be due to entanglement of the pathogenic microörganisms in the meshes of fibrin and bits of necrotic tissue, or to a greater resistance to the chlorinating action of the hypochlorites, must be left undetermined. The fact that after apparently satisfactory cleansing certain dangerous pathogenic organisms for a while may linger in the wound, suffices to indicate that the antiseptic treatment must be continued for a period beyond that at which obvious pus has disappeared. A bacterial control on considerable quantities of secretion can alone ensure confidence that sterilization has been completed. The character of this control will receive further consideration.

Since the active chlorine constituting the essential antiseptic agent of this group of substances, passes into other combinations during the process of disinfection and is finally locked up in combinations rendering it inert, the antiseptic substance is itself necessarily destroyed in that process. The process is, therefore, a summation of reactions in which all the reagents undergo changes that destroy their powers for good on the one hand, for evil on the other. To secure progress in a favorable direction, it is therefore important that the mass of antiseptic used should more than keep pace, not only with the multiplication of the bacteria present, but also with the production of other chemical substances appropriating to themselves the active chlorine which may be present. The mass of antiseptic which should be employed in a given case will depend upon the pathological processes and their extent. No rigid rule can be formulated. But it is possible to form an estimate of the rate at which the active chlorine is consumed by testing the secretions for chlorine in that condition at intervals after a given amount has been applied. This can be done with paper previously impregnated with a mixture of potassium iodide dissolved in a thin starch paste and then dried. If a drop of the wound secretion be used to moisten this paper, a distinct blue spot will at once be formed if available chlorine be present. An absence of this reaction demonstrates the absence of chlorine in this state. If viable bacteria still exist in the exudate, they then have opportunity to multiply.

The most direct and conclusive way of following the progress of disinfection is, at intervals, to estimate the number of bacteria present in the exudate. This can be done in either of two ways, each of which has certain advantages over the other, and not infrequently it will be desirable to employ both.

The most ready method for estimating the abundance of bacteria in secretions is to prepare films and count the organisms per field of an immersion objective. If the film be stained by Gram's method, any abundant infection with anaërobic gas bacilli will be revealed; for these retain the gentian violet. A rapid survey is also afforded of the variety of bacterial forms and their approximate number. It is generally assumed that if the total number does not greatly exceed one bacterium in ten fields, the wound is, for practical purposes, substantially sterile. But this rule does not hold if streptococci be present; for these are not readily cared for by the secretions or phagocytosis.

A less rapid method than the foregoing is the preparation of poured culture plates after mixing a considerable and definite amount of the secretion with a suitable culture medium. This procedure does not yield results as promptly as the stained film, but in many respects the information gained is more accurate and useful. A larger sample of the secretion can be taken without increasing the labor and time required for its examination. The personal equation in enumerating the number of colonies on a plate culture is somewhat less marked than in counting individual microörganisms with an immersion lens. But the most important advantage of the plate culture over the film is the insight it gives concerning the bacterial species and their relative numbers. For example, if the culture medium selected be plain agar, with an addition of from 5 per cent. to 10 per cent. of defibrinated blood, the colonies of hæmolytic streptococci will be easily distinguished from those of other species and can be enumerated. These streptococci usually appear on films as small diplococci not distinguishable from other less objectionable species.

We possess, then, convenient means both chemical and biological for obtaining information of essential value in guiding our treatment of septic conditions when active chlorine antiseptics are employed.

The specal technic which has been devised for applying Dakin's solution had its origin in the necessity that the antiseptic must be carried as directly as possible to all parts requiring its action, since its high reactivity would lead to decomposition of the hypochlorite, did one trust to diffusion for the dissemination to parts distant from the point of immediate application. This same instability necessitates frequent renewals of the applications. All of these requirements are met by the system of small tubes with fine perforations so ingeniously elaborated by Carrel and so widely known in association with Dakin's solution.

The importance of securing free drainage of a wound or cavity when Dakin's solution is used is not so generally appreciated as should be the case. Too much reliance is often placed upon the ability to disinfect the secretion, no matter how abundant this may be. Attention has, however, already been called to the reactions by which substances in the exudate rob hypochlorites of active chlorine. Free drainage reduces the mass of these substances, which in some cases is so great that difficulty is encountered in adding a countervailing amount of Dakin's solution. To drain away these inhibiting substances is often the first requisite to inaugurating successful treatment and is always a contributing factor of great importance.

When, through the use of Dakin's solution, a wound or cavity has been cleansed, *i.e.*, freed of fibrin and necrosed tissue, the question will arise whether the use of this form of chlorine antiseptic should be continued or another antiseptic of the same or some other group should be substituted. There appears to be no doubt that the hypochlorite solution exerts a solvent action upon dense fibrous tissue, including poorly vascularized cicitricial tissue. If it be desired to effect such solution in a particular case, the continued use of Dakin's solution is, in cases presenting no contraindication, advisable. If, on the other hand, such continued solvent action be inadvisable, there is good evidence that the continued use of this antiseptic beyond a certain dosage determined by the nature of the case very materially retards the development of granulations and healing. Experiments upon animals have shown the injury done to normal serous surfaces, such as the peritoneum, by the direct application of chlorine antiseptics, especially by Dakin's solution. The damage described exemplifies the rapidity with which these antiseptics react with proteins. It takes place before any outpouring of fluid can serve as a protection. Where an inflammatory exudate has been previously formed, the reactive substances within this fluid come into immediate contact with the antiseptic solution, and while themselves acted upon, shield the underlying tissues. Experiments of this character do not militate against the use of these antiseptics for purposes of disinfection.

It is possible to continue chlorine antisepsis without occasioning any marked solvent action by employing either chloramine-T or dichloramine-T. As already pointed out, these substances are a degree less reactive than the sodium hypochlorite and appear to be entirely devoid of a solvent action upon solid proteins.

Chloramine-T is a solid aromatic substance crystallizing with three molecules of water. These crystals contain something over 12 per cent. of active chlorine. Weight for weight it has about the same antiseptic potency as sodium hypochlorite, a 0.5 per cent. solution might therefore be substituted for Dakin's solution without sacrificing germicidal action upon microörganisms with which the solution came into immediate contact. Since a solution of this concentration is hypotonic, it is advisable to use physiological salt solution rather than pure water as a solvent. The chloramine-T is extraordinarily stable considering the high active chlorine contact, and solutions may be boiled without marked deterioration, and exposed to light with immaterial loss of strength. It is freely soluble in water, saturation not being reached at ordinary temperatures below 16 per cent. It may be applied in solution with the same technic as Dakin's solution, or in the form of a paste prepared with sodium stearate and water. Gauze may be impregnated with the salt and used dry for packing a wound. It does not cause appreciable irritation of the skin. These various properties fit it admirably to take the place of Dakin's solution as well as for employment in ways for which the hypochlorite is unsuited. For example, solutions containing from 0.1 per cent. to 0.2 per cent. can be used in the eye and the bladder may be irrigated with still weaker solutions with benefit. The exact strength advisable for such irrigations cannot be stated, since the susceptibility of different cases varies greatly. It is wisest to begin with very weak solutions, 1 : 10,000 in physiological salt solution, and to gradually increase the concentration until the strength comfortably tolerated is determined. It is possible that reactions taking place in residual quantities of urine may have an influence, for the bladder appears to be more susceptible than other mucous membranes. In ordinary wounds, a 2 per cent. solution is well borne and 4 per cent. is in most cases no more irritating.

In dichloramine-T we possess a very potent antiseptic containing nearly 30 per cent. of active chlorine. It is but slightly soluble in pure water. Its distinctive property is a marked solubility in certain oily substances and its practical use is based upon this property and originally had special reference to its employment in sprays and atomizers for application to the nasopharynx. It has, however, come to be used for other purposes. When pure, it is relatively non-irritating and oil solutions may be applied to the nasal mucosa without notable irritation. But as compared with the closely related chloramine-T, it is prone to undergo a rather rapid decomposition on exposure to light, particularly in the presence of moisture. It is also much more subject to deterioration by heat. Unfortunately, highly irritating substances, including hydrochloric acid and free chlorine, are among the products formed on decomposition of dichloramine-T, and it is, therefore, essential that solutions should be prepared from undeteriorated samples and be protected from decomposition until used. Among the solvents proposed for dichloramine-T, the most satisfactory is chlorcosane, a rather heavy oil prepared from paraffin wax. A 5 per cent. solution in this medium is well tolerated when applied to wounds, and a 2 per cent. solution can be freely used in the nasopharynx. In the absence of water, dichloramine-T is apparently inert. Metals immersed over long periods in a dry oil-solution are not corroded, but the presence of even a trace of moisture suffices to occasion a marked action. When used as an antiseptic, the active chlorine passes from the oil to the aqueous medium with which it is in contact, and it is here that the antiseptic action is manifested. The oil serves as a medium for storing the antiseptic, which by diffusion replenishes the supply in the wound secretions, thus maintaining action until the whole amount has been consumed. Where a mild, but prolonged, chlorine antisepsis is desired, this is a very convenient and suitable means of meeting the requirements. It is important to note, however, that it is often difficult to attain perfect contact with all parts to be treated, since the oil does not mix readily with secretions and must be actually carried to all parts requiring treatment. It is best applied to relatively dry surfaces that can be reached by sprays, swabs, or dressings soaked in the oil-solution. Where wounds secrete very freely, a sufficiently prolonged contact of the oil and wound surfaces is sometimes unattainable, but the wound secretion is very frequently markedly diminished in quantity under the influence of dichloramine-T in chlorcosane solution. In contrast to this diminution of serous exudate from the surfaces of wounds is the stimulating effect which similar applications exert on the secretion of mucus by mucous membranes. This is often so marked, that applications of the antiseptic are thereby contraindicated, particularly when the secretion cannot readily escape. This, and the difficulty of securing intimate contact between a heavy oil and all parts of a moist membrane containing infected glands, are reasonable explanations of failure to successfully treat acute urethritis with this preparation. The particular field of greatest usefulness, aside from nasopharyngeal antisepsis, for oil-solution of dichloramine-T is the maintenance of sterility on granulating surfaces; for it appears to have but little restraining influence upon growing epidermis and can here be readily applied without injury and dressings can be removed with minimal trauma from the oiled surfaces.

Before closing these preliminary remarks and proceeding to a practical illustration, I should like, by way of summary, to call attention once more to certain considerations that apply to all antiseptic procedures.

1. In the choice of an antiseptic, attention should be paid to the relative *speed of disinfection* manifested by different germicidal substances. Iodine and the chlorine antiseptics are among the most rapidly acting agents at our disposal, but iodine is by far more coagulant than the members of the chlorine group.

2. The antiseptic used must be brought in *contact* with the microörganisms to be destroyed. This is a problem in application.

3. The antiseptic must be present in adequate *mass* to enter into all the collateral reactions which may be associated with disinfection.

4. It must be present in adequate concentration for a sufficient period of *time* to complete the desired reactions; for it must be constantly borne in mind that disinfection is not an instantaneous reaction, however short the requisite period may be.

The particular example which I have chosen in illustration of the practical application of chlorine antisepsis, is the disinfection of an empyemic cavity that has been opened by thoracotomy.

Let us assume that the operation was done three months ago and a litre of pus evacuated at that time. The bacteriological examination at that time revealed the presence of innumerable hæmolytic streptococci. A tube to provide drainage was inserted and dressings renewed daily, or oftener, as required. At the present time the opening into the empyemic cavity will admit a drainage tube 3/8 inch in external diameter. The discharge is a creamy pus containing curdy masses of fibrin and does not readily escape through the tube, so that about 400 c.c. are habitually retained. The discharges have a foul odor and the dressings a greenish tinge. Poured blood-agar plates, prepared with a loopful of the discharge, show about 400,000 colonies after incubation over night and the blood has undergone complete lysis. Such is a not infrequent picture.

The first indication in such a case is to secure free drainage. While there is a large retention of pus, efforts to disinfect the cavity are so hampered by destruction of antiseptic that they are likely to prove futile. The opening should be enlarged. This can often be accomplished by inserting progressively larger rubber tubes. Should this fail, or be too slow, operation may be advisable. The opening should be large enough to accommodate a fair-sized drainage tube and one or more Carrel tubes. When this has been accomplished, the daily procedure towards sterilization may begin.

At the morning dressing, the skin about the wound is carefully wiped clean. The surfaces of the wound, the skin and the cavity are then gently irrigated with Dakin's solution applied through a soft rubber catheter. The only contraindication to such irrigation of the empyemic cavity is the presence of a pleurobronchial communication through which the solution enters the lung. This possibility imposes caution until it is certain that no such communication exists. Postponing for the moment the modifications in treatment necessitated by this complication, the cavity is irrigated until the return is clear, the patient being directed to change his position so as to completely fill and then empty the cavity. This affords an opportunity to gauge the capacity of the cavity, and if the patient be induced to cough to estimate also the resulting expansion of the lung, by the force with which fluid is ejected from the opening.

After this irrigation and cleansing and drying the surrounding skin, the latter is protected from the action of hypochlorite by close applications of gauze impregnated with vaseline and sterilized in the autoclave. A fenestrated drainage tube, just long enough to pass through the thoracic wall and guarded by a safety-pin, is then introduced, and also one or more Carrel tubes. If only a single Carrel tube can be admitted through the opening, this should extend to the remotest part of the cavity and be abundantly provided with minute perforations for the distribution of the hypochlorite to all surfaces. If more than one tube can be accommodated by the opening, they may well vary in length and, as far as feasible, in distribution within the cavity. The free ends of these tubes are carried upwards and fastened with a strip of adhesive plaster in the region of the shoulder beyond the edges of the future binder. Pieces of loose gauze moistened in Dakin's solution, or, perhaps preferably, in a stronger solution (2 per cent.) of chloramine-T, are packed around the tubes. A gauze dressing, split to accommodate the tubes is placed over this packing and beneath the safety-pin transfixing the drainage tube and the whole covered with numerous fluffs of sterile gauze. Large absorbent pads and a tight-fitting binder to hold dressings and drainage tube in place complete the dressing, which is not renewed until the following day.

The Carrel tubes projecting beyond the margin of the binder serve for the periodic instillation of Dakin's solution. An important question for decision is the frequency and amount of solution to be injected into the cavity. Let us consider for a moment the objects sought. The amount of pus produced in a cavity such as that under consideration, may be 250 c.c. per day, or even more. This secretion militates against the antiseptic action of the hypochlorite which must be introduced in amounts adequate to cope with the constant discharge into the cavity of this reactive exudate. In practice, it has been found that at least 100 c.c. of Dakin's solution should be instilled at hourly intervals during the day and not less frequently than every two hours at night. If there be more than one Carrel tube, the total amount injected is equally divided among them. The return through the drainage tube is caught in the dressings, which may become wet through, but do not as a rule have to be renewed. It is important to push the application of hypochlorite at the very beginning of antiseptic treatment, because it is at this time that the secretions destroying its activity are most abundant. Trivial amounts of hypochlorite accomplish little if anything towards an improvement in conditions. Irritation of the skin need not be feared, particularly if the instillation of hypochlorite is made slowly, for the overflow into the dressings will contain little or no active chlorine.

For ascertaining the progress of disinfection, bacteriological examinations are of great importance; for a complete understanding is essential. Poured plates made with plain agar, to which about 7 per cent. of defibrinated blood has been added, give the most satisfactory information, as has been already pointed out. Where there are a number of cases under treatment, the most convenient method is the following:

The requisite number of Petri dishes to correspond with the number of cases, each receives 5 or 6 drops of a sterile 2 per cent. solution of sodium thiosulphate. A loopful of secretion taken directly from the cavity is washed off in this antidotal solution within the dishes, which immediately stops further antiseptic action. The plates are then taken to the laboratory, and the melted blood-agar, at a temperature not exceeding 45° C., is poured into each dish and the whole well mixed by agitating and inclining the plate from side to side with a rotary motion before the medium solidifies. The plates are then incubated in the inverted position until the next day. The wire loop used to collect samples of secretion should always be the same and the loop can conveniently have a diameter of about 2 millimetres. This loop should be completely filled with the secretion each time a sample is taken. By this means, a fair degree of uniformity in the amount taken for each examination is secured. The following day, the total number of colonies, the number of colonies of the hæmolytic streptococcus, and those of any other species it is desired to record, are counted. When the hæmolytic streptococcus is very abundant, the number of colonies on the plate will be so great that the crowding brings about an inhibition of growth. The individual colonies are very minute, often invisible to the naked eye, but all the blood will be hæmolyzed. Such plates often lead to an erroneous impression that they are sterile. Examination under the microscope with a low power reveals a multitude of tiny colonies, not infrequently a hundred or more to the microscopic field. These may be counted under the microscope, the numbers per field being noted on different parts of the plate and the average taken. This number is then multiplied by a factor representing the ratio between the area of the field and that of the plate and the resulting figure is an approximation of the total number on the plate sufficiently accurate for practical purposes.[1]

These bacteriological examinations should be made twice weekly, until a sterile plate is obtained, then at more frequent intervals, as will be presently made clear, until no evidence of

[1] The ratio mentioned may be calculated with the aid of a hæmocytometer slide, the smaller squares having a side of .05 mm. The number of such squares included in the diameter of the microscopic field is multiplied by .05. Half of this squared and multiplied by 3.1416 (π) gives the area of the field in square millimetres. The area of the plate (about 6400 square mm. for a dish 9 cm. in diameter) divided by the area of the field gives the factor sought.

infection has been detected for a week, when the chances of recurrence are so small that the risk of closure may be reasonably incurred.

The first clinical sign of progress in disinfection is the abolition of foul odors. The quantity of pus then becomes progressively less, until little, if any, appears either in the return flow on irrigation or upon the dressings.

It is usual at autopsies to find the empyemic cavities in untreated cases lined with a fibrino-purulent deposit of considerable thickness overlying a thickened pleura. In the early stages of disinfection, this deposit appears to be but little affected, the action of the hypochlorite being expended upon the fluids with which it comes into more immediate contact. But when the secretions have become markedly reduced in amount, some proportion of the hypochlorite introduced into the cavity reacts with the fibrin and the process of dissolution begins. The character of the secretion collecting on the dressings then changes. In place of the purulent stain, a glairy material resulting from the action of hypochlorite on proteins collects on the dressings, and this may continue for forty-eight hours. With the appearance of this form of secreton, but usually more pronounced shortly after it has ceased, the lung shows greater freedom of expansion, the irrigating fluid is clear from the beginning, and, on coughing, may show slight streaks of discoloration due to blood pigment modified in color by action of the hypochlorite. At this period, plate cultures usually remain sterile or show less than 100 colonies, usually of hæmolytic streptococci, which are generally the last to disappear. These successive phenomena appear to indicate the chemical removal of the fibrinous deposit and thinning of the dense cicatricial tissue forming the outer part of the thickened pleura and to mark the completion of the cleansing action of the Dakin's solution. There is now much less secretion to react with the hypochlorite and the amounts instilled may be reduced.

The assumption that the fibrinous coat and thickened pleura are uniform throughout the cavity and equally acted upon by the Dakin's solution in all parts is not warranted, and it is advisable to continue this treatment with reduced quantities for a short time. But there is good reason to believe that over-prolonged treatment with sodium hypochlorite delays convalescence by retarding the development of healthy granulations, *i.e.*, the productive processes by which adhesions between the visceral and parietal pleural surfaces finally bring about obliteration of the cavity.

When the hypochlorite has wrought this cleansing of the cavity, it is well, therefore, to cease its use and to continue antisepsis with a solution of chloramine-T, which has a much less injurious action upon the animal cells. For this purpose a 0.5 per cent. solution in physiological saline is appropriate, the same procedures of irrigation and periodical instillation through Carrel tubes being employed.

In cases infected with the hæmolytic streptococcus, this is usually the last species of bacterium to disappear under antiseptic treatment. It appears, also, more important to eradicate this species than any other commonly met with; for the immunity acquired by the tissues and fluids of the body to cope with minimal infections of this character, appears to be very slight.

Before closing the wound by operation or allowing it to close spontaneously, it is wise to intermit treatments for a day or two, applying only sterile dressings, and then to test the contents of the cavity by plate culture to insure the absence of hæmolytic streptococci. In the interval, there is a chance for any streptococci still lingering where they have access to the cavity to multiply and thus reveal their presence.

The foregoing mode of treatment cannot be carried out with this thoroughness in the presence of a pleuro-bronchial communication. In such cases it is of great importance not to distend the empyemic cavity, as this tends to make the pulmonary opening more patent. The importance of free drainage is more emphatic than in other cases, since effective irrigation is precluded. It is usually found, however, that in some position taken by the patient, usually the sitting posture, small quantities of Dakin's solution can be introduced into the cavity without bronchial irritation exciting coughing. In this position small quantities (perhaps only 5 c.c.) should be instilled at hourly intervals, to be gradually increased in amount from day to day. It is often surprising to note a gradual development of tolerance which finally permits full treatment as with other cases. It would appear that in many cases a cleansing of the parts adjacent to the pulmonary opening takes place, with a healing which abolishes this complication. In one case treated with dichloramine-T, 5 per cent. dissolved in chlorcosane, a communication with a bronchus was accidentally discovered. Severe coughing followed the introduction of the oil and the patient spat chlorcosane at intervals for a period of about four hours. Treatment was suspended for a couple of days and then cautiously resumed. No further trouble ensued. The communication had closed after this single unintentionally vigorous antiseptic application.

As already pointed out, caution must be exercised, not to allow the thoracic wound to close until reasonably convinced that the cavity is sterile. It frequently happens that the bacterial count falls below a hundred within ten days or a fortnight, but persists at a low level for many days without material change. Such an occurrence gives warning that for some reason the antiseptic applications are ineffective and the presumption will be, in every case, that there is some focus of infection not readily accessible to the antiseptic applications. It may be a small side pocket with a narrow opening into the main cavity, through which small quantities of infected secretions are discharged but the instilled hypochlorite fails to gain entrance. Occasionally this opening will suddenly enlarge and a purulent discharge take place from the thoracic opening, after which disinfection to complete sterility assumes a normal course. In other cases the source of the contaminating organisms will prove to be a necrosed and infected rib or a foreign body in the crevices or meshes of which the organisms find protection and a chance to multiply. Where the antiseptic procedure fails to follow a progressive course to actual sterility, the adventitious cause must be sought and removed.

After a time the thoracic wound is prone to close down upon the inserted tubes, forming a sinus in which these fit so closely that they prevent access of antiseptic solutions to the walls of the opening. Often after the secretions within the cavity are sterile, the walls of the sinus harbor large numbers of bacteria. These may be reached by applications of dichloramine-T in chlorcosane applied before the introduction of the tubes, or with gauze impregnated with chloramine-T. Very frequently the organisms present in this situation are harmless saprophytes. In all cases, cultures from the sinus should be made as soon as this question becomes of clinical importance. Where a rib resection has been practiced, hæmolytic streptococci may be present in the secretions from an osteomyelitis. Unless removed, these are liable to reinfect the pleural cavity.

It must be obvious from all of the foregoing that earnest antiseptic treatment once begun must be unremittingly carried on until sterility is attained. The cases must receive individual study, and any remission in the procedures is liable to open the way for a reversion to the original condition. On the other hand, intensive and persistent devotion to necessary details offer the reward of a relatively brief convalescence, with a minimal subsequent disability.

THE PSYCHOLOGICAL EXAMINATION OF THE SOLDIER*

By MAJOR ROBERT M. YERKES

GENTLEMEN: As a representative of a science which is still in its infancy, I am highly honored by this opportunity to address the Harvey Society. For your invitation to speak on "The Psychological Examination of the Soldier," I am deeply grateful because it enables me to bring to you a message concerning the practical relations of psychology to medicine. Although I know little concerning your art, I am at home with you in the medical sciences. It is my earnest hope that what I shall say to-night, on the basis of academic, clinical, and military experience, may help to forge a durable and mutually profitable bond between psychology and medicine.

I invite your attention, Members of the Harvey Society, Ladies and Gentlemen, to a discourse whose plan comprehends the following related topics: (*a*) Enumeration of the several lines of psychological military service; (*b*) an historical sketch of psychological examining in the army; (*c*) a description of army methods of mental testing; (*d*) a summary of results of army psychological examining; (*e*) the exhibition of some of the chief applications and practical values of these results; (*f*) suggestions for the utilization of similar methods in education and industry; and (*g*) finally, as the conclusion to which all has tended, a discussion of the desirable relations of psychology to medicine.

The human factors in most practical situations have been largely neglected because of our consciousness of ignorance and

---

* Delivered January 25, 1919. Published with the approval of the Surgeon General of the Army, from the Section of Psychology of the Medical Department. For the factual materials, as contrasted with the opinions, of this lecture, I am indebted to the efficient, loyal and enthusiastic psychological personnel which carried army mental testing to success.

inability to control them. Whereas engineers deal constantly with physical problems of quality, capacity, stress and strain, they have tended to think of problems of human conduct and experience either as unsolved or as insoluble. At the same time there has existed a growing consciousness of the practical significance of these human factors and of the importance of such systematic research as shall extend our knowledge of them and increase our directive power.

The great war from which we are now emerging into a civilization which is in many respects new has already worked marvelous changes in our points of view, our expectations and practical demands. Relatively early in this supreme struggle it became clear to certain individuals that the proper utilization of man power, and more particularly of mind or brain power, would assure ultimate victory. The war demanded of us the speedy mobilization of our military machine and in addition the organization and training of an immense new and supplementary armed force, the manufacture of ordnance and munitions of war in well-nigh unimaginable quantities, the construction of ships, motor transports, and of varieties of rolling stock in vast numbers. All this had to be done in the least possible time. Never before in the history of civilization was brain, as contrasted with brawn, so important; never before, the proper placement and utilization of brain power so essential to success.

Our War Department, nerved to exceptional risks by the stern necessity for early victory, saw and immediately seized its opportunity to develop various new lines of personnel work. Among these is numbered the psychological service. Great will be our good fortune if the lesson in human engineering which the war has taught is carried over directly and effectively into our civil institutions and activities.

Scarcely had war been declared by our country before the psychologists were brought together in a plan to make their professional knowledge, technic, and experience useful in the emergency. In April, 1917, the American Psychological Association appointed numerous committees to study the situation and prepare for action. At the same time a Psychology Committee was organized by the National Research Council. Thus it happened that from the outset American psychologists acted unitedly, whereas their professional colleagues in France and Great Britain served individually wherever they could discover opportunity. The Psychology Committee of the National Research Council has continued active over a period of nearly two years. Almost all of the psychological contributions which the United States has made to the war are either directly or indirectly due to the efforts or the support of this body, the work of which has been carried on through conferences, subcommittees, or military appointees in the army and the navy.

In order that the psychological examining of the soldier may be seen in its proper setting, the various chiefly significant lines of psychological service will be enumerated and briefly characterized.

Under the Adjutant General, the Committee on Classification of Personnel in the Army, which was originally organized by a group of psychologists who were at the time serving as members of the Psychology Committee of the National Research Council or of committees of the American Psychological Association for the furtherance of the military service, developed and introduced throughout the army methods of classifying and assigning enlisted men in accordance with occupational and educational qualifications and also methods of rating officers for appointment and promotion. The services of this committee, to the work of which the War Department dedicated nearly a million dollars, ultimately touched, and more or less profoundly modified, almost every important aspect of military personnel work.

To the Signal Corps, and subsequently to the Division of Military Aeronautics, psychological service was rendered in connection with measurement of the effects of high altitude and also in the selection and placement of men. Numerous important methods, new or adapted, were introduced in this service by groups of psychologists whose primary concern was improved placement and the proper utilization and protection of the flyer.

The Psychology Committee promoted effectively interest in measures for the control and improvement of both military and civilian morale. The interest and persistent activity of its members ultimately resulted in the organization of a Morale Branch within the General Staff of the Army. At various times as many as twenty-five officers and enlisted men trained in military psychology have been engaged in the conduct of practical morale work.

For the Division of Military Intelligence psychological methods have been devised or adapted to assist in the selection, placement, and effective training of scouts and observers, and in addition service of minor importance has been rendered in numerous training camps.

In response to requests from the Chemical Warfare Service, psychological problems presented by the gas mask have been studied and the major recommendations resulting from these psychological investigations have been embodied in the latest improved form of mask.

The psychological problems either partially or completely solved for the navy are comprehended in the proper selection, placement, and training of gunners, listeners, and lookouts. Numerous situations were carefully analyzed for the navy, and methods and mechanical devices which have achieved extensive application and appreciation were developed.

Within the Medical Department of the Army a Division of Psychology was organized for the administration of mental tests to enlisted men and commissioned officers in accordance with plans perfected during the summer of 1917. The history of this work will be briefly told as an introduction to the account of methods and results which is to constitute the body of this lecture.

The chief purpose of the psychological assistance, originally offered to the Medical Department, was the prompt elimination of recruits whose grade of intelligence is too low for satisfactory service. It was believed by psychologists assembled in conference that their profession is better prepared technically and by practical experience to measure intelligence than are members of the medical profession and that psychologists therefore should be able in the military emergency to render invaluable assistance to army medical officers by supplying reliable measures of intelligence which might be used as basis for rejection or discharge. It was thought that thus the efficiency of the service might be considerably increased and the costs materially diminished. As it happens, the purposes of this service as actually developed differ radically from that originally proposed; moreover, they serve to identify this work even more closely with the personnel work of the Adjutant General's Office and of the General Staff than with anything in the Medical Department of the Army aside from neuro-psychiatric work.

To meet the prospective need of psychological assistance a committee of seven experts in practical mental measurement was organized in the summer of 1917 and called together for the preparation or selection of suitable methods. This group of men worked almost continuously for a month, devising, selecting, and adapting methods. Another month was spent in thoroughly testing the methods in military stations in order that their value might be definitely established before they should be recommended to the Medical Department of the Army. The results were gratifying and the methods were therefore recommended to the Surgeon General of the Army in August, 1917, and promptly accepted for official trial. During October and November they were applied in four cantonments under conditions which could scarcely have been more unfavorable but with results which led the official medical inspector to formulate the following statements and recommendations:

"The purposes of psychological testing are (*a*) to aid in segregating the mentally incompetent; (*b*) to classify men according to their mental capacity; (*c*) to assist in selecting competent men for responsible positions.

"In the opinion of this office these reports (accompanying recommendation) indicate very definitely that the desired results have been achieved.

"The success of this work in a large series of observations, some five thousand officers and eighty thousand men, makes it reasonably certain that similar results may be expected if the system be extended to include the entire enlisted and drafted personnel and all newly appointed officers.

"In view of these considerations, I recomend that all company officers, all candidates for officers' training camps, and all drafted and enlisted men be required to take the prescribed psychological tests."

In January, 1918, this new work of the Medical Department was extended in accordance with the above recommendation. Subsequently, adverse criticisms and misunderstandings caused delays and obstruction of the work which virtually destroyed its value during weeks which should have been filled with the most fruitful labor. It cannot be forgotten that these weeks were wasted in the most trying of struggles for the existence and continuation of this service.

The methods originally prepared for army use were subjected to repeated revisions, in the light of results, for increase in reliability and military value. The procedure finally adopted and used throughout the army consists of two chief types of examination, the group examination and the individual examination. The former was necessitated by the demand for speed of examination and reporting, the latter by the desire for reliability and fairness to the individual.

Of group examinations there are two varieties used in the army; the one for men who can read and write English fairly well (literates), known as Alpha; the other for men who are unable to read and write English well (illiterates), known as Beta. The individual examination includes three varieties developed as were the group examinations to suit different types of subjects. They are: (1) The Point Scale examination; (2) the Stanford-Binet examination; and (3) the Performance Scale examination. Both the Point Scale and the Stanford-Binet are used in the army in three forms: (*a*) As complete scales, for literate subjects; (*b*) as abbreviated scales, for literate subjects; (*c*) as specially adapted scales, for relatively illiterate subjects. These two types of examination, the Point Scale and Stanford-Binet, are used as alternates, the examiner selecting in accordance with his preference.

For the examination of foreign and illiterate men who can neither read nor write English and of whom many speak and understand it very imperfectly, the special form of examination known as the Performance Scale, has been developed and is effectively used.

Examination Alpha consists of eight tests, describable by title as follows: Test 1, Directions or commands test; Test 2, Arithmetical problems; Test 3, Practical judgment; Test 4, Synonym-antonym; Test 5, Disarranged sentences; Test 6, Number series completion; Test 7, Analogies; Test 8, General information.

With this method men are examined in groups as large as five hundred. Every man is supplied with a pencil and an examination blank. He then, under military discipline, follows directions to the best of his ability. The examination requires approximately fifty minutes. It demands almost no writing, since responses are indicated by underscoring, crossing out, or checking. The examination papers are quickly scored by means of stencils, and mental ratings recorded for prompt report. To avoid, within reasonable limits, the risk of coaching, several duplicate forms of this examination have been made available.

Each test of Examination Alpha consists of a number of parts arranged in order of difficulty from low to high. It is therefore possible for low-grade subjects to make a start on each test, and, at the same time, practically impossible for highly intelligent subjects to complete the tests within the time allowed. The tests are varied in character and undoubtedly sample the most important types of intellectual process.

Examination Beta consists of seven tests, listed thus by title: Test 1, the Maze test; Test 2, Cube analysis; Test 3, the X–O series; Test 4, Digit-symbol; Test 5, Number checking; Test 6, Pictorial completion; Test 7, Geometrical construction. This examination which was devised, after Alpha had been put into use, to meet an unexpected demand for the examination of subjects of low literacy and extreme unfamiliarity with English, is in effect, although not in strictness test for test, Alpha translated into pictorial form so that pantomime and demonstration may be substituted for written and oral directions. Beta may be given successfully to men who neither speak nor understand English.

Examinations Alpha and Beta are so constructed and administered as to minimize the handicap of men who, because of foreign birth or lack of education, are little skilled in the use of English. These group examinations were originally intended and are now definitely known to measure native intellectual ability. They are to some extent influenced by educational acquirement, but in the main the soldier's inborn intelligence and not the accidents of environment determines his mental rating or grade in the army.

Like Alpha, Examination Beta requires about fifty minutes and the papers are scored by the use of stencils.

Both Alpha and Beta yield numerical scores or intelligence ratings which for practical military purposes are translated into letter grades. The several letter grades used in the army, with their score equivalents, and appropriate definitions are presented in the following table:

Intelligence Grade	Definition	Score (Alpha)	Score (Beta)
A	Very Superior	135–212	100–118
B	Superior	105–134	90– 99
C+	High Average	75–104	80– 89
C	Average	45– 74	65– 79
C—	Low Average	25– 44	45– 34
D	Inferior	15– 24	20– 44
D—	Very Inferior	0– 14	0– 19

E grade was reserved for men who were recommended for rejection, discharge, development battalion, or service organization. All men deemed satisfactory for regular military duty were graded D– or higher.

Neither the Point Scale [1] nor the Stanford-Binet Scale [2] need be described in detail, since both are widely known and adequate descriptions are available. The military adaptations of the scales may prove useful in various civil situations, but it is not feasible within the limits of this lecture to describe these

[1] See "Point Scale for Measuring Mental Ability," by Yerkes, Bridges and Hardwick; Warwick & York, Baltimore.

[2] See "The Measurement of Intelligence," by L. M. Terman; Houghton, Mifflin Company, Boston.

modifications of the methods or to present standards of judgment which have been secured and used to increase military efficiency. It is true, however, that the several procedures of individual examining have played a most important rôle in the military service and that the examiner who lacks familiarity with them and reasonable skill in their application and the interpretation of their results is ill-prepared for psychological military service.

The army Performance Scale cannot be adequately described by reference, since it is in the main a product of military experience and effort. It consists of ten tests, the titles of which fairly well suggest their nature: Test 1, the Ship test; Test 2, Manikin and feature profile; Test 3, Cube imitation; Test 4, Cube construction; Test 5, Formboard; Test 6, Designs; Test 7, Digit-symbol; Test 8, Maze; Test 9, Picture arrangement; Test 10, Picture completion.

As in the case of group examinations Alpha and Beta, so also in that of the several forms of individual examination, numerical ratings for subjects were secured which could be translated into letter grades.

The general procedure of examining which was developed to meet military requirements is briefly describable as follows: A group of draftees, the size of which is determined by the seating capacity of examining rooms (it varies from one hundred to five hundred men), is reported to the psychological examining building for mental test. The first essential step is the segregation of the illiterates. This is accomplished by having all men who cannot read and write their own letters and those who have not proceeded beyond the fifth grade in school step out of the original group. The remaining men are sent to the Alpha room. Naturally, among them there are likely to be several who will subsequently have to go to the Beta examination. The illiterates are sent direct to the Beta room.

Men who fail in Alpha are sent to Beta in order that injustice by reason of relative unfamiliarity with English may be avoided. Men who fail in Beta are referred for individual examination by means of what appears to be the most suitable and altogether appropriate procedure among the varied methods available. This reference for careful individual examination is yet another attempt to avoid injustice either by reason of linguistic handicap or accidents incident to group examining.

It is to be emphasized that the interests of the individual who is either in the army or in the process of being accepted for military service are safeguarded by a system of three types of examination which serve as sieves. Every soldier is required to take at least one examination. Men who are of low mentality, those who are of foreign birth, or for other reasons illiterate, and those who exhibit marked peculiarities of behavior, may be required to take either two or three examinations before psychological report can be completed.

Despite the necessity for haste, which in some instances compelled small examining staffs to grade and report on as many as two thousand soldiers per day, the army mental test work has been done with an average thoroughness and degree of reliability which would do credit to any school system or other civil institution.

When psychological examining was originally accepted by the Medical Department for official trial, there was extreme and widely prevalent skepticism even among psychologists themselves concerning the reliability of the measurements of intelligence which could be secured and still more concerning their practical value to the army. The measures of reliability or validity of army methods of mental measurement which have been obtained during the past eighteen months are therefore quite as important as partial basis for safe opinion concerning the significance of this service as are the evidences of practical value which have accumulated. Effort will be made to present, as adequately as is possible within brief compass in this lecture, samples of both kinds of measure. First, let us consider reliability.

For examination Alpha the probable error of the score is approximately 5 points. This is one-eighth of the standard deviation of the score distribution for unselected soldiers. The reliability coefficient is approximately .95. Alpha yields correlations with other measures of intelligence as follows: (1) With officers' ratings of their men, .50 to .70; (2) with Stanford-Binet measurements, .80 to .90; (3) with Trabue B and C completion tests combined, .72; (4) with Examination Beta, .80; (5) with composite of Alpha, Beta, and Stanford-Binet, .94; (6) in the case of school children Alpha measurements correlate with (*a*) teachers' ratings .67 to .82, (*b*) school marks .50 to .60, (*c*) school grade location of thirteen- and fourteen-year-old pupils .75 to .91, (*d*) age of pupils .83.[1]

Results for Examination Beta correlate with Alpha, .80; with Stanford-Binet, .73; with composite of Alpha, Beta, and Stanford-Binet, .915.

Results of repetition of the Stanford-Binet examination in case of school children correlate .94 to .97. The abbreviated form of the Stanford-Binet scale consisting of only two tests per year, extensively used in the army, correlates .92 with results for the entire scale.

Reliability coefficients for results of Point Scale examination closely approximate those for the Stanford-Binet scale.

The several tests of the Performance Scale correlate with Stanford-Binet measurements, .48 to .78. Five of the ten tests of the Performance Scale yield a total score which correlates .84 with Stanford-Binet results.

It is definitely established that Examination Alpha measures literate men very satisfactorily, considering the time required, for mental ages above eleven years. Examination Beta is somewhat less accurate than Alpha for the higher ranges of intelligence. There are convincing evidences that some men are not fairly measured by either Alpha or Beta and that the provision of careful individual examination for men who fail in Beta is therefore of extreme importance.

A brief statistical summary of psychological examining in the army with be presented at this point as an introduction to the discussion of military applications and evidences of practical value.

After preliminary trial in four cantonments psychological examining was extended by the War Department to the entire

[1] Chiefly because of the relatively narrow age range, the correlation of Alpha score with age of recruits is practically zero.

army, excepting only field and general officers. To supply the requisite personnel, a school for training in military psychology was established in the Medical Officers' Training Camp, Fort Oglethorpe, Georgia. Approximately one hundred officers and more than three hundred enlisted men received training at this school.

The work of mental examining was organized finally in thirty-five army training camps. A grand total of 1,726,000 men had been given psychological examination prior to January 1, 1919. Of this number, about 41,000 were commissioned officers. More than 83,000 of the enlisted men included in the total had been given individual examination in addition to the group examination for literates, for illiterates, or both.

Between April 27 and November 30, 1918, 7749 men (0.5 per cent.) were reported for discharge by psychological examiners because of mental inferiority. The recommendations for assignment to labor battalions, because of low-grade intelligence, number 9871 (0.6+ per cent.). For assignment to development battalions, in order that they might be more carefully observed and given preliminary training to discover, if possible, ways of using them in the army, 9432 men (0.6+ per cent.) were recommended.

During this same six-month interval there were reported 4744 men with mental age below seven years; 7762 between seven and eight years; 14,566 between eight and nine years; 18,581 between nine and ten years. This gives a total of 45,653 men under ten years mental age. It is extremely improbable that many of these individuals were worth what it cost the government to maintain, equip, and train them for military service.

The psychological rating of a man was reported promptly to the personnel adjutant and to the company commander. In addition, all low-grade cases and men exhibiting peculiarities of behavior were reported also to the medical officer. The mental rating was thus made available for use in connection with rejection or discharge, the assignment of men to organizations, and their selection for special tasks. The mental ratings were used in various ways by commanding officers to increase the efficiency of training and to strengthen organizations by improved placement.

It was repeatedly stated and emphasized by psychological examiners that a man's value to the service should not be judged by his intelligence alone, but that instead temperamental characteristics, reliability, ability to lead and to "carry on" under varied conditions should be taken into account. Even after the feasibility of securing a fairly reliable measure of every soldier's intelligence or mental alertness had been demonstrated, it re-

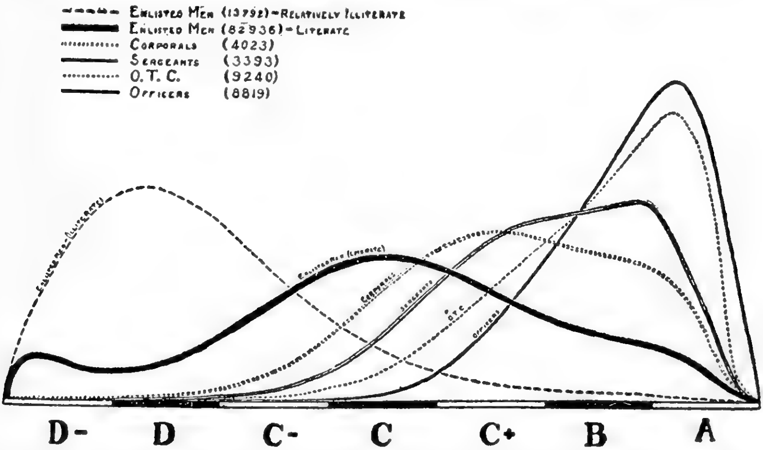


Fig. 1.—The distribution of intelligence ratings for typical army groups. The illiterate enlisted men were given group examination Beta. All others were given group examination Alpha.

mained uncertain whether these measurements would correlate positively with military value to a sufficient degree to render them useful. Data which have become available during the past year settle this question definitely by indicating a relatively high correlation between officers' judgments of military value and the intelligence rating.

The various figures which follow are presented not as a summary of the results of psychological examining in the army, but as samples of these results, the chief value of which is to indicate their principal relationships and practical values.

The sample distribution curves of Fig. 1 indicate the value of mental ratings for the identification and segregation of different kinds of military material. The illiterate group of this figure was examined by means of Beta, all other groups by means of Alpha.

Comparison of various military groups, distinguished from one another by actual attainment in the service, shows that the psychological tests discriminate between these groups with definiteness. This point may be illustrated by reference to the percentages of men of different groups making A and B grades in Examination Alpha: Officers, 83.0 per cent.; officers' training

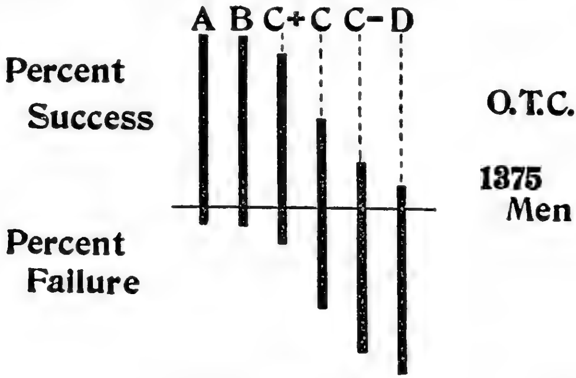


Fig. 2.—Relation of intelligence ratings to the success of students in officers' training schools.

school candidates, 73.2 per cent.; sergeants, 53.4 per cent.; corporals, 39.7 per cent.; literate privates, 18.8 per cent. The comparison of measures of central tendency reveals equally striking differences. Moreover, within the officer group itself significant differences appear for different branches of the service.

The relation of success or failure in officers' training schools to intelligence ratings is exhibited by Fig. 2, in which it is to be noted that elimination through failure in the school increases rapidly for ratings below C+. Of men rating above C+, 8.65 per cent. were eliminated; of those below C+, 52.27 per cent. The data for this figure were obtained from three schools with a total enrollment of 1375 men.

Similarly, Fig. 3 shows the relation between success or failure in non-commissioned officers' training schools and intelligence ratings. The elimination increases rapidly for grades below C+. Of men rating above C, only 18.49 per cent. were eliminated; of men rating below C, 62.41 per cent. The results presented in this figure were obtained from four schools with a total enrollment of 1458 men.

Increasingly extensive and effective use has been made of the psychological rating as an aid in the selection of men for officers' training schools, non-commissioned officers' training schools, and other lines of training or service which require special ability. It

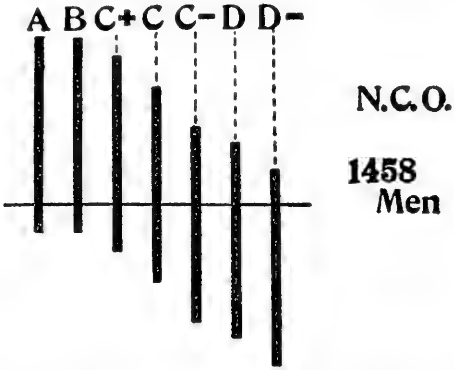


Fig. 3.—Relation of intelligence ratings to success of students in non-commissioned officers' training schools.

has been convincingly demonstrated that the data of psychological examinations can readily be used to diminish necessary elimination during training and thus to increase the efficiency of the schools.

The extreme differences in the intellectual status of army groups are fairly indicated by Fig. 4, which presents the data for groups whose military importance cannot readily be overemphasized. Roughly, the groups in the upper half of the figure are important because of their relatively high intelligence and the mental initiative demanded for success, whereas those in the lower half of the figure are important because of poor intelligence and relative inefficiency or uselessness.

These results suggest that if military efficiency alone were to be considered, the army would undoubtedly gain largely by rejecting all D– and E men. This procedure would greatly lessen the group of disciplinary cases so troublesome and costly in the military organization and also the group which in the figure is distributed among "ten poorest privates," "men of low military value" and "unteachable men."

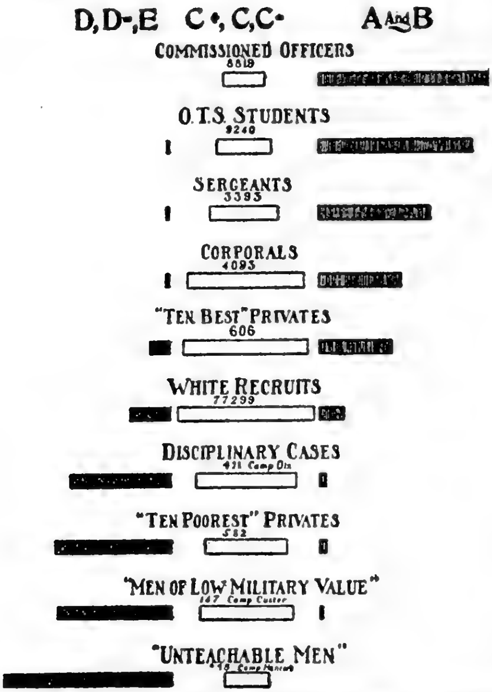


Fig. 4.—Proportions of low, average, and high-grade men in various important army groups.

Numerous varieties of evidence indicate the extreme military importance of the prompt recognition of low-grade men. The percentages of men ranking below the average in psychological examinations are notably large for the disciplinary group, men having difficulties in drill, men reported as "unteachable" and men designated by their officers as "poorest" from the standpoint of military usefulness.

The comparison of negro with white recruits reveals markedly lower mental ratings for the former. A further significant difference based on geographic classification has been noted in that the Northern negroes are mentally much superior to the Southern.

The relation between officers' judgments of the value of their men and intelligence ratings is exhibited in somewhat different ways by Figs. 5 to 7. Thus the median scores for five groups of

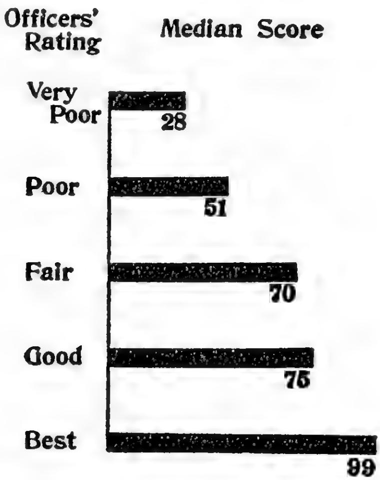


Fig. 5.—Median intelligence scores for groups of soldiers designated as "best," "good," "fair," "poor," and "very poor," with respect to military usefulness. The numbers in the figure represent median scores.

privates, arranged in order of military value from "very poor" to "best," are presented in Fig. 5. The total number of individuals in the group is 374. The men were selected from twelve different companies, approximately thirty men in each company being ranked by an officer in serial order from "best" to "poorest." The rank order for each company was then correlated by the psychological examiner with the rank order supplied by psychological examination. In seven of the twelve companies the correlations ranged from .64 to .75. The average correlation was .536. These correlations are high, considering the large number of factors which may influence a man's value to the service.

The median score for the "very poor" group of Fig. 5 is 28 points in an examination whose maximal score is 212 points. By contrast with this, the median score of the "best" group of privates is 99 points.

The commanding officers of ten different organizations, representing various arms of the service, in a certain camp were asked to designate (1) the most efficient men in their organizations, (2) the men of average ability, and (3) men so inferior that they are "barely able" to perform their duties.

The officers of these organizations had been with their men from six to twelve months and knew them exceptionally well. The total number of men rated was 965, about equally divided among "best," "average," and "poorest." After the officers' ratings had been made, the men were given the usual psychological test. Comparison of test results with officers' ratings showed:

(*a*) That the average score of the "best" group was approximately twice as high as the average score of the "poorest" group.

(*b*) That of men testing below C–, 70 per cent. were classed as "poorest" and only 4.4 per cent. as "best."

(*c*) That of men testing above C+, 15 per cent. were classed as "poorest" and 55.5 per cent. as "best."

(*d*) That the man who tests above C+ is about fourteen times as likely to be classed "best" as the man who tests below C–.

(*e*) That the per cent. classed as "best" in the various groups increased steadily from 0 per cent. in D– to 57.7 per cent. in A, while the per cent. classed as "poorest" decreased steadily from 80 per cent. in D– to 11.5 per cent. in A.

In an infantry regiment of another camp were 765 men (regulars) who had been with their officers for several months. The company commanders were asked to rate these men as 1, 2, 3, 4, or 5 according to "practical soldier value," 1 being highest and 5 lowest. The men were then tested, with the following results:

(*a*) Of 76 men who earned the grade A or B, none was rated "5" and only 9 were rated "3" or "4."

(*b*) Of 238 "D" and "D–" men, only one received the rating "1," and only 7 received a rating of "2."

(*c*) Psychological ratings and ratings of company commanders were identical in 49.5 per cent. of all cases. There was agreement within one step in 88.4 per cent. of cases, and disagreement of more than two steps in only .7 per cent. of cases.

Fig. 6 exhibits a striking contrast in the intelligence status and distribution of "best" and "poorest" privates. The per-

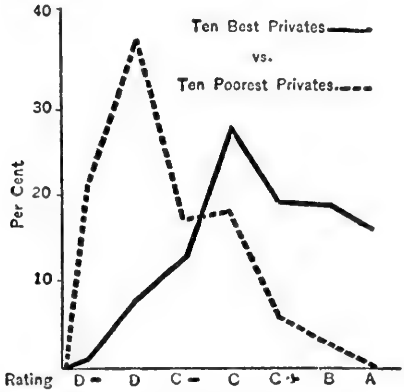


Fig. 6.—Distribution of intelligence ratings of "best" (————) and "poorest" (..........) privates. The "best" numbered 606; the "poorest," 582.

sonal judgment data for this figure were obtained from sixty company commanders who were requested to designate their ten "best" and their ten "poorest" privates. Of the "poorest," 57.5 per cent. graded D or D–; less than 3 per cent. graded A or B. The results suggest that intelligence is likely to prove the most important single factor in determining a man's value to the military service.

In one training camp excellent opportunity was offered to compare a group of soldiers selected on the basis of low military value with a complete draft quota. In the "low value" group there were 147 men, in the complete draft quota 12,341 men.

The distribution of intelligence ratings for these two military groups appears as Fig. 7, from which it is clear that if all men with intelligence ratings below C– had been eliminated, the "low-value" group would have been reduced by at least half.

In a certain training camp 221 inapt soldiers, belonging to a

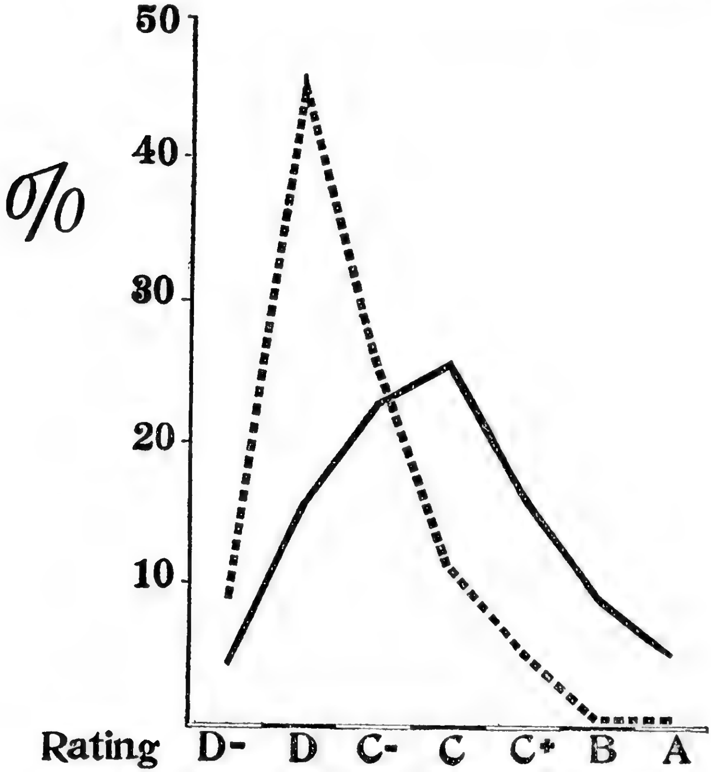


Fig. 7.—Distribution of intelligence ratings for men of low military value (..........), as compared with that of a complete draft quota (————).

negro regiment of Pioneer Infantry, were referred by their commanding officer for special psychological examination. Nearly one-half (109) of these men were found to have mental ages of seven years or less. *The army nevertheless had been attempting to train these men for military service.* In justice to the Psychological Service, it should be stated that these negroes had been transferred from camps where there were no psychological examiners. For this reason they had not been examined before being assigned to an organization for regular training.

In another instance some 306 soldiers from organizations about to be sent overseas were designated by their commanding officers as unfit for foreign service. They were referred for psychological examination with the result that 90 per cent. were

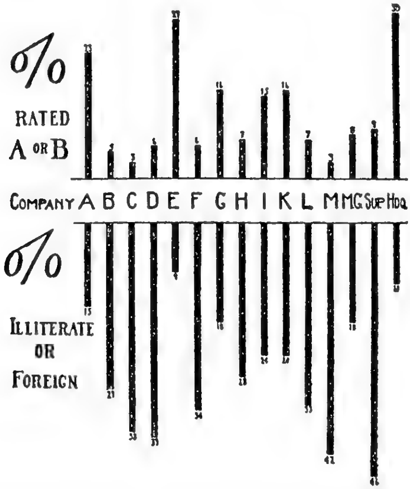


Fig. 8.—Inequality of companies in an infantry regiment with respect to intellectual strength. The upper line of figures indicates the percentage of men in the respective companies who attained grades of A or B. The lower line similarly indicates the percentage of illiterate or foreign individuals in the several companies.

discovered to be ten years or less in mental age, and 80 per cent. nine years or less.

It has been discovered that when soldiers are assigned to training units without regard to intelligence, extreme inequalities in the mental strength of companies and regiments appear. This fact is strikingly exhibited by Figs. 8 and 9, of which the former shows the proportions of high grade and of illiterate or foreign soldiers in the various companies of an infantry regiment. Compare, for example, the intelligence status of C and E companies.

The former happens to have received only 3 per cent. of A and B men along with 38 per cent. of illiterates and foreigners; the latter received by contrast 29 per cent. of high-grade men with only 9 per cent. of men who are, as a rule, difficult to train. It is needless to attempt to emphasize the military importance of this condition. The tasks of the officers of these two companies are wholly incomparable, but more serious even than the inequalities in response to training are the risks of weak points in the army chain as a result of such random or unintelligent assignment.

Naturally enough the officers of the army were quick to

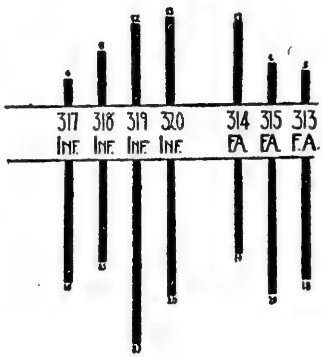


Fig. 9.—Inequality of regiments with respect to mental strength. The upper line of figures indicates the percentage of men rated as A or B. The lower line of figures similarly indicates the percentage of illiterate or foreign individuals in each regiment.

appreciate the disadvantages of a method of assigning recruits which permits such extreme inequalities in mental strength to appear and persist. They promptly demanded the reorganization of improperly constituted units and assignment in accordance with intelligence specifications so that the danger of weak links in the chain and of extreme difference in rapidity of training should be minimized.

That serious inequalities existed in regiments as well as in smaller units prior to assignment on the basis of intelligence is proved by the data of Fig. 9, which pictures the differences found in four infantry regiments and three regiments of field artillery.

Following the demonstration of the value of psychological ratings in connection with assignment, the experiment was tried in various training camps of classifying men in accordance with intelligence for facilitation of training. To this end A and B grade men were placed in one training group, C+, C, and C– men in another, and D and D– men in a third. The three groups were then instructed and drilled in accordance with their ability to learn. Thus delay in the progress of high-grade men was avoided and the low-grade soldiers were given special instruction in accordance with their needs and capacity.

The marked differences in the mental strength of groups in different officers' training schools are shown by Fig. 10. For the eighteen schools of this figure, the proportion of A grades varies from 16.6 per cent. to 62.4 per cent.; the proportion of A and B grades combined, from 48.9 per cent. to 93.6 per cent., and the proportion of grades below C+, from 0 to 17.9 per cent. Since it is unusual for a man with an intelligence rating below C+ to make a satisfactory record in an officers' training school, it is clear that the pedagogic treatment of these several student groups should differ more or less radically and that elimination must vary through a wide range if the several schools are to graduate equally satisfactory groups of officers.

Far more important than the contrast in student officers' training groups noted above are the differences in the intelligence status of officers in different arms of the service as revealed by psychological examining. Fig. 11 exhibits the data obtained for several groups. The variations are extreme and seemingly unrelated to the requirements of the service. Medical officers, for example, show a relatively large percentage of men rating C+ or below,[1] whereas engineering officers head the list with relatively few men whose intelligence is rated below B.

[1] The facts indicate the desirability of more careful scientific selection of applicants for admission to medical schools.

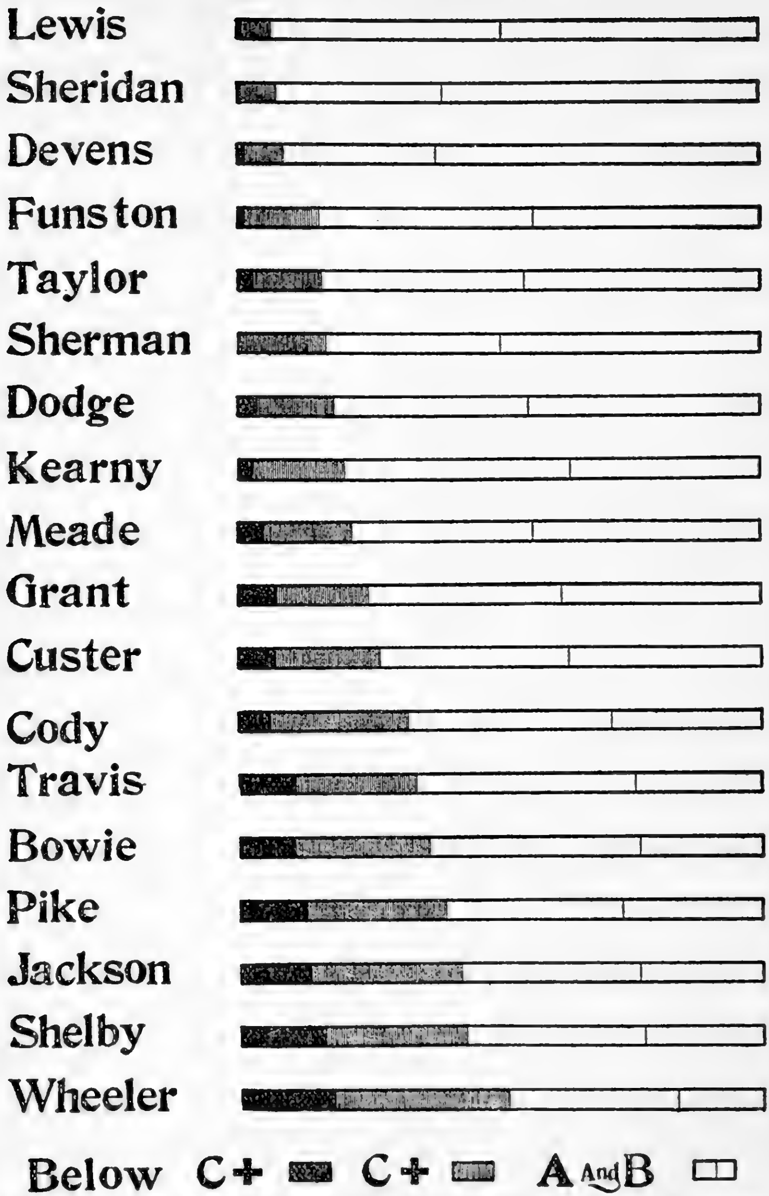


Fig. 10.—Difference appearing in the distribution of intelligence ratings in eighteen officers' training schools, fourth series. (Total enrollment, 9240.)

There is no obvious reason for assuming that the military duties of the engineer demand higher intelligence or more mental alertness than do those of the medical officer. Since it is improbable that any arm of the service possesses more intelligence than can be used to advantage, the necessary inference is that certain arms

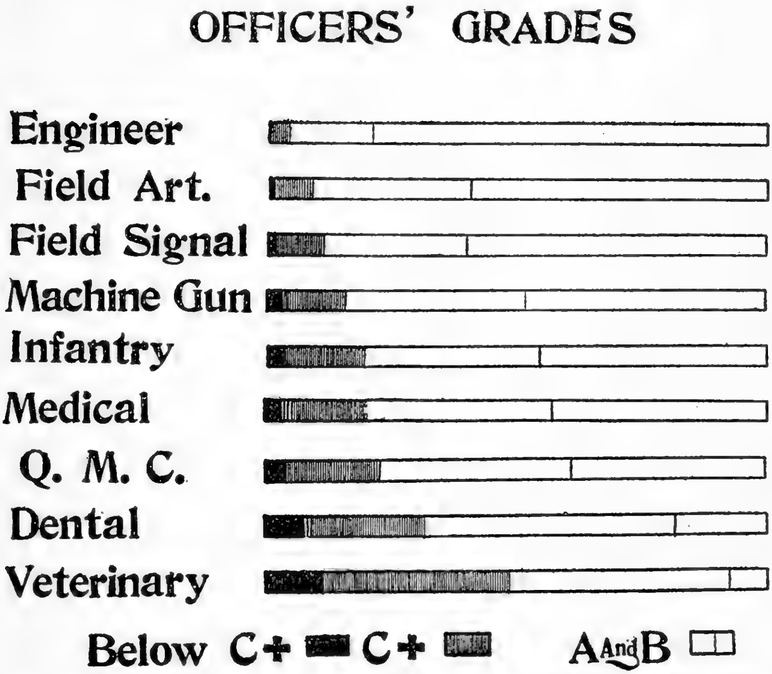


Fig. 11.—The distribution of intelligence ratings for officers of different arms of the service.

would benefit by the elimination of low-grade men and the substitution of officers with better intellectual ability.

The principal results of psychological examining in the army have been sampled and the more important of their applications to the military situation have been indicated. It remains for us summarily to appraise this work and to inquire concerning its principal relations to prospective scientific, educational, and industrial developments.

By way of appraisal of values, it may safely be said that the development of successful procedures for group examining and the convincing demonstration of the practicability of mental measurement in connection with placement are the conspicuously important contributions of psychological service to the army. It is generally admitted by those who have taken the trouble to consider the matter, that the methods prepared to meet military needs have wide applicability and possibility of indefinitely increasing value. Within the army, experienced officers as well as men new to the service, recognize that the utilization of mental ratings has increased efficiency by improving placement and facilitating elimination. Psychological service has suddenly created a large demand for technological work. This demand is most insistent from education and industry, although the sciences also are making their needs known. Before the war mental engineering was a dream; to-day it exists, and its effective development is amply assured. From leaders in our school systems, from administrative officers and teachers in colleges and professional schools, and from specialists in educational psychology come requests for permission to use the army mental tests. It is the hope of many of these men that mental ratings, as soon as it is made possible to secure them conveniently and reliably, may be used in our public schools as partial basis for grading, promotion, and vocational advice and that they may prove valuable also in institutions of higher learning as partial basis for admission, classification, grading, promotion, assignment to special work, and vocational guidance. Such applications of mental measurement would, it is true, radically change our educational system, for at present mental achievement, the extent of information or the lack of it, is virtually the sole basis for admission, classification, and promotion. Mental measurement of school pupils, college and professional students indicates extreme differences in mental ability throughout the educational range as well as important differences in mental constitution. These facts must be taken into account if educational procedure is to benefit the individual in highest degree. It therefore is proposed that children should be classified in accordance with mental ability either as they enter school or shortly thereafter, and that mental ability should subsequently be taken into account in connection with their educational treatment.

The following plan is offered as a means of utilizing mental ratings in the interests alike of education and of vocational placement.

On the basis of reliable mental ratings, children should be

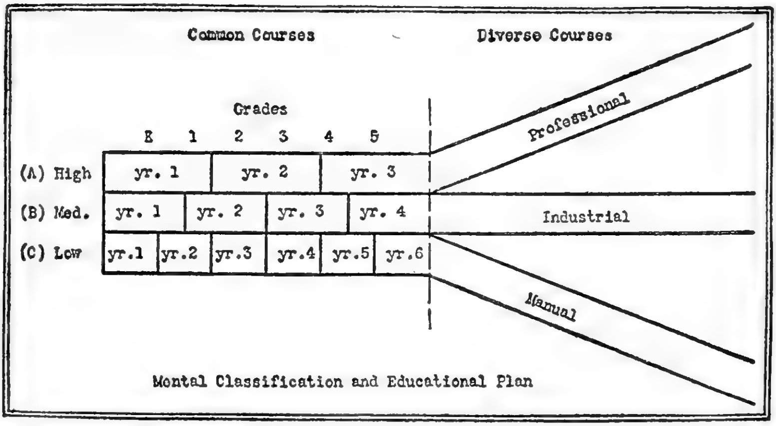


Fig. 12.—Diagram of a scheme of mental classification in relation to differentiation of educational treatment.

classified in one of three intellectual groups, which may be designated by the letters A, B, and C. Group A would consist of children of superior intelligence; group C, of children possessing relatively inferior intelligence; and group B, of those of intermediate grade. The three groups would not necessarily be of equal size.

Mental classification having been effected, educational treatment should be adapted to the needs and possibilities of the individual. To this end the following facts must be recognized: (1) That both rate of educational progress and limit of educability are conditioned chiefly by degree of native or inborn mental ability; (2) that range of vocational choice varies directly with mental ability. The diagram which is presented as Fig. 12 indicates a seemingly feasible way of adapting educational procedure to these facts. It assumes that the children of a given grade will be classified in three sections, which shall be taught either in the same classroom or in different rooms. Each section shall be permitted and required to progress in accordance with its mental ability; thus Section A might readily pass through the grades at twice the speed of Section C.

Up to a certain point in their educational development these three sections can profitably follow the same course of instruction. This point, as indicated in the diagram, is the completion of the fifth grade of elementary school. By the time this stage of educational development has been achieved, many individuals of the C section will exhibit difficulties in learning and diminution of interest, both of which, as a rule, indicate approach to the limit of one particular sort of educability. In recognition of the fact that there is a limit to the educability of every living being, the diagram indicates after the fifth grade divergence of the courses followed by the three sections. The A grade pupils may profitably continue, if they have the will, their primarily intellectual course of training toward those vocations or professions which require high-grade intelligence and excellent educational training. The middle-grade individuals may more profitably follow a course in preparation for highly skilled industrial vocations or those lines of professional work which make less exacting educational and intellectual requirements than do the learned professions, so called. Pupils of grade C should, by contrast, follow a manual training course as a means of continuing their intellectual development to its limit and simultaneously fitting themselves for the most appropriate type of vocational activity.

Mental classification and educational treatment in accordance with this plan, although seemingly undemocratic, is quite the reverse. While boasting of equality of opportunity in our national life and particularly in our educational system, we are, as a matter of fact, seriously discriminating against individuals because of our failure to take their characteristics and needs into account. Equality of opportunity in our schools necessitates classification in accordance with ability, individualized treatment, recognition of limitations and of practical limits of educability,

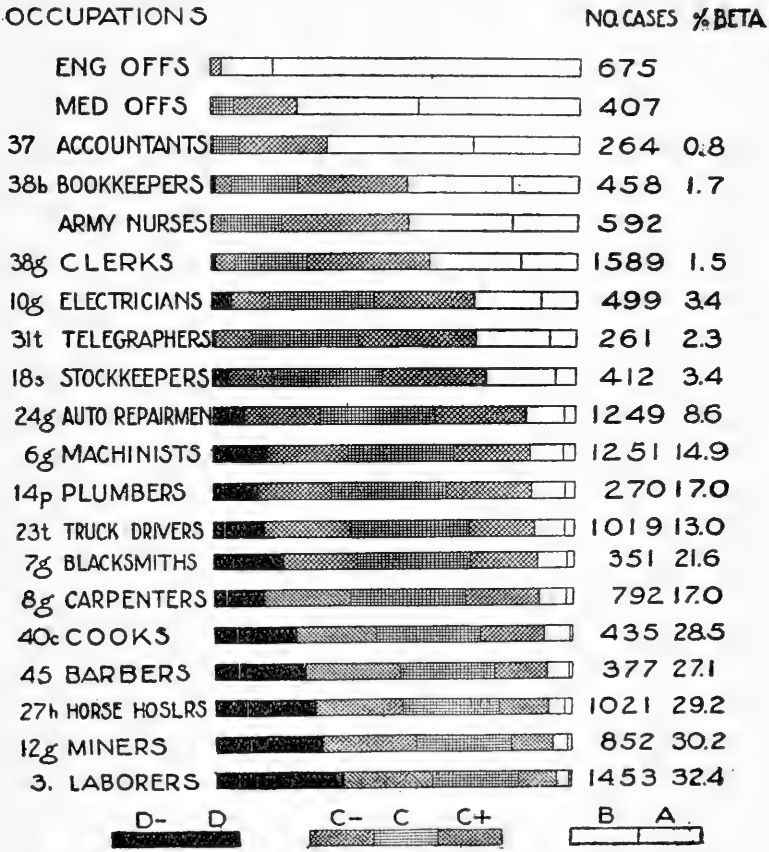


Fig. 13.—Relation of intelligence ratings to occupation in the United States Army. The last column of figures (right) indicates the percentage of individuals in each occupation who were given the examination for illiterates.

differentiation of courses, and vocational direction and training which shall enable the individual to avoid failure by reason of undertaking the impossible or waste because of the choice of an occupation which makes slight demand upon his ability.

The relation of intelligence to occupation, as studied in the army, is of very obvious importance for education and for industry. Fig. 13 presents the proportions of the three chief groups of intelligence ratings for a number of army occupations. The data are not comparable with those which would be obtained from civilian groups because of various selectional factors which appear in the army.

In order of diminishing intelligence the occupational groups represented may be classified thus: Professions, clerical, occupations, trades, partially skilled labor, and unskilled labor. The greatest differences in intelligence required or exhibited by different occupations appear at the ends of the scale, whereas differences in the trained group are relatively slight. These differences in range of intelligence for the various occupations are considerable and probably significant. The range in general diminishes from unskilled labor to the intellectually difficult professions for the obvious reason that whereas any individual may attempt tasks which require relatively little intelligence or education, only able individuals can succeed in the learned professions. It is well worthy of remark that, whereas the group of army laborers contains few individuals of high-grade intelligence (A or B ratings), the group of engineering officers contains very few except high-grade individuals.

Fig. 14 presents the relation of intelligence to occupation for a similar group of army occupations, but in quite different manner. The median intelligence grade for each occupation is indicated by a vertical cross-bar.

The data sampled by Figs. 13 and 14 suggest both the possibility and desirability of securing intelligence specifications for use in education and industry. Such specifications, if satisfactorily prepared, should greatly assist teachers in advising and directing pupils in accordance, for example, with some such plan of educational organization as has been suggested in this lecture. They should also prove of value in connection with industrial placement.

Within the industrial sphere, as contrasted with the educational, intelligent employment management requires abundant

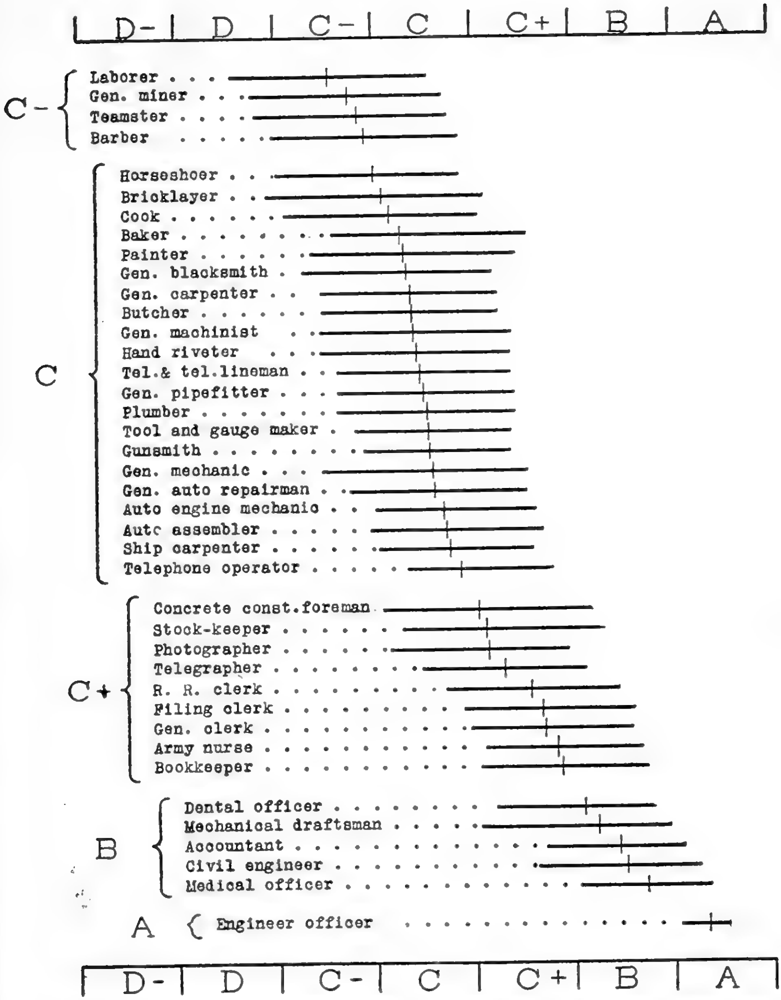


Fig. 14.—Relation of intelligence ratings to occupations in the United States Army. The heavy bar for each occupation indicates the range of intelligence ratings for the middle 50 per cent. of individuals rated. The vertical cross-bar marks the position of the median rating. The typical occupations exhibited by this figure constitute five groups which are designated A, B, C+, C, and C–, in accordance with the position of the median.

information and the development and use of scientific methods. Individuals, if hired and placed at random, seldom hold their jobs for more than a few weeks. The enormous labor turn-over of many industrial concerns is due chiefly to three causes: (*a*) The relative unfitness (by nature or training) of the individual for the work assigned; (*b*) unsatisfactory conditions of labor, and (*c*) the mechanization and the resulting dehumanizing of industrial process.

For wise and effective industrial placement and occupational guidance, two things at least are absolutely essential: First, definite knowledge of the physical and mental requirements (specification) of the job, and second, equally definite knowledge of the physical and mental characteristics and capacities of the individual to be placed.

If these requirements are to be met satisfactorily, occupations will have to be carefully analyzed in their relations to the individual and for each specifications will have to be prepared. In addition, individuals will have to be classified in accordance with intelligence, temperament, education, and occupational taste or preference. It is now possible to prepare specifications and to classify individuals suitably with reference to intelligence, education, and occupational taste.

For the present at least it is probable that if three grades of intellect were distinguished in industry, as has been suggested for the school, a very great gain would be made in degree of fitness of the individual for his task, his resulting content and efficiency.

Concerning temperamental measurement and classification, there is little to say, for methods at once simple and reliable are not yet available. It is nevertheless obvious that temperament is as important as intelligence for industrial placement and vocational guidance. Despite the seemingly infinite variety of temperament, there are probably just a few classes which have great occupational importance. It is possible, indeed, that even three classes, as in the case of intelligence, might suffice for immediate practical requirements, could we but devise methods of measuring temperamental characteristics as satisfactorily as those now used for measuring intelligence.

The relations of psychology to medicine could nowhere be more appropriately considered than in a lecture before the Harvey Society. The subject is not threadbare, and it has the additional advantage of timeliness in view of the association of the psychological with the neuro-psychiatric service in the United States Army.

Without further preamble it may be stated that a thesis is to be defended, namely, that psychology, like physiology, should be made a basic medical science. It is not such at present. Only a few medical men, and among them, fortunately, some of the ablest of the profession, accept the thesis as it has been stated.

We may proceed to our consideration of the subject by way of preliminary definitions of our major terms. Psychology shall mean for us the science of behavior and experience, whose varied applications in mental engineering constitute the art of controlling human behavior. The science, as we conceive it, differs as markedly from what is popularly known as psychology as does modern chemistry from alchemy. Medicine we may define as the art of preventing or curing diseases and the corresponding composite science of health and disease.

If the above definitions be accepted, it is necessarily true, first, that psychology is intimately and importantly related to medicine because it deals with a body of facts which are of fundamental importance to medical students and practitioners, and further, because it develops and uses methods and scientific instruments which should be invaluable to the medical profession; and second, that it has equally important relations to education, industry, the various other professions, and to both the physical and the biological sciences.

Assuming the acceptance of these facts of relationship and dependence, it is suggested that the following pedagogical or instructional situation should be created: (1) A thoroughgoing experimental training course in general psychology or preferably the science of human action should be required of pre-medical students. The course should be informational, although planned primarily for training in scientific method and to appreciation of the facts and principles of the science of human nature.

It is freely admitted that psychologists who are wholly competent to give such a course are difficult to find. It is also true that an entirely satisfactory course in psychology for pre-medical students has not been developed. Given the demand, however, on the part of our medical schools, psychology will develop both personnel and courses.

In the medical school, psychology should be taught either as a branch of physiology or as an allied subject. The laboratory methods should be used and every medical student should be acquainted with and drilled in the principal methods of mental measurement while acquiring those psychological facts which are of greatest importance for his profession.

Special courses in psychology or lectures in allied subjects should meet the needs for instruction and practical experience in connection with psychopathology or abnormal psychology, clinical psychology, and psycho-therapy.

The ideal situation would be one in which psychology would bear the same relation to the other medical sciences and to medical practice that physiology, bacteriology, and anatomy now bear. There is, on the one hand, no obvious reason for attempting to dissociate psychological aspects of medicine from the whole or, on the other, to attempt to identify psychology with medicine and to claim for the latter science all of its methods and practical results. It would seem entirely reasonable to maintain that experts in psychopathology, clinical psychology, and psychotherapy should be thoroughly trained in medicine as well as in psychology, but this is far enough from assuming that all psychologists who make mental measurements for practical purposes should be doctors of medicine or have been trained even in a preliminary way in the medical sciences. Instead, we desire to emphasize the fact that quite independent of medical relations or requirements, the expert in psychological measurement or the consulting psychologist is about to take his place beside the medical consultant in our schools and our factories. The prestige of the medical profession, even more insistently than the success of this new type of service, demands that the physician should recognize the distinctive province and the services of the consulting psychologist in accordance with their scientific and practical significance. The fact is that, along with mental engineering, the consulting psychologist has necessarily arrived. It is for the medical profession to decide whether it shall systematically develop the medical aspects of mental engineering or whether by neglecting them it shall practically compel psychologists to give them attention.

This lecture is in effect as well as intent a plea for the immediate recognition and use of modern psychology as a basic medical science.

THE HUMAN MACHINE IN THE FACTORY *

DR. FREDERIC S. LEE
Columbia University and the U. S. Public Health Service

TO every student of current events it must be obvious that labor presents to-day one of the most serious and difficult of all social problems. It is a problem that has long existed and has many aspects. From any one of these aspects its consideration may be approached profitably, and from almost every one of them its solution has been attempted; yet the problem remains. Human knowledge may become more abundant, human intelligence may become more keen, science may become more universally applied to human affairs, wars may come and wars may go, monarchies may give place to democracies; but the problem of labor we have ever with us and, as time goes on, it appears only to increase in intricacy and difficulty of solution. If we try to analyze it we see at once that two fundamental questions are involved: How much work ought the individual to do, and how much wage ought he to be paid? These two questions arise anew in almost every labor dispute. While I am not prepared to grant that it may not yet be necessary to call in the aid of the science of physiology before the question of wages is correctly answered, it is rather to a consideration of the extent to which it is legitimate to call upon the laborer to work, that I wish to call attention here.

The views of employers and of workers as to the correct answer to this question are likely to be diametrically opposed—employers demand more, workers less, work—and this difference has often led the two into sharp conflict, a conflict that has increased in intensity and led to increased bitterness of feeling as time has passed.

The first attempt, and indeed most of the attempts to put an end to the conflict and allay the feeling, proceeded from the

* Delivered March 1, 1919.

humanitarian standpoint. It was in 1784 that investigations by Dr. Thomas Percival, and others, of Manchester, drew attention to the monstrous over-work to which children were subjected in the British factories, investigations that led to definite action by the Manchester magistrates toward limiting the hours of children's labor and later doubtless influenced Parliament to pass in 1802 the Health and Morals of Apprentices Act, which had been introduced by Sir Robert Peel. Thus was begun a long series of legislative measures to bring within reasonable limits the work of the working class. Economists have also pointed out the evils of over-work, and occasionally enlightened employers have on their own initiative introduced mitigations of working conditions. But all would-be reformers, whether employers, workers, philanthropists, economists or legislators, have builded on a basis of ignorance, and, while their combined efforts have accomplished much, the fundamental questions remain unanswered and the conflict still continues. And it must ever continue until we know more than we know now concerning the conditions under which work can best be performed.

During the quarter century that ended with the beginning of the war there appeared here and there isolated, though exact, studies that prepared the way for what was to come—laboratory studies by Mosso and others on the physiology of fatigue, measurements by Mather, Abbe and Fromont of the effects of reducing the length of the working day, the analysis by Imbert of industrial operations through the application of physiological methods, and endeavors by Münsterberg to determine through the aid of psychological tests the fitness of workers for specific occupations. All these were signs of a growing recognition by men of science that there was need of the employment of the methods of exact scientific inquiry in the field of industrial occupation, a need that was made still more evident by Josephine Goldmark's sagacious summary of the situation in her "Fatigue and Efficiency," published in 1912.

Then came the war, with its intensive demands upon industry to make more, and still more, munitions, demands which industry patriotically endeavored to meet by frantic efforts. Discerning men and women perceived that these efforts, however praiseworthy in intention, were often ill-judged and often tended to defeat their own ends and that science must lend her aid in supplying the information by which industry might be properly directed. In England a preliminary inquiry into some of the physiological conditions of factory work from the economic standpoint, conducted by the British Association for the Advancement of Science, gave place to a more extensive investigation by the Health of Munition Workers Committee. In France a similar project, contemplated by the Marey Institute, was laid aside for the time. In America the U. S. Public Health Service, aided by the Committees on Industrial Fatigue of the Council of National Defense and the National Research Council, inaugurated a project similar in general to that of England. The American and the English investigations were directed by intelligent, broad-minded men of science and government officials, and have achieved positive and valuable results. In America the work of the Public Health Service is still continuing; in England the Health of Munition Workers Committee has been replaced by the Industrial Fatigue Research Board under Professor Sherrington, and an ambitious plan for further investigation is under consideration. Toward the end of the war the universities perceived the trend of events and began to make preparations for contributing to the general advance. Victoria University, Manchester, established a new Department of Industrial Administration and called to its chair Professor Stanley Kent, one of the tried investigators of the physiological aspects of occupational work. At Johns Hopkins University the new School of Industrial Hygiene contemplates under Professor Howell the study of physiological topics in industry. At Harvard these topics will be made prominent in the newly established courses for the training of industrial physicians. Other universities are not inactive.

In all this we perceive the birth and rapid growth of a science of industrial physiology, whose sphere is the industrial occupations of the human machine, and which by supplying exact information in place of opinion, sentiment, passion and prejudice is destined, I believe, to contribute valuable aid to the ultimate solution of the vexing problem of labor.

It is pertinent for the Harvey Society to give a place on its program to this new topic, and I welcome the opportunity to lay before you some of the newly acquired knowledge. I shall speak first of the methods that have been used in acquiring the data and then of the two topics: How the human machine actually works in the factory, and how it may be made more efficient.

I. METHODS OF STUDYING THE HUMAN MACHINE

In studying the human industrial machine endeavor has been made to employ, so far as possible, the methods of all exact science and to secure quantitatively measured data. The importance of this cannot be too strongly emphasized. Psychological tests have been used comparatively little, but there is doubtless a large field for them here. Of the various technical physiological tests I will mention only two, since they have been found the most valuable of all the objective tests that have so far been introduced. These are the spring balance strength test of Martin, and the vascular skin reaction test of Ryan.

The spring balance strength test, which was devised originally for determining the return of power in muscles paralyzed in poliomyelitis, consists in measuring in pounds the force that is required to overcome the contraction of certain selected groups of the subject's muscles and computing from the figures thus obtained the total strength of the individual. It is found that the strength of most men factory operatives varies roughly from 3000 to 5000 pounds, while the strength of women averages much less, say from 1500 to 3000 pounds. A diminution in strength, indicative of fatigue, is often found at the end of a day's work.

The vascular skin reaction test consists in making by a blunt instrument a stroke on the skin of the forearm, thus driving the blood from the capillaries, and then measuring in seconds the time that is required for the resulting dermographic streak to reach its maximum of whiteness. This time is shorter in fatigue.

One of the most common and most fruitful methods consists in measuring the output of the individual worker for a given period, such as each successive hour of the day. This is comparatively simple in so-called repetitive operations, where the individual's task consists of the constant repetition of a simple act.

A fairly correct estimate of the output of the whole factory or one of its divisions may often be made from the measurement, not of the output of individual workers, but of the electrical or other power that is used by the machinery.

In specific cases it has been found profitable to analyze the worker's movements into their component elements. This has been done by means of tambours by Imbert and Amar, by the cinematographic method by Amar, Gilbreth and the Marey Institute, and by electric connection between the work bench and signals recording on a drum by Ryan and Florence under the U. S. Public Health Service.

In specific cases the medical examination of workers has been resorted to in order to determine their physical condition and the presence or absence of chronic fatigue. The results of factory tests and measurements are at times elucidated, too, by inquiries into the worker's occupations outside the factory.

While these are the chief methods that have been used so far, there is need for others, and suggestions of methods are always to be welcomed that will satisfy the requirements of exactness and ready applicability to factory workers, without arousing their suspicions of unfairness. As an instance of a method that is inexact and therefore not to be commended, I might mention the studies that are now being made on the results of reducing working hours in several industries by the National Industrial Conference Board, an association of American manufacturers. Instead of making exact measurements of output before and after the reduction in time the Board bases its conclusions on the opinions of the employers, opinions that were obtained by the inexact method of the questionnaire with all its pitfalls. Conclusions based on data obtained by such means are always to be viewed with suspicion. I speak of the need of the ready applicability of any test to workers because of their disinclination to submit to tests that require long absence from their daily wage-earning occupation. An instance of the danger of arousing the suspicions of workers is afforded by the rumor that was circulated among the operatives of a certain factory that was being investigated by the Public Health Service to the effect that the introduction of the spring balance test was for the purpose of determining the fitness of the workers for military service.

II. HOW THE HUMAN MACHINE WORKS

1. *The Diurnal Course of Work*

The diurnal course of work, as determined by output, varies with individuals, with the nature of the work, with the length of the working period, and with the part of the twenty-four hours, whether day or night, in which the work is performed. The investigators of the Public Health Service have been making a considerable study of this subject, measuring output for each successive hour of the working period, and their data may best be presented in the form of graphic curves, which, while alike in certain main qualitative features, present quantitative differences varying with the conditions of the work. Where the individual works honestly and naturally, without artificial limitation of his output, the main features of the diurnal course for each spell are the following: Following the output of the first hour there is usually an increase in production, which may reach a maximum in the second, third, or sometimes even as late as the fourth, hour, and is followed by a decrease. The corresponding graphic curve thus shows at first a rise and then a fall. The rise is usually ascribed to the effect of practice, the fall in part to the effect of fatigue, although it is probable that each of these features will be ultimately capable of further analysis. Between the two spells occurs the luncheon period, which is characterized physiologically by two antagonistic features: On the one hand there come to the worker rest and food, both acting to restore working power and thus to establish the proper conditions for subsequent increase in production; and, on the other hand, practice ceases during the luncheon period, a condition of decrease in production. According to the dominance of the one or the other of these antagonistic influences there may be either a temporary improvement or a temporary impairment of the productive power, indicated graphically by a heightened or a lowered curve at the beginning of the second spell. During the second spell the practice rise is usually less pronounced than during the first spell, and there is a greater fall, indicating in part at least the cumulative fatigue of the day. Our investigators have made a tentative classification of the factory operations that have been studied, into four groups, namely, the dexterous, muscular, lathe-machine, and miscellaneous machine type of work, the names of which are self-explanatory, and each type presents an output curve that is characterized by certain distinctive features. The dexterous type is marked by a moderate practice effect, a late appearance of the maximum, a lack of recovery after the luncheon period, and a late postponement of the effect of fatigue. The muscular type is characterized by a less pronounced practice effect, an early maximum followed by fatigue, recovery after luncheon, and a very marked fatigue effect during the second spell; the two falls in the curve are sometimes broken each by a slight rise, indicating a spurt on the part of the worker. The lathe machine work is characterized by an unusually low early production, and a pronounced practice effect during the first, and a general maintenance of production during the second, spell. The output curves of the miscellaneous machine types of work appear to be less distinctive than the others.

Sharply contrasted with the course of production during the day is that of the night. This has been studied in one prominent and reputable munition factory which maintains, as is not uncommon, a ten-hour day, and a twelve-hour night, shift. Here the striking features of the curve are the unevenness of production, as compared with that of the same operation in the day shift, and especially an extraordinary fall during the last two hours, which in some cases reaches zero forty minutes before the end of the final hour. The time required for a certain specific operation for the four succesive three-hour periods of the night was found to be 12, 13.3, 16.5, and 17.4 seconds, a slowing of nearly 50 per cent., while a count made during the final three hours showed 43 per cent. of a gang of seventy-four men asleep at some period. Night workers at the same plant were found to be muscularly weaker, by 500 pounds, than day workers, but whether this was a result of their work is not determined. All these facts, brought to light by the American observers, testify to the less efficiency of night, as contrasted with day, work, and this is confirmed by observations made under the British Committee, which reveal that with approximately equal working times night workers produce from 6 to 17 per cent. less than day workers.

I have spoken of the fall in the diurnal curve of output as indicative of fatigue, but the American observers have felt that more objective evidence than that of output was needed before a correct conclusion as to the existence of fatigue was possible. In an endeavor to secure such evidence they have used the strength and the vascular skin reaction tests, and have found both valuable in revealing a parallelism between their respective showings and output. The strength test shows, first, that on days when strength is high, output tends to be high; and secondly, that there is frequently a definite measurable falling-off in strength coincident with the day's work, an effect that is more pronounced with the hard jobs and the weaker workers, than with the easy jobs and the strong workers. The skin reaction also reveals fatigue for both the forenoon and the afternoon work, the cumulative fatigue of the day, and a greater fatigue with a greater output.

2. *The Self-limitation of Work*

All investigators of the work of the human machine observe one baneful feature of it, which unfortunately is very common in the factories. It would hardly seem necessary to emphasize that one of the fundamental conditions of industrial efficiency is that workers should do their best; in other words, that the human machine when working should approximate its capacity for work; and yet deliberate limitation of output, "soldiering," or as the American investigators have called it, "stereotyping" of output, is extremely common and is indeed one of the traditional ways of labor. The American observers found it prevalent in more than half of the departments of one of our progressive factories. For example, in one of the many operations on shell fuses one man finished exactly 1000 pieces on each of 44 out of 45 nights observed; in another operation each of sixteen different workers, night after night, for one week, turned out 3600 pieces, no more and no less. If the operator's machine were stopped for a brief period and the working time were thus shortened, the operator speeded up for the remaining time and finished the day's work with the usual production to his credit. I cannot here go into a detailed discussion of the causation of stereotyping, which is probably complex, but I may merely say that the main factor appears to be found, not in the human machine itself, but in the far too common and unwise custom of employers, who reduce the piece rate when in their opinion the worker is earning too large wages. The worker therefore protects himself by restricting his output. It is a lamentable condition of labor. ''Soldiering'' not only complicates the work of the investigator enormously, but its existence in antagonistic to the organization of industry on the proper physiological basis. Physiological capacity should be the guide for achievement for both employers and workers. By physiological capacity I do not mean physiological exhaustion. One of the most important tasks of the industrial investigator is to determine the physiological capacities of individuals and the amount of work which each can do and still maintain unimpaired his working power.

3. *Industrial Accidents*

The human machine, like other machines, experiences accidents, and this is another detriment to efficiency. By far the most of industrial accidents have a physiological origin, that is, they are due to something within the body of the worker, rather than occurrences outside his body. Industrial accidents have received considerable study from various investigators and both the Americans and the English have recently contributed to the subject. The American observers of the Public Health Service have secured the records covering some 40,000 accidents in two factories and are now engaged in making an analysis of the data. Accidents usually increase in number during the working spell and reach their maximum shortly before the close of work, the peak of the curve being followed by a sharp decline. The American observers emphasize the importance of tabulating the accident risk, by which is meant the ratio of accidents to output—while during much of the day the curve of accident risk runs fairly parallel to the curve of accidents, at times the two are far apart. Thus, in the final hours of the day's work at the ten-hour plant, while there is a marked decline in both accidents and output, the accident risk shows an enormous increase.

There exists considerable difference of opinion as to the relative importance of various factors concerned in the causation of accidents. Fatigue appears to be one of the leading factors, and as one of its manifestations, probably less exact neuromuscular coördination. Speed of production also enters into causation. But a more exhaustive analysis of the physiological state of the worker at different stages of his work must be made before the subject of accidents is fully elucidated. An especially interesting fact has been discovered by the American observers. This is a very close parallelism in the monthly curves of accidents and the number of new hands employed—an indication of the part played by inexperience in accident causation.

4. *Labor Turnover*

This brings us to the consideration of another cause of inefficiency, namely, the constant change in the personnel of the workers. It is obvious that no factory could be conducted economically if its machinery, once installed, were worked for a few days or weeks and then scrapped or replaced by other machinery. This applies with equal force to the human machines, and yet "labor turnover," as it is called, is one of the prominent features of modern industry. It, too, has received much attention from recent investigators. It has been estimated that the introduction of each new worker costs the employing company the sum of $52.92, and probably the most considerable item in this expense is the low output of the new hand. When, as is not uncommon, more than 50 per cent. of the working force of an establishment has to be replaced during the year, the total cost of the labor turnover surpasses all conceptions.

III. HOW THE HUMAN MACHINE MAY BE MADE MORE EFFICIENT

I have spoken so far of some of the ways in which the human machine in the factory works. Now let us consider how it may be made more efficient.

1. *Selection of Workers*

In the first place, the present empirical method of selecting workers and assigning them to their tasks, at best a costly procedure, ought to be replaced by more scientific methods, in which the qualifications and capacities of the individuals may be learned before they are actually put to work. Here there is great need of investigation: First, a variety of typical operations should be studied and the human qualifications which they require for their proper performance should be determined; and then proper tests should be devised for determining whether prospective workers possess the required qualifications. Here, Martin, under the Public Health Service, has made one important contribution. He has found that the workers in each specific factory operation approximate a certain standard of strength and that the standards differ with the different operations. If the spring balance method were introduced into the factories as a routine procedure in hiring new hands the economic disadvantage of assigning the worker to the task to which his strength is not adapted, would be avoided. I am very hopeful that the psychologists will contribute important tests in the near future. notwithstanding the enthusiasm and the dreams of Münsterberg as to the possibilities of vocational psychology, comparatively little has been achieved. Perhaps the advance, which is inevitable, will come along the lines that have been so successfully followed by Major Yerkes and his co-workers in the army.

The problem of qualification is immediately acute in the matter of women's work. One of the most striking of all the industrial features of the war has been the increase in the employment of women and the incursion of women into types of work heretofore limited to men. In France, England and America the technical processes in the manufacture of munitions, largely a new industry, were performed to a large extent by women, and in the non-munition industries women replaced men in an amazing degree. A British report enumerates some 2000 processes in which women were substituted for men, and these include such diverse procedures as turning and gauging shells, lathe working, correcting type, driving horse-vans and motor trucks, wheeling heavy barrows, stoking, butchering, clerking in shops and offices, carpentering, acting as railway porters, repairing railway carriages, tanning, digging and shoveling, carrying heavy steel bars in ship yards, etc. Women's industrial possibilities have thus been shown, and yet to mention these occupations is not necessarily to commend them—what is permissible in an emergency may not be wise as a permanency. That women have overworked during the war seems to be demonstrated by an intelligent medical examination of some 2500 workers that has been conducted by Dr. Janet Campbell and her staff. They came to the conclusion that 42 per cent. of the workers examined were suffering from fatigue or ill-health. This means probably that many women undertook tasks for which they were not physically fitted.

We must accept the fact, I believe, that, just as men and women differ anatomically, so they differ physiologically and psychologically. The problem, therefore, is to discover, not the relative efficiencies of the two in industry in general, but the kinds of work for which each is best adapted. There are two ways by which this might be done: The empirical way, of trying women out and learning by experience, bitter if need be, what they are capable of doing efficiently; and the more scientific way of determining their qualifications before assignment. Here physiology and psychology have already accomplished something, but there is a vast field for further work. The matter is urgent, especially in England. Before I left London in December bands of women workers from the factories were marching up Whitehall to the government offices, fearing for their industrial future and demanding to be taken care of.

2. *Shortening Hours*

One way of increasing efficiency is to shorten working hours. Yet here we ought not to judge without careful quantitative data. While there is a considerable fund of evidence showing increased output with diminished working time, the nature of the operation is probably of considerable moment. The British observers report that reduction of the weekly working time in a "heavy" operation from 58.2 to 51.2 hours resulted in an increase of total output of 22 per cent.; reduction in a "moderately heavy" operation from 66.2 to 45.6 hours resulted in a 9 per cent. increase in total output; and reduction in a light machine operation from 64.9 to 48.1 hours diminished total output by only 1 per cent. The financial loss from such a slight diminution as the last mentioned may easily be more than counterbalanced by a saving in overhead charges for the lessened time required to keep the factory in operation, while the workers may gain physiologically. A recent and yet unpublished study by Vernon of the very exhausting work of millmen in the manufacture of tinplate shows that their total output was 8.3 per cent. greater on 6-hour than on 8-hour shifts.

Such figures as these, and they are now being contributed from many directions, indicate that the greatest increase in output by shortening hours occurs in those operations in which the physiological factor, as distinguished from the machine factor, is most pronounced. In other words, the output of a lifeless machine is directly proportional to the time during which it works—the longer the day the larger the output; with the living machine, within limits, the longer the day the smaller the output. With what duration of work the maximum output can be obtained, while at the same time the health and working power of the worker are maintained, probably varies greatly with the kind of work and the capacity of the worker. The general tendency of accurate research is toward the 8-hour day and the

44- to 48-hour week as the optimum for most operations and most workers.

In this connection the comparative study of an 8-hour and a 10-hour plant by the Public Health Service is interesting. The 8-hour factory was engaged in the manufacture of automobiles; the 10-hour factory produced brass goods, and especially fuses for explosive shells. Because of the difference in the kind of work and the different personnel no conclusions as to comparative total outputs of the two plants were attempted. One of the most significant features of the comparison is the relatively steady maintenance of output during the day in the 8-hour plant, and in the 10-hour plant the variation from the maximum and especially the marked fall in the second spell. At the 8-hour plant there was a minimum of lost time; at the 10-hour lost time was abundant. At the 8-hour plant output seemed to vary with physiological capacity; at the 10-hour plant stereotyping of output was widely prevalent. The accident risk was greater at the 10-hour than at the 8-hour plant, and this was associated with greater fatigue. Whether these findings are peculiar to the factories studied or are applicable to the 8-hour and 10-hour systems in general cannot now be said, but they are most suggestive.

The Industrial Fatigue Research Board is now beginning a comprehensive comparative investigation of an 8-hour and a 12-hour plant in the steel industry of Wales. Such studies must be multiplied and extended before the question of the length of the working day can be decided rationally. It appears probable that they will show that the 8-hour day is too long for certain kinds of work and certain individuals, and too short for other kinds of work and other individuals, and hence that there is no rational universal working day. The universal institution of an 8-hour day would not end the discussion. A prominent labor leader announced in my hearing in a public meeting in this city a few years ago that as soon as this was achieved labor would proceed at once to attempt to secure a day of six hours. In England, Lord Leverhulme is already seriously advocating, on the grounds of lessened fatigue and increased total production, the introduction of the 6-hour day for the individual, with two separate shifts for a total day of twelve hours or, if still greater production is required, four shifts for twenty-four hours.

Much of the current discussion of the subject is confused by the lack of a clear distinction between eight hours as a work day and eight hours as a pay day. Many workers who are clamoring for the shorter time are comparatively indifferent to the duration of the labor; they are willing to work more than eight hours provided they are paid relatively higher wages for the overtime. The extension of the 8-hour system to the railways merely establishes a basic day for payment and has practically nothing to do with the question of the duration of work. This is primarily a question for physiology to decide, and physiology ought to recognize here its opportunities and its obligations.

3. *Introducing Resting Periods*

The chief resting period in the day's work is the luncheon period, and its desirability as affording an opportunity to recuperate is supported by statistical data. The luncheon period eliminates fatigue, as is shown by the Ryan test, and arrests the downward course of production. British investigators unanimously condemn, however, the common custom in their country of requiring work before breakfast and then a breakfast interruption; and it is encouraging to see that, as the war progressed, more and more factories abolished this pernicious custom. Endeavors to determine with scientific exactness the influence of resting periods have related so far chiefly to their effect upon output. Here it is necessary to distinguish between the average output of the hour and the total output of the whole day. Whatever the effect of the introduction of a resting period may be on hourly output, if it does not diminish, or even increases, the total output it may be regarded as probably advantageous to both the employer and the worker; if it diminishes total output it may or may not be advantageous, and further investigation would then be needed.

There exist many isolated instances of a striking improvement in production accompanying recess periods, and both the American and the English investigators have tried to study the problem carefully. These studies are not completed, and indeed the whole subject deserves much more extensive investigation; but certain indications of the final results are interesting. In the majority of cases the break of a spell by a ten- or fifteen-minute recess appears to increase the average hourly output. Thus, Vernon under the British Health of Munition Workers Committee reports that the introduction of a quarter-hour break in the forenoon spell, together with the abolition of the interval for breakfast, increased the hourly output 5 per cent. The American observers have made a considerable number of observations on the experimental introduction of a 10-minute resting period into each of the two spells of both an 8-hour and a 10-hour factory. The data secured at the 8-hour plant were fragmentary and indeterminate. At the 10-hour plant the hourly production was frequently increased. Moreover, while there was considerable variation among individuals, in all but one of the twelve operations studied there was an increase in the average daily output of the worker, and this augmented with each successive period of observation. A striking instance of this appeared in a certain soldering operation in which for three successive periods of two or three weeks each after the introduction of the two 10-minute rests there was an average increase in production of 3, 17 and 26 per cent. respectively.

Thus, present evidence is strongly in favor of the allowance of brief resting periods for the human machine during the working spell as an aid to efficiency.

Holidays, too, are beneficial. It will be recalled that the U. S. Fuel Administrator closed the factories in January, 1918, for a period of five days. The American observers found the average output of the men on a certain automobile operation, as measured for three days before and after the closure, to increase 8 per cent. Since the men were on time, instead of piece, payment, the result did not signify a spurt to make up lost wages. The Fourth of July increased the average production of each of seven men at one of our factories by 2 per cent., the week of the fourth being compared with the previous week.

4. *Improving the Physical Conditions of Work*

That the human machine is affected by its physical environment is a truism. I will speak here only of atmospheric conditions. It has now been abundantly shown that the human body works best when the surrounding air is at a reasonably low temperature, is only moderately humid, and is in motion. These general principles have now received striking confirmation from the unpublished observations by Vernon in the work of millmen in the tinplate industry. The totals of five factories that were studied show the least output during the summer and the greatest during the winter months, with a striking contrast in the curves of output and temperature. Output was 10 per cent. less in August than in January. High humidities, *e.g.,* from 85 per cent. upward, decreased production. The influence of these baneful conditions was counteracted to a considerable degree in some of the factories by artificial ventilation—seasonal variation of output was least in well-ventilated factories—and Vernon estimates that thoroughly efficient ventilation may increase the average output of a previously unventilated factory by 14 per cent.

IV. CONCLUSION

In the brief course of a single lecture I have been able to present only selected instances of research, and mainly those in which there has already been definite achievement. Others are in progress or in contemplation. The American investigators have well under way a promising study of rhythm in factory operations; the beginnings of a determination of the amounts of energy that are transformed by the worker in different operations are being made in England; Hastings, of the Public Health Service, has been studying in my laboratory for more than a year some of the chemical changes that occur in the body in fatigue, such as relate to the sulphurs and phenols, the hydrogen-ion content of the urine, and the alkaline reserve of the blood; and plans for still other investigations are contemplated in the United States, Canada, England and France. There are alluring opportunities for work of this nature in almost any direction.

What we are observing in all this is, as I have already intimated, the making of what is virtually a new science, a science of industrial physiology. While sufficiently distinctive to deserve the name of a new science, it really represents the extension of the physiological point of view—and within the physiological I would include much of the psychological as well—to the peculiar problems that are presented to the human body in industrial occupation. Industrial physiology needs investigators, organizers, advocates. Offering, as it does, a new line of thought, and being, as it now is, largely in the hands of university men, whom as a class it is customary to stigmatize as idealistic and unpractical men, industrial physiology incurs the risk of being classed as academic. The term "academic," I might be permitted to say, is in these present days losing much of its customary opprobium. Industrial physiology is capable, I believe, of showing itself to be preëminently practical. It affords, I think, the most promising line of progress of all endeavors to solve the vexing problem of labor. It is not partisan, as between employer and worker; it is in the interests of both. It sees clearly that the work of the human machines in industrial establishments, if they are to be organized properly, must be organized on a scientific basis. Empiricism and tradition, long the obstacles to medical advance, are potent to-day in the factory; and, just as science has been the savior of medicine, so it must, sooner or later, come to the rescue of industry. Here America has, I believe, a wonderful opportunity for leadership.

THE PHYSIOLOGY AND EXPERIMENTAL TREATMENT OF POISONING WITH THE LETHAL WAR GASES *

DR. FRANK P. UNDERHILL

Yale University

Recently Lieutenant-Colonel, Chemical Warfare Service, United States Army

THE gases employed in the recent war may be divided into four great groups, as follows:

1. Asphyxiant or suffocating gases. For example, chlorine, phosgene ($COCl_2$), diphosgene and chlorpicrin (CCl_3NO_2).

2. Tear gases or lachrymators. For example, xylyl and benzyl bromide.

3. Sneezing gases or sternutators. For example, diphenylchlorarsine.

4. Blistering gases or vesicants. For example, yperite mustard gas $(C_2H_4Cl)_2S$.

This division of gases is, however, only a rough classification inasmuch as a gas may fall into more than one of the groups quoted. Thus a gas may have at least two different warfare uses, it may be both a lachrymator and an asphyxiant, or again possess suffocating properties in addition to a blistering action.

The classification given then carries with it the conception that the placing of a gas in one or another group is on the basis of the most important effect elicited by a given gas.

From the viewpoint of the *military purpose* for which gases are employed they may be divided into two large groups: (*a*) the Lethal Gases, and (*b*) the Neutralizing Gases. Under the term of lethal gases are included all those gases used in warfare which are employed for the object of killing the enemy. The principle substances comprising this group are chlorine, phosgene (carbonyl chloride) and chlorpicrin (nitrochloroform). On the other hand, extensive use was made of a large variety of gases

* Delivered March 15, 1919.

the main purpose being not to kill the enemy but to make him work under difficulties; in other words, to neutralize his military efficiency. Hence this group of substances received the name of neutralizing gases and included the lachrymators, the sneezing gases and the vesicants.

In general, the neutralizing gases produce effects upon the human organism of a nature which cause discomfort rather than serious injury. On the other hand, many of these substances, if in sufficient concentration, are quite capable of inducing grave effects or may even be the direct cause of death. For example, mustard gas was used primarily for its vesicant action, producing blisters which in certain cases might involve the entire skin and cause death in this manner; or again, a sufficient quantity of gas could be inspired so as to seriously injure the respiratory tract in such a way that the whole mucous membrane of the upper respiratory passages would peel off as a cast. Portions of this cast might get into the bronchi or bronchioles, acting as a mechanical plug and so interfere with respiration as to cause death by asphyxia.

In general, the sneezing gases and the lachrymators induced effects, such as relatively slight irritation and congestion, which called for no special investigation to alleviate or combat the detrimental influence. The treatment involved in such cases was obvious. In a large measure the same may be said of the vesicant gases where the primary effect to be treated was the blister or the burn. Here a serious sequel to the gassing is dependent almost entirely upon the evil effects of secondary infection. In the treatment of mustard gas the prevention of infection was the object aimed at and it was attained by a variety of means, all of which were designed to keep the wound as aseptic as possible.

While these statements are true in general for these three groups of gases, the sneezing gases, the lachrymators and the vesicants, they are capable of producing additional effects if inspired in sufficient quantities. On the other hand, such effects were not especially prominent in producing casualties in the field and hence the exact character of these additional influences has not been extensively investigated.

THE LETHAL GASES

Of especial importance in warfare have been the lethal gases. This group contains such substances as chlorine, phosgene and chlorpicrin. Other substances are also included in this group, but from a practical standpoint the gases cited are the most important. Chlorine was the first gas employed, phosgene followed, and then chlorpicrin appeared. These three substances are unlike in that chlorine and phosgene are gases, whereas chlorpicrin is a liquid. Chlorine and phosgene, especially when mixed, allow their use in the form of a cloud, the first method of gas warfare. The perfection of the gas shell, however, increased the number of substances that could be employed and greatly augmented the efficiency of gas as a means of warfare, inasmuch as the substance could be distributed in the area desired without dependence upon the conditions of the wind or the dangers of the gas being blown back.

These three gases are alike in that each contains chlorine as an essential part of the molecule, and one might assume at first glance that the physiological effects produced by phosgene and chlorpicrin are due to the action of the free chlorine or the hydrochloric acid formed as a result of the hydrolysis or other decomposition of the gases. This is an interesting hypothesis, but from the pathologists' findings can hardly be true, inasmuch as the lesions produced in the three cases are quite distinct and specific.

The three gases are lachrymators as well as respiratory irritants. Chlorine is preëminently a respiratory irritant and is characterized by the extreme rapidity with which it produces its typical effects, namely, pulmonary œdema and congestion. On the other hand, phosgene is less likely to cause immediate œdema, but it is regarded as a more effective fighting weapon as its use leads to a large number of casualties and deaths. The toxic action of phosgene is slower than that of chlorine, probably because to produce its effects it must undergo chemical change. This latent period in the action of phosgene has earned for it the name of having a delayed action. Chlorpicrin is not as rapid in its action as chlorine, but produces its typical effects much sooner than phosgene. This gas is regarded as especially valuable from a military standpoint, since it penetrates masks more readily than either of the other two gases.

THE SYMPTOMS OF GAS POISONING

The exposure of the dog to the gases elicits reactions which are quite characteristic for each gas. The general clinical symptoms induced by gassing with chlorine are, at first, general excitement as indicated by restlessness, barking, urination and defecation. Irritation is distinctly evident as seen by the blinking of the eyes, sneezing, copious salivation, retching and vomiting. Later, the animal shows labored respiration with frothing at the mouth. Food is refused, although a large quantity of water may be drunk. The respiratory distress increases until eventually death may occur from apparent asphyxiation. On the other hand, if the concentration of the gas is not lethal the animal may present an emaciated appearance and be greatly distressed for several days, followed by ultimate recovery and return to apparently normal conditions.

Phosgene acts chiefly as a respiratory irritant, but is also a lachrymator. Very small doses, scattered in the air, cause coughing, watering of the eyes, and intense dyspnœa. It differs from chlorine in that in these small concentrations its influence is limited mainly to the terminal air cells of the lungs. This effect leads to œdema of the lungs and consequent cyanosis, which may terminate in death. The first symptoms are dizziness and cyanosis on exertion. It usually takes several hours for the serious symptoms to develop and in the interval there is no sign of danger.

At high concentrations there is slight lachrymation and uneasiness. The pupil becomes clouded but the animal exhibits no violent symptoms. Subsequently there may develop a hard cough, respiration becomes more and more difficult, usually there is a rattling in the throat and death follows within the first twenty-four hours after exposure. The heart action grows weaker as death approaches but persists after all attempts at breathing have ceased.

Exposure to chlorpicrin produces coughing, nausea and vomiting, and in large quantity may cause unconsciousness. Secondary effects are bronchitis, shortness of breath, a weak irregular heart, and gastritis. It may also cause acute nephritis. Liquid chlorpicrin has a corrosive action on the skin, and scratches and abrasions, if exposed to chlorpicrin fumes invariably become septic and abscess formation may result.

A comparison of the three gases shows quite plainly that chlorine has a very strong irritating action, the animal becoming excited and in evident distress. With chlorpicrin the character of the reactions produced is very similar to those of chlorine poisoning, except that the symptoms are less pronounced. Phosgene, on the other hand, appears to cause the animal no immediate distress. Instead of becoming unduly excited the dog lies quietly in the chamber and even when the symptoms appear hyperexcitability is not present. It would seem that a certain degree of peripheral anæsthesia is present, handling the animal failing to act as a stimulus to muscular activity, struggling, so characteristic with chlorine and chlorpicrin dogs.

PATHOLOGY OF GAS POISONING *

From the pathological aspect chlorine produces injury to the organism by causing immediate death of the epithelium lining the upper respiratory tract. Areas of focal necrosis in the lung itself are attributed to the direct action of chlorine on parts of the lung not protected by bronchiolar spasm. The destruction of the epithelium of the trachea and bronchi removes the normal protective mechanism of the upper respiratory tract and allows pathogenic bacteria from the mouth to find their way into the injured bronchioles within a very short period after the epithelium has been destroyed. This bacterial infection results in a pneumonia, lobar, lobular or necrotizing, the type depending upon the organism concerned. The pneumonia is associated in all cases with an infection lesion of the bronchi. The infection tends to persist in animals surviving the acute period, resulting in a chronic bronchitis, organizing or obliterative bronchiolitis

* Taken from the reports of Dr. M. C. Winternitz.

with scarring of the lung. Such lesions are demonstrable in dogs dying or killed as late as six months after gassing. The irritating action of chlorine results in a bronchiolar spasm, which, interrupting the normal inflow and outflow of air, causes an acute emphysema or atalectasis, most marked in animals dying in the acute stage.

Œdema of the lungs, trachea and bronchi is the most striking feature of acute death from chlorine gassing. It is probably brought about by the direct action of the gas which so damages the bronchi and alveoli as to render permeable the adjacent capillary wall. The coagulation of the plasma as it passes out through the alveolar wall leads to the deposition of fibrin in this situation which must seriously interfere with the inflow of blood through the lung, thus putting a strain upon the right side of the heart.

With phosgene gassing the lesions seen at autopsy vary according to the length of time the animal survives after exposure to the gas. At first there is a severe pulmonary œdema associated with extreme congestion, which reaches a maximum after the first 24 to 36 hours and disappears gradually in animals surviving ten days or longer. The œdema is associated with an inflammatory exudation of fibrin and leucocytes, which is most marked in and around the finer bronchioles and which spreads to a variable extent through the lung tissue. A typical lobular or pseudo-lobar pneumonia is the result. The pneumonia is frequently complicated by a necrotization of the wall of the bronchus, which may involve the adjacent alveoli to form abscesses. On the other hand, the inflammatory process may be combated successfully but in an attempt at healing, foci of organizing pneumonia and obliterative bronchiolitis result. They constitute chronic foci of infection, as shown by bacteriological studies.

The character of the phosgene lesion is explained by the localization of the action of the gas upon the air tubes. The epithelium of the trachea and larger bronchi is not damaged, while that of the smaller bronchi and bronchioles is seriously injured, the more distal portion suffering most. In addition to the changes in the mucosa the bronchi also show pathological contractions and distortions which result in the more or less complete obliteration of their lumina. These in turn lead to mechanical disturbances in the air sacs, resulting in a chronic condition of atalectasis or emphysema.

Chlorpicrin injures the epithelium of the entire respiratory tract, but all portions of the tract are not equally affected. The trachea and largest bronchi, though irritated, suffer only transient injury. The medium-sized and small bronchi are the most affected. There is a uniform and widespread damage of the alveolar walls which, however, is not severe enough to lead to necrosis. The alveoli are apparently nowhere protected by constriction of the bronchi.

The overwhelming œdema of the lungs rapidly follows exposure to the lethal concentration of the gas. In extreme cases practically every alveolus is filled with fluid. In addition to the fluid in the lung itself there is also marked œdema of the mediastinal tissues and pleura which is even more striking than in phosgene and chlorine gassing. The œdema fluid contains fibrin and a great deal of fibrin is found in the alveolar walls. Partial or complete occlusion of the smaller bronchi by inflammatory exudate or masses of necrotic cells leads to focal emphysema or atalectasis, but this is not such a striking feature at autopsy, as in the case of death from some of the other respiratory irritant gases, for example, phosgene. Infection of the lungs with the development of a widespread bronchitis and broncho-pneumonia is seen in a large percentage of those animals which do not die in the first few hours after gassing. Abscess formation, pleurisy, fibrinous or purulent, and organizing pneumonia are common complications. In recovered animals there is a regeneration of the epithelium of the bronchi and alveoli, and organization of the necrotic bronchiolar wall with scar formation. Focal atalectatic emphysematous patches remain as prominent gross evidence of the gas injury.

A comparative study of the pathology of chlorpicrin, chlorine and phosgene shows that chlorpicrin in its action on the respiratory tract occupies a position somewhere between chlorine and phosgene. It damages the trachea and larger bronchi less than chlorine but more than phosgene. In its action on the bronchioles and alveoli it resembles phosgene very closely, but in several other respects the lesions are more like those of chlorine. The gross and microscopic differences in the effects of the three gases on dogs are sufficiently clear cut to enable an experienced observer to determine by autopsy[4] which gas has been used.

AN INTERPRETATION OF GAS POISONING

In the time allotted it would be impossible to describe in detail the character of the various types of work carried through in our investigation on the war gases. It will suffice to say that under carefully controlled conditions the influence of the lethal gases upon the organism of the dog has been studied both intensively and extensively. In this investigation several thousand animals were employed. As a result of this work it may be stated that pulmonary œdema is the prominent feature of the effects induced by these gases. In addition to pulmonary œdema, gassing has a definite influence upon the respiration, heart-beat, temperature, the concentration of the blood, the water content of the lungs and other tissues, the chloride content of the blood and tissues with resulting changes in chloride excretion by way of the kidney, the number of the red and white cells of the blood, and the respiratory function of the blood leading to dyspnœa and partial asphyxia. Acidosis is present at times and there is a distinct influence upon protein metabolism. Some of these effects are of course dependent upon the development of pulmonary œdema, but others are not so readily explained in this way. It should be stated that so far as can be determined by experimental methods, the lethal gases act specifically upon the respiratory tract, which action results in œdema. Little or none of the gases is absorbed. Hence, whatever influence is exerted upon the organism by these gases must be explained by an interpretation of the effects induced in the respiratory tract.

The effects of gassing as enumerated above are so various that an attempt at correlation or the assignment of cause and effect seems at first glance well-nigh impossible. Further study of the problem, however, brings to light one significant feature which stands out clear and distinct from all the other effects induced by exposure to gas. This is the well defined curve of changes in blood concentration. Upon the basis of alterations in blood concentration quite definite stages in gas poisoning may be outlined. These stages stand out most clearly with phosgene and therefore the picture presented by this gas will be considered first.

STAGES IN PHOSGENE POISONING

First Stage:

In the first few hours (5–8) *after phosgene poisoning there is a notable decrease in the concentration of the blood.* The decrease occurs rapidly and then the blood gradually tends to assume the normal concentration. In this period there may be significant dilatation of the heart (observed by Eyster). Accompanying the decreased concentration of the blood, there is a sharp drop in the chlorides of the blood and a marked increase in the chlorides and water content of the lungs. The chlorides of the urine increase immediately after gassing, reaching a maximum between the third and seventh hours, then decreasing. The heart-beat is distinctly slowed at first, with a tendency to regain the normal, or be somewhat above the normal before this period is over. The immediate effect upon the respiration is a distinct increase in the rate. During this period the temperature shows a marked increase, attaining a maximum coincident with the termination of this period. *Oxygen capacity of the blood, the number of erythrocytes and hæmoglobin follow a curve parallel with that of the changes in the blood throughout all stages of phosgene poisoning.* The oxygen content of both arterial and venous blood decreases significantly. The saturation of hæmoglobin with oxygen decreases somewhat. In general the decrease is more marked in the venous than in the arterial blood. In the first period of phosgene poisoning an influence upon protein metabolism is not noticeable.

Second Stage:

The period of blood dilution is followed by an interval during which the blood rapidly becomes concentrated to a point far above the normal value and remains near this level for several hours.

In this stage the heart may be markedly decreased in size (Eyster). During the period of increased blood concentration the chlorides of the blood show a tendency to regain the normal. The water and chloride content of the lungs reach a maximum and then gradually fall. The heart-beat and respiration are both markedly accelerated. In animals that are in a serious condition, although the rate of respiration is markedly increasing, there is a decrease in depth so that rapid, shallow breathing exists. The temperature steadily decreases to a degree or more below normal. If the animal dies in this stage, the temperature may fall steadily up to the time of death. *Most of the fatalities occur in this stage.* The oxygen content of arterial blood remains fairly stationary at a nearly normal value, whereas that of venous blood falls rapidly to a very low level. The saturation of hæmoglobin with oxygen decreases rapidly in both arterial and venous blood, but the fall is greater in venous blood. There is no evidence of an influence upon protein metabolism.

Third Stage:

After the period of increased concentration the blood gradually becomes more dilute until it is slightly under the normal value, which is eventually gained, and the animal recovers. The chlorides of the blood gradually tend to regain the normal level. The chloride and water contents of the lungs follow a similar course. In animals reaching this stage, the heart-beat and respiration rise to a maximum and then gradually attain the normal. The temperature rises to normal or above in those animals that eventually recover. In those animals that die during this period the heart-beat and respiration rise but the temperature steadily falls. The oxygen content of arterial and venous blood tends to regain the normal. Chloride excretion by the kidney is markedly decreased but later is much augmented. Coincident with the increased chloride excretion is a noticeable increase in the protein metabolism.

The interpretation which may be placed upon the different stages of phosgene poisoning is as follows: In the first stage there is marked dilution of the blood. There are at least two ways in which this dilution may be explained. In the first place it may mean an increased blood *volume,* the excess fluid finding its way into the blood from the tissues in response to the strong irritation stimulus exerted by the gas upon the respiratory tract. Or secondly, a diluted blood would result if the red cells were removed in part and deposited in some organ or tissue. In the present investigation no studies have been made to determine actual changes in blood volume. Reports by Eyster and Meek, however, who have made such estimations, tend to the conclusion that in the stage of phosgene poisoning under discussion blood volume is not increased, and they account for the dilution of the blood on the hypothesis that red cells are stored in the lungs, at least temporarily. Whichever explanation is correct, it is certain that during this first stage two features may be quite prominent, namely, œdema of the lungs and dilatation of the heart. Œdema can be explained very readily on the hypothesis of increased blood volume and it is also possible that such a condition might lead to a dilated heart. On the other hand, the deposition of corpuscles in the lungs, by causing an obstruction in the circulation, would lead to a dilated heart. The relatively large transport of fluid to the lungs during this period is, however, not so easily explained by this hypothesis. Whichever hypothesis is accepted, œdema of the lungs prevails and there may be a dilated right heart.

In the second period œdema has reached its maximum development and here also blood concentration is at its height. The latter state is undoubtedly induced by the withdrawal of fluid which finds its way into the lungs. During the interval of blood concentration the blood volume is definitely decreased and the heart may be noticeably diminished in size (Eyster). This would presumably result in a decreased efficiency of this organ and lead to an inadequate circulation. Later, when the blood resumes its normal degree of circulation, normal heart action is reëstablished.

The development of œdema induces a mobilization of chlorides in the lungs at the expense of the chlorides of the blood, the lowered chloride content of which may be explained in part by loss of chlorides through the kidneys, since at this period the output of chlorides in the urine is appreciably augmented. Later, during the second stage, the chlorides of the lungs reach a maximum, the blood content is not called upon and therefore an approximately normal blood chloride content may be found which is maintained thereafter. This chloride retention by the lungs coincides with the fact that on the second day of phosgene poisoning the urinary excretion of chlorides is usually below normal. The period of readjustment now follows, during which œdema subsides in the lungs, and presumably both fluid and chlorides are demobilized by the lungs and find their way into the blood. The excess of chlorides over the normal in the blood is eliminated through the kidneys, which would account for the large output on the third day after gassing.

The changes in oxygen capacity, erythrocytes and hæmoglobin follow the curve of alterations in blood concentration throughout the entire course of phosgene poisoning which might well be anticipated. Oxygen content of arterial blood in general shows relatively unimportant changes, whereas that of venous blood progressively diminishes throughout the first and second periods of phosgene poisoning. This may be explained in the first period by the fact of diluted blood and in the second period is undoubtedly caused by the longer contact of the blood with the tissues induced by an inefficient circulation.

The respiratory changes are correlated with the impaired respiratory functions of the blood, such as lowered oxygen content and incomplete saturation of the hæmoglobin with oxygen.

In the first stage decreased heart-rate may be explained best perhaps on the hypothesis of nervous inhibition. The later rapid pulse is directly induced by the viscous character of the blood which causes oxygen want. Although specific data are lacking, it appears quite evident that there is a distinct fall of blood pressure. One may assume a direct relationship between the heart's efficiency and temperature. Thus, in the first part of the first stage the heart action is slow, there is inefficient circulation, and the temperature falls. Later the greatly accelerated pulse is accompanied by a rise in temperature far above the normal. From this it would appear possible that the heart has temporarily overcompensated, resulting in an efficiency of the circulation above the normal.

Now follows the stage of concentration of the blood. This concentrated blood is, without doubt, more difficult to circulate through the body, and if the heart is only doing its normal work there will be, as a result of the thickened blood, a circulation of less than normal efficiency and such a condition apparently results in a falling temperature. In case the heart responds with a much higher rate during the period of concentration, so that even with the thickened blood it appears that a circulation of close to normal efficiency is being maintained, it will be found that the temperature is also well maintained.

In the animals which are less seriously affected and in which only a slight œdema of the lungs develops, with a consequent slight loss of fluid from the blood, it will be found that the temperature is well maintained, provided the heart-rate is normal. However, even in such cases, the continuous, even though slight, loss of fluid from the blood, will eventually result in a concentration of the blood which will bring the circulation below normal efficiency, even with a high pulse-rate, and the temperature will slowly drop until at about the twenty-fourth hour it is about one degree centigrade below the normal. On the other hand, in the animals which are seriously affected, the blood concentrates very rapidly. The heart, even though the rate is maintained far above normal, is nevertheless not able apparently to maintain a circulation of normal efficiency, the temperature drops very rapidly and the animal dies within less than twenty-four hours after gassing.

In brief, then, it seems plausible that the temperature is directly related to the efficiency of the circulation and this in turn is determined, in part at least, by the concentration of the blood and the pulse-rate.

This view seems to be further strengthened by the results obtained from a study of animals gassed with chlorine and chlorpicrin. In both of these cases there is, in general, a state of concentration of the blood beginning immediately after gassing. Only in rare instances does dilution of the blood occur and then it is only for a short time. From the first, then, in animals poisoned with these last-named gases, there obtains a condition in which the blood is above normal in concentration and in correspondence with this the temperature remains below normal and the more seriously the animal is affected and the greater the concentration of the blood, the greater will be the fall in temperature.

Phosgene poisoning has been considered in detail since it is unique in showing among its effects the initial stage of dilution of the blood. At times chlorpicrin presents a similar stage, but this interval is never so pronounced either in degree or length as obtains in phosgene poisoning. Usually a preliminary dilution period is lacking. It is this period that undoubtedly gives to phosgene the distinction of possessing a so-called "delayed action." Chlorine gas rarely if ever causes a period of blood dilution. In general, if one should consider the changes in blood concentration outlined for phosgene, minus the initial dilution period, the remaining curve would represent fairly accurately the alterations occurring in the blood in both chlorine and chlorpicrin poisoning. This would, of course, entail differences in *time* relationships, but under the conditions noted the changes in blood concentration of chlorine and chlorpicrin would be accompanied by the same general type of effects which is obtained with phosgene. Under these circumstances it appears superfluous to recite further the correlation of the effects of chlorine and chlorpicrin poisoning.

THE CAUSE OF DEATH IN GAS POISONING

It is generally assumed that the cause of death in gas poisoning is due directly to œdema of the lungs aided, of course, by the accompanying congestion. It has been said that death is caused by an individual literally drowning in the water of his lungs. The quantity of water may reach as high as a liter or more, and such a conception as the cause of death seems quite obvious. On the other hand, one may well ponder whether death is usually induced in this way or whether there may be some other cause to which one may point with more certainty. The most obvious condition, other than œdema, which could lead to death is the concentration of the blood. Of course, it is evident that œdema and blood concentration are closely associated. Œdema is assuredly the cause for blood concentration and thus indirectly at least brings about death, but it would appear that blood concentration is much more likely to produce death than is the presence of fluid in the lungs. There are therefore two possibilities open.

Death by œdema could be caused by the prevention of an adequate oxygen supply in the pulmonary blood. On the other hand, through extensive experiments of Winternitz,* it is quite possible to introduce large quantities of fluid directly into the lungs of normal dogs without causing death, the fluid being absorbed with surprising rapidity. It must be conceded, however, that the conditions obtaining in the lungs of a normal dog and in those of a gassed animal are quite different, for in the experiments cited simple salt solution was introduced, whereas in the œdematous lung the fluid more nearly represents blood plasma. Such a fluid would have a much greater tendency to inhibit adequate oxygen exchange than would a simple salt solution. The adherents of the idea that œdema is the cause of death must ascribe death to asphyxiation. There is little doubt that well-developed œdema does interfere with oxygen exchange of the pulmonary blood, but usually the efficiency of the arterial blood as an oxygen carrier is surprisingly high. It would seem a simple matter to put the question to the test experimentally. Thus, it might be assumed that if œdema is the cause of death, this operating by producing asphyxia, administration of oxygen should save the animal provided the oxygen could be absorbed. Such experiments have been carried through in this investigation and the results have demonstrated that though the oxygen in the arterial blood may be raised and maintained within the higher normal limits, death intervenes an usual. Then again some animals seem to die with much less œdema than others and the different gases also possess different degrees of ability in provoking œdema. If œdema is the cause of death it is difficult to explain why some animals with an apparent excessive quantity

* Unpublished.

of fluid in the lungs should survive. Death is caused by something more than simple inability of the blood to absorb oxygen, by something more than a physical obstacle in the lungs.

It seems quite logical to assume that blood concentration is immediately responsible for death. Blood concentration means a failing circulation, an inefficient oxygen carrier, oxygen starvation of the tissues, fall of temperature, and finally, suspension of vital activities. The whole aim of treatment in gas poisoning has been to prevent blood concentration or else restore it to a level more nearly normal. When this is accomplished the animal survives in spite of the fact that the lungs may be very œdematous. It may be stated, then, that in the presence of œdema and a concentrated blood entrance of oxygen into the circulation does not prevent death. On the other hand, restoration of blood to a more normal concentration enables an animal to survive even though an extensive œdema exists. Administration of oxygen under the last named conditions undoubtedly makes recovery easier.

Therefore, while it is accepted that indirectly the œdema of gas poisoning results in death, the immediate cause of death must be assigned to blood concentration.

THE TREATMENT OF PHOSGENE POISONING

From the foregoing considerations it is quite apparent that changes in blood concentration constitute the most important and significant action of phosgene upon the animal organism. It is, therefore, quite logical that in any endeavor toward alleviation of the effects of phosgene poisoning efforts should be directed toward the restoration of the blood to a concentration more nearly approximating the normal.

It must also be evident that for the successful accomplishment of such a purpose there should be some criterion, or criteria, which shall indicate *time* of treatment and if possible *type* of treatment. Such criteria are to be found in changes in temperature and in hæmoglobin estimations. Both are very simple procedures and best results are obtained when they are employed in conjunction. There are conditions, however, especially in the field where hæmoglobin estimations may be impracticable. Under these circumstances treatment may be successfully applied in accordance with the temperature changes alone. It should be stated that hæmoglobin determination is selected inasmuch as it may be substituted for the more arduous total solid estimation. Changes in hæmoglobin and total solids in gassed dogs follow similar if not exactly parallel courses and hæmoglobin estimation is a much more sensitive test for changes in blood concentration than is total solid determination.

In accord with these principles an outline of the treatment evolved in this investigation is as follows:

Treatment of First Stage:

Approximately one hour after gassing, blood is drawn from a vein to the extent of one per cent. of the body weight. Bleeding at any time up to four hours after gassing is beneficial, but the best results are obtained when the withdrawal of blood is practiced about an hour after gassing.

Treatment of Second Stage:

In the first stage blood concentration may exhibit one of two features after bleeding. (*a*) The blood becomes markedly dilute and *slowly* returns to normal concentration. (*b*) There is no significant dilution of the blood. The latter is an exceptional condition. The time of further treatment will therefore depend upon which of these two conditions obtains. When the blood becomes markedly dilute and then *slowly* returns to the normal, infusion of 0.97 per cent. sodium chloride solution equal in amount to the blood withdrawn should be practiced when the blood concentration regains the normal level. This usually takes from 8 to 10 hours. On the other hand, when even after bleeding the concentration of the blood is not definitely decreased, infusion of salt solution should be delayed until there is a clear indication that the blood is becoming concentrated. This usually occurs from 6 to 8 hours after gassing. In any case the *infusion should not be delayed beyond the point where the blood has reached a concentration of more than 25 per cent. above normal.*

After the infusion of the salt solution the concentration of the blood is followed at one-hour intervals by determination of hæmoglobin in order to ascertain whether subsequent salt infusion is indicated. In general, after the first infusion the blood may begin to concentrate again within one hour and when this concentration continues it may be desirable to infuse subsequently, but judgment must be exercised in order to strike a proper mean between insufficient and excessive infusion. Insufficient infusion leaves the blood concentrated. Excessive infusion augments œdema. So long as the concentration of the blood remains constant, infusion is unnecessary, and when the concentration diminishes the individual is on the road to recovery.

Treatment of Third Stage:

Usually rest and warmth are all that are necessary in this stage but if the blood should become greatly diluted again and remain so a further bleeding may be necessary. This condition, however, rarely occurs.

The principles of treatment are therefore very simple—venesection when the blood is diluting and infusion of salt solution during the initial period of blood concentration. Venesection tends to diminish the degree and extent of dilution. Infusion of salt solution tends to keep the blood concentration at a level where it is possible to maintain an approximately efficient circulation; in other words, blood concentration is kept at a level where an animal may survive. *Infusion actually accomplishes this and when properly practiced does not augment pulmonary œdema.*

The treatment as given must be considered as a mere outline of the principles followed rather than as a recital of the detailed procedure. Experience with the method soon showed that *intensive* treatment in the first stage of phosgene poisoning, that is, in the period of dilution, will, in the majority of cases, prevent extreme concentration of the blood characteristic of the second stage. In other words, the second stage is very greatly modified by proper treatment of the first stage. During the first stage water should not be given.

Proper treatment of the first stage consists in venesection to the extent of 0.5 per cent. body weight as soon after gassing as practicable. The temperature and hæmoglobin are then followed at one-half hour intervals. So long as the temperature remains normal and blood concentration does not diminish, further treatment is not indicated. When, however, the temperature rises rapidly and a fall in blood concentration occurs (the two changes take place simultaneously) a second venesection of 0.5 per cent. body weight is practiced. This procedure may be repeated a second time, that is, until blood to the extent of 1.5 per cent. of the body weight has been withdrawn. The large majority of cases need no further treatment and practically every animal survives.

If in spite of intensive treatment in the first stage the blood becomes markedly concentrated and a marked fall in temperature takes place, the condition of the animal must be considered as very serious, and if left untreated will surely die. At this point, of course, infusion of salt solution is indicated.

The essential feature in the stage of blood concentration is to diminish if possible the degree of concentration and we have found by experience that it matters little how this is attained. Thus this purpose may be accomplished by infusion of salt solution, by oral administration of water or even by intraperitoneal injection of salt solution. Probably one-half the animals in a serious condition in this stage of blood concentration may be saved by following either procedure. The fact that fluid by mouth or peritoneal cavity acts with about the same efficiency as direct infusion into the circulation, increases the practicality of the method when applied to man under field conditions where in many instances infusion into a vein would be out of the question.

The efficiency of the method of treatment may be realized from the following figures. When dogs are gassed at a concentration of 80 to 90 parts phosgene per million of air for one-half hour and given no treatment 21 per cent. recover. Under the same conditions treatment as outlined enables 63 per cent. of animals to recover. Presenting it differently, treatment increases the recoveries three-fold.

With respect to the treatment of chlorine and chlorpicrin poisoning the principles enunciated for phosgene hold true. While the principles are the same there is a difference in the *time of application,* for in general in chlorine and chlorpicrin poisoning the initial stage of dilution is lacking. With phosgene *early* bleeding and *delayed* infusion are advocated; with chlorine and chlorpicrin *early* bleeding and *early* infusion are imperative. Moreover, in chlorine poisoning there is evidence of a significant acidosis, hence, administration of sodium bicarbonate by mouth is advocated, in addition to the treatment outlined for phosgene.

When dogs are gassed with chlorine at a concentration of 800 to 900 parts per million of air for one-half hour and given no treatment 9 per cent. of animals recover. Under the same conditions with treatment as outlined 30 per cent. of dogs recover.

When dogs are gassed with chlorpicrin at a concentration of 110 to 130 parts per million of air for one-half hour and given no treatment, 43 per cent. of animals recover. With treatment 80 per cent. recover.

Various other types of infusion fluids, such as other salt solutions, dextrose solutions, acacia solutions, etc., have been tested in an endeavor to obtain a blood diluent which would remain in the circulation for a considerable period. An extended experience has shown that none of these solutions answered our purpose so well as simple isotonic sodium chloride solution.

The results of the treatment as given justify the conclusion that the factor in gas poisoning exerting the greatest detrimental influence is the alterations in blood concentration, and further, that if blood concentration can be controlled a gassed individual has very fair chances of recovery from the effects of the gas.

OXYGEN IN THE TREATMENT OF GAS POISONING

Lack of oxygen in certain stages of gas poisoning plays a significant rôle. There is little or no evidence of an inadequate supply of oxygen in the arterial blood during the first part, if not the whole of the first period. When, however, blood concentration becomes marked insufficient oxygen in the arterial blood is quite apparent. In this investigation changes in blood concentration have been assumed as the responsible factors leading to the condition of anoxæmia. According to this view the viscosity of the concentrated blood leads to impaired circulation in the tissue capillaries, thus accounting for the extremely low oxygen content of the venous blood, which is so characteristic of gas poisoning.

The question naturally arises, "Will administration of oxygen eliminate anoxæmia?" Again, if anoxæmia is alleviated will this allow the individual to survive the effects of phosgene poisoning? From clinical experience there seems to be conflicting evidence as to the value of oxygen in the treatment of gas poisoning. On the whole, however, it would appear that the consensus of opinion indicates that oxygen administration is decidedly beneficial in the circumstances under discussion. On the other hand, from an experimental viewpoint, oxygen as the only treatment of gas poisoning appears to have very little value, inasmuch as just as many gassed animals die when continuously kept in an atmosphere of 50 per cent. oxygen as without oxygen treatment. Though this conclusion is inevitable from the data, it must be conceded that oxygen administration seems to relieve the animal. It rests more quietly, respiration is less difficult, and obvious cyanosis disappears or is absent.

An analysis of the situation reveals the reason for the failure of oxygen to change the death-rate in phosgene poisoning. Oxygen administration to lethally gassed dogs may improve markedly or even restore to normal the oxygen content of arterial blood, without, however, significantly increasing the content of the *venous* blood. In those instances where venous oxygen content is maintained within approximately normal limits recovery follows. *The same thing may occur, and to the same extent, without oxygen treatment.* It is therefore quite evident that though arterial blood contains sufficient oxygen the tissues are undergoing oxygen starvation. Oxygen treatment alone does not strike at the fundamental difficulty namely, oxygen starvation induced by an inadequate circulation. The concentrated blood is responsible for the inefficient circulation, and if the gassed individual's condition is to be improved, measures must be taken to restore the blood to a concentration at which life is possible. It has been found that when the blood is treated in this way by the method outlined earlier, sufficient oxygen may be provided for tissue respiration without oxygen administration. It is a significant fact, however, that bleeding and infusion followed by oxygen administration results in the restoration of both arterial and venous blood to approximately normal conditions with respect to oxygen content. It would appear from these facts that bleeding plus infusion so changes the physical character of the blood as to render possible a more complete oxygenation of the tissues.

From another viewpoint the value of oxygen in treatment is indicated. Exposure to phosgene diminishes appreciably the oxygen consumption. Breathing oxygen under these circumstances increases oxygen consumption. Bleeding slightly increases oxygen consumption, although it is still below normal. It is thus apparent that venesection increases somewhat the ability of the animal to obtain oxygen. Breathing oxygen after venesection still further raises oxygen consumption. Infusion raises the oxygen consumption to a still higher level. Oxygen administration after infusion brings the oxygen consumption back to the normal level and may indeed carry it above. This should be considered in connection with the percentage saturation of arterial and venous blood. As has been pointed out above, the venous blood carries more oxygen after infusion than before. The administration of oxygen after infusion, results practically in complete saturation of the arterial blood as well. The oxygen consumption is equal to or greater than normal; while the arterial blood is almost completely saturated and the venous percentage saturation indicates that the tissues are getting an ample supply of oxygen.

The conclusion is therefore warranted that the method of treatment involving venesection, infusion and oxygen administration is definitely indicated for the reëstablishment of normal conditions in the respiratory functions of the blood in an animal gassed with phosgene. Under these circumstances recovery is made possible.

THE PHYSIOLOGY OF THE AVIATOR *

DR. YANDELL HENDERSON

Yale University

DOUBTLESS you have all read the delightful historical accounts by the late Admiral Mahan of the great naval battles of the eighteenth century, when France and England struggled for the mastery of the sea. You will recall the stress laid on the weather gauge, or windward position. If the wind blew from the eastward, as does the "northeast trade" among the Caribbean Islands where a great part of the struggle occurred, whichever admiral was able so to manœuvre as to be to the east of his enemy obtained a great, and often a decisive, advantage. He could choose the time and mode of attack, while his antagonist was compelled to remain on the defensive, unable either to force the fighting or to escape it.

In modern naval warfare the position of the sun in relation to the enemy's fleet affects the accuracy of aim. The speed of the ships is of importance equalling that of their gunfire. But there is no element of position which quite corresponds to that of the weather gauge for a fleet under sail.

In the battles of the ships of the air, however, there is again a condition which corresponds quite closely to the tactical advantage of manœuvring between the wind and the enemy. In this case it is not a direction in the plane of the horizon, except so far as light is important; but it is the direction at right angles, vertical to this plane. It is the upper position—the advantage obtained by him who can climb above his enemy, and, choosing the moment of attack, can swoop down upon him from above.

With this as one of the fundamental conditions of aerial warfare, it was inevitable that in the development of the battle plane there should be the utmost effort to produce machines of continually greater speed and, its correlative, climbing power.

* Delivered March 22, 1919.

Likewise in the air, the greatest practicable altitude has meant for the flying man at once an advantage over his enemy and a reduction of his own chance of being hit by anti-aircraft fire from the enemy's guns on the ground.

Accordingly, from the comparatively low altitude at which the aerial fighting of the first year of the war usually occurred, the struggle rose, as more and more powerful airplanes were constructed by both sides, until at the end of the war it was quite common for battle planes to ascend to altitudes of 15,000 to 18,000 feet—three miles up, higher than the summits of the Rocky Mountains or the Alps.

Along with this development there occurred with increasing frequency among the aviators a condition of so-called "air-staleness." It is a condition closely similar to, perhaps identical with, the "overtraining" or staleness, the physical and nervous impairment of athletes in a football team or college crew. In the last year of the war this condition had become so common that, as reported to us by some observers, the majority of the more experienced aviators in the British service were incapacitated to ascend to the necessary altitude, and many could no longer fly at all. It was to make good this most serious military deficiency that the enlistment and training of aviators was undertaken by the American Air Service on the enormous scale that it was. It was for the purpose of testing our airmen initially, and of keeping tab on their physical condition thereafter, that the work at the Mineola laboratory, of which probably you have heard, was undertaken.

It is work which lies in a field of physiology in which before the war not half a dozen men in America, and not many more in Europe, were interested, and for them it was a field of what is called "pure" science. To-day it promises contributions of practical value not only to aviation, but to problems in medicine, climatology, athletics and hygiene.

We will turn then to the problem of the aviator and the methods of human engineering which have been developed for its solution. But first, it will be advisable to review briefly what is known concerning the immediate effects of low barometric pressure and the functional readjustments involved in acclimatization to elevated regions; that is, life at great altitudes.

Paul Bert,[1] the brilliant French physiologist, was the first to demonstrate, in 1878, that the effects of lowered barometric pressure or altitude are wholly dependent on the decreased pressure of oxygen. He carried out experiments upon men and animals both with artificial gas mixtures and reduced barometric pressure in a steel chamber.

He showed that in pure oxygen at 21 per cent. of atmospheric pressure life goes on in practically the same manner as in air, which contains 21 per cent. of oxygen, at the ordinary pressure. So also the breathing of an artificial gas mixture containing only 10.5 per cent. of oxygen has the same untoward effects at sea level that breathing pure air has at an altitude of about 20,000 feet, where the barometer is reduced by one-half.

These considerations are fundamental for the differentiation of the disorders induced by rarefied air—so-called mountain sickness—from the conditions resulting from work in compressed air—so-called caisson disease. It is clear that it is from the former, and not at all from the latter, that aviators suffer; but, as the two disorders are sometimes confused, a few words regarding the latter are in place here.

Caisson disease—known also as the "bends," "diver's palsy," and by other names—depends upon the fact that, under the high pressure necessary for diving, tunneling, and other work below water, the nitrogen of the air dissolves in the blood and in the other fluids and tissues of the body in amounts proportional to the pressure. This in itself does no harm, and has in fact no effect upon the body, until the subject comes out of the pressure lock or caisson, or rises from the depth of the sea where he has been working. Then the nitrogen which has been dissolved begins to diffuse out of the body. This also does no harm and has no effect unless the pressure under which the man has been working is so high, and the lowering of the external pressure is so rapid, that the dissolved nitrogen separates in the form of bubbles. Such bubbles may form in the blood, in the synovial fluid of the joints, and even in the brain. They induce intense pain, and even paralysis and death. In order that bubbles may be formed it is essential, however, that the pressure with which the tissues are in equilibrium should have been lowered considerably more than half its absolute amount in a few minutes.

In the present state of the art of flying it is scarcely possible for an aviator to rise to a height of more than 20,000 feet, where the barometer would be less than half of that at sea level, in a period sufficiently short to allow bubbles of nitrogen to form in this way. The disorders from which aviators suffer are, therefore, of a different class from those to which workers in compressed air are exposed.

When the study of the effects of lowered barometric pressure was begun, it was supposed that the circulation might be primarily disturbed. The blood in the arteries of a healthy man is under such a pressure that, if a glass tube were inserted vertically into one of the arteries of his neck, and the blood were allowed to flow up the tube, the column of blood would come to rest at a height of 4 or 5 feet above his heart, corresponding to pressures of 120 to 150 mm. mercury. Knowing that the air pressure is reduced at great altitudes, some of the earlier writers made the mistake of supposing that such a column of blood would rise higher, and the blood-vessels would be under a greater strain, and more likely to burst therefore, at a great altitude than at sea level. That which they looked for they found. One writer has left a lurid description of how, while crossing a pass in the Andes, he got off his mule and walked for a time to rest the animal. On the least exertion his breathing became oppressed, "his eyes bulged and his lips burst." The odd part of this is that in reality the blood-vessels are under no greater strain at a high altitude than at sea level. When the air pressure upon the exterior of the body and in the lungs is reduced, a part of the gas—at least the nitrogen dissolved in the blood—rapidly diffuses out through the lungs, so that the gas pressures within and without the blood-vessels are again equal just as at sea level. The idea is still prevalent that hemorrhages occur under low barometric pressures. However, among thousands of people whom I had an opportunity to observe on Pike's Peak during a five weeks' stay at the summit, I saw not a single nose bleed, except one which was caused by the forcible application of a hard object to the organ in question.

The only direct effects of changes of pressure are those which are felt in the ears, and occasionally in the sinuses connected with the nose. The ear-drums are connected with the throat and contain air at the prevailing pressure. If the pressure is lowered this air expands, and forces its way out through the Eustachian tubes into the throat. If the outside pressure is increased, it sometimes happens, particularly when the subject has a cold and the Eustachian tubes are inflamed, that air does not pass readily into the middle ear. Accordingly the tympanic membranes are forced inward by the pressure; and this may cause acute pain. Workers in compressed air are accustomed, while going "into the air," *i.e.*, into pressure, to hold their noses and blow at frequent intervals as a means for expanding the ear-drums. Aviators, even during very rapid descents, are generally relieved by merely swallowing.

To sum up all that has been said thus far, the influence of low barometric pressure is not mechanical but chemical. Life is often compared to a flame; but there are marked differences, depending upon the peculiar affinity of the blood for oxygen. A man may breathe quite comfortably in an atmosphere in which a candle is extinguished. The candle will burn with only slightly diminished brightness at an altitude at which a man collapses. The candle is affected by the proportions of oxygen and nitrogen. The living organism depends solely upon the absolute amount of oxygen—its so-called partial pressure.

Unlike the flame, a man may become acclimatized to a change of atmosphere in the course of a few days or weeks. He is thus adjusted to the mean barometric pressure under which he lives. Every healthy person is so adjusted, New Yorkers to a mean barometric pressure of 760 mm. no less than the inhabitants of Denver or Cripple Creek to their altitudes. Even your tall buildings could probably be shown to exert a slight climatic effect upon the tenants of the upper stories. The study of the processes involved in such acclimatization affords us one of the most promising means of analyzing some of the fundamental problems of life.

In fact, is not the gaseous interchange of protoplasm, the carbon and oxygen metabolism of the cell, the central fact of life? Is not the mode of regulation of the interior environment of the body—the constants of the "humours"—the prime problem of the "vegetative" side of physiology.

Among the ill effects of lack of oxygen we may distinguish three more or less distinct conditions. They are comparable, in terms of more common disorders, to acute disease in contrast with chronic conditions of various degrees. Thus any one suddenly exposed to acute deprivation of oxygen, as is the balloonist or the aviator in very lofty ascents, shows one set of symptoms. If the exposure is less acute, as in the case of one taking up residence on a high mountain, the effects develop gradually; he passes through the stages of mountain sickness, a condition much like sea sickness, to a state of acclimatization and renewed health. If, however, the ascent or the flight is for only two or three hours, a period too short for any degree of acclimatization to develop, and this strain on the oxygen-needing organs is repeated daily, as is the case with the aviator of the upper air, the condition of "air staleness" is likely sooner or later to result. It is the effect of repeated slight oxygen deficiency on an individual who does not become acclimatized. It is, I believe, closely related to those effects of repeated overexertion and oxygen shortage which appear in the overtrained athlete.

The classic description of collapse from oxygen deficiency is that written by Tissandier,[2] the sole survivor of a fatal balloon ascent in 1875.

I now come to the fateful moments when we were overcome by the terrible action of reduced pressure. At 7000 metres (Bar. 320 mm.) we were all below in the car. . . . Torpor had seized me. My hands were cold and I wished to put on my fur gloves; but without my being aware of it, the action of taking them from my pocket required an effort which I was unable to make. At this height I wrote, nevertheless, in my notebook almost mechanically, and I reproduce literally the following words, though I have no very clear recollection of writing them. They are written very illegibly by a hand rendered very shaky by the cold. My hands are frozen. I am well. We are well. Haze on the horizon, with small rounded cirrus. We are raising. Crocé is panting. We breathe oxygen. Sivel shuts his eyes. Crocé also shuts his eyes. I empty aspirator. 1.20 P.M.,–11°, Bar. 320. Sivel is dozing. 1.25–11°, Bar. = 300. Sivel throws ballast. Sivel throws ballast. (The last words are scarcely legible.) . . . I had taken care to keep absolutely still, without suspecting that I had already perhaps lost the use of my limbs. At about 7500 metres (Bar. 300 mm.) the condition of torpor which comes over one is extraordinary. Body and mind become feebler little by little, gradually and insensibly. There is no suffering. On the contrary one feels an inward joy. There is no thought of the dangerous position; one rises and is glad to be rising. The vertigo of high altitudes is not an empty word; but so far as I can judge from my own impressions this vertigo appears at the last moment, and immediately precedes extinction, sudden, unexpected and irresistible. . . . I soon felt myself so weak that I could not even turn my head to look at my companions. I wished to take hold of the oxygen tube, but found that I could not move my arms. My mind was still clear, however, and I watched the aneroid with my eyes fixed on the needle, which soon pointed to 290 mm. and then to 280. I wished to call out that we were now at 8000 metres; but my tongue was paralyzed. All at once I shut my eyes and fell down powerless, and lost all further memory. It was about 1.30.

In this ascent the balloon continued to rise until a minimum pressure, registered automatically, of 263 mm. was reached. When Tissandier recovered consciousness Sivel and Crocé-Spinelli were dead. They were all provided with oxygen, ready to breathe; but all were paralyzed before they could raise the tubes to their lips. Tissandier's notes are characteristic of the mental condition when oxygen-want is becoming dangerous.

In marked contrast to this condition is that of men who, gradually ascending into the mountains, day by day become acclimatized without realizing that any change has occurred. The record for the greatest altitude attained by mountaineers is held by the Duke of Abruzzi and his party in the Himalayas. They reached an altitude of 24,000 feet, where the atmospheric pressure is only two-fifths of that at sea level, or practically the same as that at which Tissandier's companions lost consciousness. At this tremendous altitude the Duke and his Swiss guides were not only free from discomfort, but were able to perform the exertion of cutting steps in ice and climbing. Doctor Filippi, the physician who accompanied them, in discussing this matter, says that the fact of their immunity admits of but one interpretation:

Rarefaction of the air under ordinary conditions of the high mountains to the limits reached by man at the present day (307 mm.) does not produce mountain sickness.[3]

In this statement, however, he is certainly mistaken, for the observations of others show conclusively that the sudden exposure of unacclimatized men to an altitude considerably less than that reached by this party would either produce collapse like that of Tissandier's companions, or if long continued would result in mountain sickness. The latter effect especially is one which was the subject of careful study by an expedition of which I was a member, and which during the summer of 1911 spent five weeks at the summit of Pike's Peak, Colorado, altitude, 14,100 feet, Bar. 450 mm. We were there enabled to make observations upon hundreds of tourists who ascended the Peak, and who were acclimatized at most to the altitude of Colorado Springs or Manitou at the foot of the mountain. We saw a number of cases of collapse —fainting—from oxygen deficiency, as shown by the striking cyanosis.

In the majority of cases, however, tourists who spent no more than the regulation half hour at the summit of the Peak, and then descended, experienced no acute ill effects. Headache and some degree of nausea were common even among these persons, however—often developing slowly for some hours after their descent. On the other hand, among persons who remained over night, and were thus exposed for several hours to deficiency of oxygen, the classic symptoms of mountain sickness occurred; and few escaped. Their second day at the summit was marked usually by extreme discomfort—headache, nausea, vomiting, dizziness and extraordinary instability of temper—symptoms which were strikingly exacerbated by even the smallest use of alcohol.

Our immediate party passed through these conditions and after two or three days, or in one case nearly a week, re-attained practically normal health. A definite functional readjustment had occurred. To illustrate and emphasize the nature of this readjustment I will quote a recent experiment * of my friend the leader of the Pike's Peak expedition, Dr. J. S. Haldane.

* Personal Communication.

He has equipped his laboratory at Oxford with a small lead-lined chamber in which a man can be hermetically closed. The carbonic acid which he exhales is continually absorbed by alkali, so that no accumulation occurs, while the oxygen is progressively decreased by the breathing of the man himself. Doctor Haldane found that after a day or two in this chamber he had reduced the oxygen to an extent comparable to Pike's Peak. At the same time there had evidently occurred in himself a gradual process of adjustment, for he felt quite well. At this stage he invited another person to come into the chamber with him, and he had the satisfaction of observing the immediate development of blueness and the other symptoms of oxygen collapse in his companion.

Evidently acclimatization is a very real phenomenon and of the utmost importance to any one exposed to a lowered tension of oxygen.

As we observed it in ourselves during our stay on Pike's Peak acclimatization consists in three chief alterations: (1) increased number of red corpuscles in the blood; (2) some change in the lungs or blood (Haldane considers it the secretion of oxygen inward by the pulmonary tissue) which aids the absorption of oxygen, and (3) a lowering of the CO_2 in the alveolar air of the lungs. This lowering of the CO_2 in the lungs is bound up with increased volume of breathing. It is the concomitant of a decreased alkaline reserve in the blood just as in nephritis and diabetes. Acclimatization in this respect consists therefore in the development of a condition which would nowadays be called acidosis.

All of these changes are of a quantitative character. Miss FitzGerald [4] has supplemented the results obtained on Pike's Peak by an extensive series of careful observations on the inhabitants of towns of closely graded altitude from sea level up to that of the highest inhabited place in our western country. She has thus shown that the mean hæmoglobin and the mean alveolar CO_2 of the inhabitants of any town are functions of the mean barometric pressure of the place.

I shall not discuss pulmonary oxygen secretion now, because the problem is still extremely obscure; nor the increased production of red blood-corpuscles, which is a slow process requiring weeks for completion, and playing no considerable part in the matter particularly before us.

We will fix our attention upon the fact that both the alveolar CO_2 of the pulmonary air and the alkaline reserve of the blood are reduced in accurate adjustment to any altitude, or oxygen tension, to which a man is subjected for a few days or even a few hours. This functional readjustment is, I believe, of great significance in relation to aviation, since it involves a larger volume of breathing per unit mass CO_2 eliminated: it thus compensates in part for the rarefaction of the air.

But how is it brought about? And why are the changes of breathing gradual, when the changes of altitude and oxygen tension are abrupt? The answer lies in part at least in the mode of development, and the nature of that acidosis of altitude to which I have referred. It is scarcely necessary to remind you that, as L. J. Henderson has shown, the balance of acids and bases in the blood, its CH, depends upon the maintenance of a certain ratio between the dissolved carbonic acid, H_2CO_3 and sodium bicarbonate, $NaHCO_3$, or, as Van Slyke terms it, the alkaline reserve. On the basis of this conception the prevalent view of acidosis is that, when acids other than carbonic are produced in the body, the bicarbonate is in part neutralized. The alkaline reserve is thus lowered, and the carbonic acid of the blood being now in relative excess, an increased volume of breathing is caused as an effort at compensation.

Recent investigations[5] by Dr. H. W. Haggard and myself show that an exactly opposite process is likewise possible. We find that whenever respiration is excited to more than ordinary activity, and the carbonic acid of the blood is thus reduced below the normal amount, a compensatory fall of the alkaline reserve occurs. The body is evidently endowed with the ability to keep the ratio of H_2CO_3 to $NaHCO_3$ normal, not only by eliminating CO_2 when the alkali is neutralized, but also by the passage of sodium out of the blood into the tissue fluid (or by some equivalent process) to reduce the alkaline reserve. A loss of CO_2 during over-active breathing is thus balanced. If it were not balanced a state of alkalosis would occur, which would inhibit respiration and induce a fatal apnœa.

It is really in this way I believe that some of those conditions arise which nowadays are called "acidosis." If so they are not truly acidosis, or rather the process producing them is not acidosis, although the resultant condition gives some of the most characteristic tests of this condition. It is on the contrary a state, or rather a process, which Mosso was the first to recognize, although obscurely, and which he termed "acapnia" an excessive elimination of CO_2. Recent papers [6] from my laboratory have shown that a sudden and acute acapnia induces profound functional disturbances, including circulatory failure.

It is one of the well-known facts in physiology that deficiency of oxygen, or anoxæmia, causes an "acidosis." Recent and as yet unpublished work of Doctor Haggard and myself indicates that the process involved is almost diametrically the opposite of that which has heretofore been supposed to occur, and that the result is not a true acidosis. Under low oxygen, instead of the blood becoming at first more acid with a compensatory blowing off of CO_2, what actually occurs is that, as the first step, the anoxæmia induces excessive breathing. This lowers the CO_2 of the blood, rendering it abnormally alkaline; and alkali passes out of the blood to compensate what would otherwise be a condition of alkalosis.

We regard the current explanation, based on the production of lactic acid, as needing reversal.

The application of this idea to the changes of breathing and of the blood alkali in acclimatization clears up some of the points which heretofore have been obscure. Thus on Pike's Peak we saw that persons whose breathing under the stimulant of oxygen deficiency increased quickly to the amount normal for the altitude suffered correspondingly little, while those whose respiratory centre was relatively insensitive to this influence suffered severely. The one type readily developed the acapnia and in consequence the pseudo-acidosis which the altitude requires. The other did not.

Here let me pause a moment to bring these conceptions into some degree of harmony with fundamental doctrines regarding respiration. For more than a century, in fact ever since the days of Lavoisier, the argument has been active whether our breathing is controlled by oxygen need or by the output of CO_2. For the past thirty years, and especially during the last ten or twelve, the theory of regulation by CO_2, or in its later form by C_H, has held the field. Indeed it is established now—almost beyond the possibility of contradiction, it would seem—that during any brief period of time, and under conditions to which the individual is accustomed, the amount of CO_2 produced in the tissues of the body, through its influence on the C_H of the blood, is the factor controlling the volume of air breathed. Its effects are immediate.

But when we view the matter more broadly it is clear that this is by no means the whole story. The oxygen tension of the air is the influence which determines just how sensitive the respiratory centre is to excitement by CO_2. But the effects of any change of oxygen tension are slow in developing, requiring in some persons, as we saw on Pike's Peak, hours to begin and several days to become complete. In fact, there are many perfectly healthy persons who, if caused to breathe progressively lowered tensions of oxygen down to 6 or 7 per cent. in the course of half an hour, feel nothing. Their breathing shows no considerable augmentation. They simply lose consciousness, and if left alone they would die, without any apparent effort on the part of respiration to compensate for the deficiency of oxygen. In such persons the stimulant of oxygen deficiency exerts only a slowly developing influence upon the sensitiveness of the respiratory centre to the stimulus of CO_2. They can become acclimatized to great altitude only at the cost of prolonged mountain sickness. Evidently they are not suited to be aviators.

In very sensitive subjects, on the contrary, the period of readjustment is much shorter. It is a matter not of days but of hours, and the functional alterations begin to develop almost immediately even under slight oxygen deficiency. The upper air is for those men whose organization readily responds with vigorous compensatory reactions.

With this inadequate sketch of present scientific knowledge regarding life at great altitudes as a background, we may turn to the application of this knowledge to the problems of human engineering in the aviation service of our army during the war. In September, 1917, I was appointed chairman of the Medical Research Board of the Air Service and was asked to lay out a plan for the development of a method of testing the ability of aviators to withstand altitude.

You will readily guess the line along which one would attack such a problem. It consisted in the development of an apparatus from which the man under test breathes air of a progressively falling tension of oxygen. The particular form which we use is called a rebreathing apparatus. It consists of a steel tank holding about 100 litres of air, connected with a small spirometer to record the breathing, and a cartridge containing alkali to absorb the CO_2 which the subject exhales. Breathing the air in this apparatus through a mouthpiece and rubber tubing the subject consumes the oxygen which it contains, and thus produces for himself the progressively lower and lower tensions of oxygen which are the physiological equivalent of altitude. To control and test the accuracy of the results with the rebreathing apparatus we installed in our laboratory at Mineola a steel chamber, in which six or eight men together can sit comfortably, and from which the air can be exhausted by a power-driven pump down to any desired barometric pressure.

Such apparatus was, however, only the beginning. The practical problem was to determine the functional changes—pulse-rate, arterial pressure, heart sounds, muscular coördination and psychic condition occurring in the good, the average and the poor candidates for the air service, and then to systematize and introduce these standards on a very large scale at the flying fields in this country and in France.

That this program was successfully carried through, and was approaching completion when the armistice was signed, was due chiefly on the scientific side to the brilliant work of my colleagues Majors E. C. Schneider, J. L. Whitney, Knight Dunlap and Captain H. F. Pierce, and on the administrative side to the splendid coöperation of Colonel W. H. Wilmer and Lieutenant Colonel E. G. Seibert.

We have recently published a group of papers,[7] brief but fairly comprehensive in their technical details, and I shall not now repeat what has there been said, but shall confine myself to a few salient points. One of these is a final and striking demonstration of our main thesis. Schneider and Whitney went into the steel chamber and the air was pumped out of it until the barometer stood at only 180 mm., 23 per cent. of the pressure outside: the equivalent of an altitude of 35,000 feet. Throughout the test they were supplied with oxygen from a cylinder through tubes and mouthpieces. They experienced no discomfort except from flatus: the gases of the stomach and intestine of course expanded nearly fivefold.

In comparison with this observation is to be placed the recent record ascent by Captain Lang and Lieutenant Blowes in England to a height of 30,500 feet. They were supplied with oxygen apparatus; but a defect developed in the tube supplying Lieutenant Blowes and he lost consciousness. Captain Lang seems to have suffered only from cold.

From this it might appear that the simplest way to solve the problem of lofty ascents would be by means of oxygen apparatus. The Germans evidently made use of such apparatus, for it was found in the wreck of one of the German planes shot down over London. The British also had such apparatus, but it was difficult to manufacture, wasteful in operation, and in other respects left much to be desired. In fact, the devising of such apparatus and its adaptation to the peculiar requirements of the human wearer are problems which can be solved only by the close coöperation of a physiologist and a mechanical engineer. Mr. W. E. Gibbs, of the Bureau of Mines, with whom I had coöperated in developing mine rescue oxygen apparatus, took up this problem and produced a device which should prove valuable. Unfortunately the common tendency to favor ideas and apparatus coming to us from Europe operated against the adoption of the better American device.

It is doubtful, however, whether any apparatus of this sort will ever quite take the place of physical vigor and capacity to resist oxygen deficiency on the part of the aviator himself. Imagine him, when fighting for his life above the clouds, handicapped by goggles over his eyes, wireless telephone receivers on his ears, a combined telephone transmitter and oxygen inhaler over his mouth, and a padded helmet on his head!

The importance of determining the aviator's inherent power of resistance to oxygen deficiency, if he is to be even for a few moments without an oxygen inhaler, is demonstrated by the results of the routine examinations made with the rebreathing apparatus in the laboratory. These results show that 15 to 20 per cent. of all the men who pass an ordinary medical examination are unfit to ascend to the altitudes now required of every military aviator. On the other hand, these tests pick out a small group of 5 to 10 per cent. who, without apparent immediate physical deterioration, withstand oxygen deficiency corresponding to altitudes of 20,000 feet or more.

It is particularly interesting to note that when the rebreathing test is pushed beyond the limit that the man can endure, be it the equivalent of only 10,000 or 25,000, two different physiological types with all gradations between them are revealed. The fainting type collapses from circulatory failure and requires an hour or two to recover. Often the heart appears distinctly dilated. The other and better type, on the contrary, goes to the equivalent of a tremendous altitude on the rebreathing apparatus and loses consciousness, becoming glassy-eyed and more or less rigid, but without fainting. When normal air is administered such men quickly recover.

Perhaps I ought to say at least a few words regarding the other aspects of the work at Mineola: for example, the valuable psychological investigations and the controversy over the rotation tests, which has figured so largely in our medical journals of late. It seemed best, however, to confine myself this evening to my own special field. Nevertheless, I can not suppress a public expression here of my sympathy for the brave and able scientific men in the psychological group at Mineola, who insisted on investigating the validity of the rotation tests. I am sure that you will feel as I do, when I tell you that they were threatened with punishment for insubordination when they refused to recognize that a regulation of the army, which prescribes the duration of nystagmus after the rotation test, necessarily makes this a physiological fact.

I would gladly devote a few minutes also to pointing out some of the lessons to be drawn from the rather unusually good opportunities which fell to my lot to observe the mingling of science and militarism. The chief lesson can be put in a single-phrase: They do not mix. The War Gas Investigations, which formed the nucleus on which the Chemical Warfare Service finally developed, and the Medical Aviation Investigations, of which I have spoken this evening, were both successful largely because at first they were developed under civilian control, under that splendid scientific arm of the government, the Bureau of Mines and its able director. It is a wise provision of our government by which the Secretary and Assistant Secretaries of War are always civilians. It would also be wise for the general staff in any future war to keep scientific men on a scientific status instead of practically forcing them into uniform.

We all hope that we are done with war, and with soldiers—at least for a generation. We can, however, derive certain broad lessons applicable to the conditions of peace from the experiences and intense activities of war, when almost unlimited funds were obtainable for research and the experiences ordinarily scattered over years were crowded into a few months. One of these lessons is that scientific men need to develop the capacity to become the heads of large enterprises without ceasing to be scientific, without degenerating, as is too often the case, into the super-clerk, who seems to be the American ideal of the high executive official. It is not enough for the scientific man to become the expert adviser to the unscientific administrator. If the latter has the responsibility he will use his power as he, and not as the scientific man, sees fit. To this rule I have known only one splendid exception.

For the most part among us the great prizes go to the man who works up through clerical rather than through expert lines. We must find some way to change this. The path of science must lead to the top, and at the top must still be science. To achieve this ideal, the scientist must show generosity toward colleagues and subordinates, an enthusiastic recognition of their merit and an abnegation of self-aggrandizement, no less than skill in plan and energy in execution. It is essential also that he should develop methods for conserving time and strength by assigning clerical work to clerks instead of becoming a clerk himself, in order that he may keep mind and desk clear for the really important things.

The Chemical Warfare Service was a success largely because the chief of the Research Division followed these principles as the spontaneous promptings of science and patriotism.[8] Medical research in aviation was productive just so long as it pursued a similar course.

He who charts this course, so that others may follow it through the pathless seas of the future, will make a great contribution to science, education, government, and indeed to nearly every phase of trained activity in America.

[1] Paul Bert, "La Pression Barometrique," Paris, 1878.

[2] Quoted from Paul Bert, *op. cit.*, p. 1061.

[3] Quoted from Douglas, Haldane, Henderson and Schneider, "Physiological Observations on Pike's Peak," Phil. Trans., 1913, B. 203, p. 310.

[4] FitzGerald, M. P., Phil. Trans., 1913, B. 203, p. 351, and Proc. Royal Soc., 1914, B. 88, 248.

[5] Henderson and Haggard, Jour. Biol. Chem., 1918, 33, pp. 333, 345, 355, 365. Further investigations will be published in the same Journal for August 1920.

[6] Henderson and Harvey, Amer. Jour. Physiol., 1918, 46, p. 533, and Henderson, Prince and Haggard, Jour. Pharmac. Expr. Therap., 1918, 11, p. 189.

[7] Y. Henderson, E. G. Seibert, E. C. Schneider, J. L. Whitney, K. Dunlap, W. H. Wilmer, C. Berens, E. R. Lewis and S. Paton, Journal American Medical Association, 1918, vol. 71, pp. 1382–1400.

[8] G. A. Burrell, Journal of Industrial and Engineering Chemistry, 1918, 2, p. 93.

HUMAN BEHAVIOR IN WAR AND PEACE*

DR. STEWART PATON

I

IN August, 1914, we were suddenly and tragically reminded of our ignorance of what constitutes the foundations of temperament and character. A demonstration on a scale of exceptional magnitude alarmed us by showing that it was possible for civilized man to revert within a few hours to primitive man. Evidences of the advance of a people to the period of national development were then replaced by signs indicating the return to tribalism. The change at first startled and then depressed us; and the depression deepened as the consciousness of our ignorance of human nature and consequent inability to forecast behavior was impressed upon us. Indeed there have been times during the past four years when those who did not have some rational philosophy to sustain them were almost ready to blame Prometheus "for fashioning such animals as men."

One striking evidence that already we are becoming indifferent to the study of the emotional and mental forces that resulted in Germany's aggressions, is reflected in our failure to realize, with the historian Lecky, that a "study of predispositions is much more important than the study of arguments." At the present time when the world has been turned topsy-turvy and disorganizing influences are operating in society, it is very desirous that we should make every effort to find out the causes that predispose men to be peaceful or warlike, to be impulsive or deliberate, to be quick to resent a supposed injury or to be cautious in forming an opinion and slow to anger; and, finally, what peculiar combination of circumstances has resulted in the overvaluation of ideas expressed in such beliefs as are entertained

---

* Delivered April 12, 1919.

by persons who are obsessed with the notion of having found the only road to ethical, cultural or political salvation. If we are intelligent in making preparations for peace, then we should be fully alive to the danger threatening civilization whenever and wherever egotism, belief in the infallibility of any system, and efficiency of organization are combined. We should not judge Prussianism, Bolshevism or Pacifism by the arguments presented, but should go deeper to study the predispositions of those professing these doctrines, which will be found to be the product of minds having many traits in common. Predispositions and not the arguments of those who plead, either the cause of Democracy or Autocracy, are the potent influences in the development of our civilization.

Already there are signs that there is a return of the old spirit of indifference to finding solutions for the problems of human behavior and to the state of unpreparedness for either peace or war; and if it renders us insensitive to our present responsibility and opportunity, we shall drift along as we did before the war, until some catastrophe brings us once again to our senses.

II

The greatest foe of civilization to-day is nervousness. We do not now refer to the great number of well-recognized types of nervous and mental diseases, but to the nervousness of many persons of unstable emotional equilibrium possessing unusual intellectual capacity. No adequate provision is being made to study these super-idealists, fanatics, and visionaries. The menace of these wishful thinkers is far greater than that caused by tuberculosis or any of the contagious or infectious diseases; and yet our medical schools, the Army Medical Corps and the Red Cross do not seem to appreciate the urgent need of attempting to increase the supply of psychiatrists able to cope successfully with the dangerous malady rapidly spreading by suggestion, and even now threatening the foundations of society.

The civilized world is asking for peace, and the adoption of every reasonable precaution that will diminish the possibility of another war. At the Peace Conference many "arguments" have been presented but we have heard very little of any inquiry into those "predispositions" which incline people either to make peace or drive them into war. Under the influence of wish-directed thoughts, and without any deep and comprehensive knowledge of the forces shaping character, we have begun to build up a social structure on the shifting sands of conjectural opinion as to what we imagine man to be. Only when we are surrounded by instances of man's inability to control his passions do we understand that "Le génie n'est probablement pas le resultat de la connaissance de la matière, mais de la connaissance de l'homme."

Nevertheless, in spite of the storm clouds there is more reason to be optimistic in regard to the future of civilization than there was four years ago. Society has not only survived a capital operation but it has been driven literally at the point of the bayonet to take a more rational interest in human behavior. Of course there are dark spots on the horizon, but to-day, in contrast to the condition four years ago, the problem we have to solve is taking definite shape. Although organized fury no longer menaces civilization, throughout the world morbid instability, quarrelsomeness, extravagances of all kinds, and the neurotic tendency of blaming everybody except ourselves for our misfortunes make difficult sometimes the realization that man is a rational being. We are like children crying aloud for peace, promising ourselves only good things, dreaming of Utopias, formulating schemes for the reorganization of society, planning new republics, and advertising our faith in the efficacy of "isms" to take the place of that accurate knowledge we should be interested in securing about the genesis and nature of the impulses, motives, sentiments and trains of thought which either drive people into war or inspire them to make and preserve peace. We draw up schemes for redeeming society much faster than we take steps to add to our knowledge of man. So many successive plans having as their object the redemption of Society are proposed that one is tempted to ask, "Which way go the physiognomists, metoscopists and chiromantists to work?"

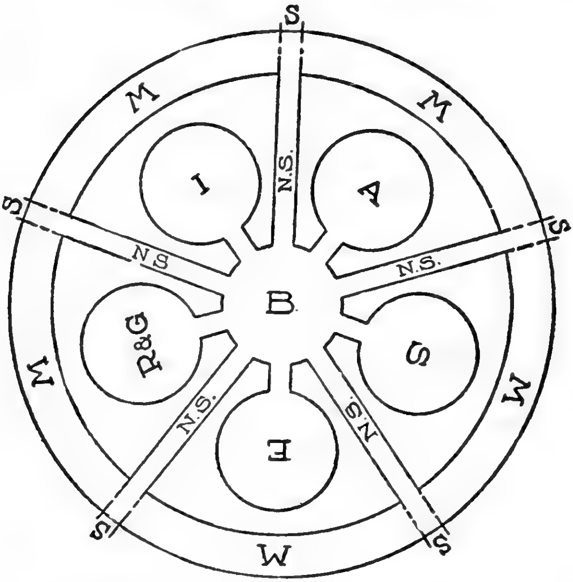
III

The members of the medical profession have a magnificent opportunity to assist in developing the mental prepardedness essential either for maintaining peace or for prompt prosecution of war, if this is again necessary to overthrow unjust aggressors.

The physician should be well qualified to undertake the study of human character. Unlike the psychologist, the physician does not have to be reminded of the very close interaction of mind and body. Even before the days of Aristotle he had approached the study of the mind from the side of the body. Long ago he recognized the necessity of understanding something about the structure and the relation of the various organs as preliminary to the study of the machine in action. The medical man while only vaguely appreciating the value of functions like feeling and thinking as processes assisting in the adjustment of life, recognized that although there was a close connection between mental phenomena and those related to the circulation, respiration and secretion of the internal glands, analysis was so difficult that little attention was given to exploring emotional and mental adjustments. Even if he has not been able to explain the connection, intimate as it is between body and mind, his line of approach to the ancient problem has at least made it easier for him than for other investigators since he should see the body-mind problem in its proper biologic setting. The physician should be ready by reason of his medical training to grasp the significance of the recent rediscovery of a very old truth, namely, the doctrine of biologic unity. This doctrine when stated in practical terms stresses the impossibility of dissociating mind and body and emphasizes the importance of considering as a whole that which for so many centuries by some observers have been considered as two entirely separate systems working independently of each other.

The body-mind problem as it was once formulated appealed only to the speculative philosopher, but as recast in the world's laboratory of life it has acquired an immediate and tragic interest for every thinking person "Life" and "living" have forced these questions into the centre of the field of interest. Doubtless we shall soon visualize correctly the present opportunity, see the problems in their right perspective and make provision for teaching mental hygiene in connection with departments of hygiene. As a matter of fact many physicians do not yet recognize the importance of considering these two departments, Physical and

Diagrammatic Representation of Factors Concerned in Adjustments of Human Machine



Organs governing intake (I), assimilation (A), storing (S), and elimination (E), of energy, and processes of reproduction and growth (R & G), controlling mechanism, brain and nervous system, (B, N. S).

Motor apparatus, (M).

Environmental contacts, sense organs, (S).

In health the human organism is capable of shifting gears from reflex to automatic, emotional or intellectual levels to effect the adjustment of internal conditions to external conditions essential for efficiency and the maintenance of a well-balanced personality.

Mental Hygiene, as inseparable and as representing two phases of one great problem.

Will it be necessary for an intelligent lay public to lead the medical profession to appreciate its present opportunity and responsibility in this particular field?

The war has served to remind medical men of the fact that there was one side of the great human problem to which they have unfortunately given comparatively little attention. They have been occupied in getting the human machine in order to run, but have given little or no attention to the amount of strain it would stand, the distance it would go without repairs, and took little notice of the kind of work it is best fitted to perform. Every day the physician has been accustomed to ask his patients "how they felt," "whether they were worrying about anything," or "whether it was not possible for them to take a more rational view of living," but little time and attention have been devoted to investigating emotional disorders, the causes of worry, and the reasons for the psycho-neurotic's general feeling of dissatisfaction with life, all of which have such an important bearing upon the present complex of symptoms of social unrest. To some persons the analysis of "sensations," "sentiments," "instincts," "feelings" and "ideas," seems to be outside the ordinary field of exploration reserved for the physician. But on the contrary, the rapid growth of functional nervous and mental diseases, more general belief in the efficiency of "isms," and the spread of the Christian Science—Pacifistic—and Bolshevist—psychoses are decidedly within the field of the medical investigator.

IV

At every turn there are signs that many people have strayed into a special field of investigation representing the study of mind, in which they should be guided by medical men trained in the art of studying the human personality. A visit to almost any book shop in order to count the number of books in which such subjects as "Thought Transference," "Speaking with the Dead," "Theosophy," "Christian Science," "The Search for the Philosopher's Stone," and various other forms of mysticism are discussed, is sufficient to indicate the vagaries of wish-directed thinking which represent unsuccessful attempts to satisfy deep-seated needs. It is very unfortunate that the members of the medical profession have not been more active in directing these currents of thought into proper channels. They have waited until the public has begun to be impatient at its failure to secure reliable information in regard to the problems of human behavior. Already many intelligent people are showing signs of uneasiness because they cannot receive intelligent assistance from members of the medical profession in securing satisfactory adjustments in their emotional and intellectual life.

The assumption is often made by a group of investigators who, it may be said, have never had time or opportunity to study the problems of human behavior, that a great deal is known about this subject. This belief is current among scientific men engaged in studying the behavior of the lower organisms, as well as among persons who have approached this special field from the academic point of view. A few hours in a psychiatric clinic where one is compelled to explore the personality of patients should be sufficient to convince any rational person that we have only just begun the study of human activities. Possibly it is advisable to remind those critics who affirm that very little more information is to be obtained in regard to the behavior of the human animal that a distinguished surgeon in the sixteenth century declared little remained to be done in advancing surgical knowledge!

Before the outbreak of the war there were evidences of increasing popular interest being taken in the causes and methods of preventing nervous and mental diseases. The war directed the attention of the intelligent public to special phases of the problem; to the war psychoses or to the search for some rational explanation for the Prussian psychosis, Bolshevist mania and the emotional instability which results in criminal acts and general unrest. It is indeed unfortunate that the physician has waited until he is compelled by force of circumstances to take cognizance of his present opportunity for directing so much of the energy now dissipated to strengthen the constructive forces in civilization. It is not creditable to the medical profession that largely as the result of its indifference to a very important subject it has now become much easier to secure large endowments for Christian Science temples than it is to find the funds for institutions for the study of human behavior.

The physician has interested himself in examining different parts of the human machine, and has imitated the example of the mechanician who remains in the workshop cleaning out cylinders and grinding valves but taking little interest in finding out how the motor runs while climbing hills or crossing rough roads.

If the average physician were asked why he has neglected to analyze the soul life of his patients, he would doubtless reply that he had been so preoccupied in ministering to their physical needs that practically no time remained for the study of mental processes. This reply is only partially true. In the minds of a great many doctors there exists a prejudice as old as the Lucretian philosophy that makes it extremely difficult for them to consider the study of psychological phenomena as a legitimate field for scientific exploration. Physicians have been among the most consistent and persistent opponents of mysticism, and yet curiously enough they have tacitly accepted the naïve mysticism with which the radical materialist covers up some of the defects in his logic. Science is pictured as having a certain set of symbols, microscope, balance, and test tube, and it is assumed that mental phenomena which can be neither seen, weighed nor dissolved should be immediately rejected as unworthy of scientific investigation. As a rule the average medical man takes cognizance only of those facts in individual experience which fit into his rough and ready philosophy of life, and discards those which cannot be quickly analyzed and arbitrarily adapted to suit conventionalized lines of thought.

There is another factor which has had a very decided influence in preventing the physician from developing an intelligent interest in the study of mental processes. There is nothing particularly dramatic in exploring the personality of the average patient and only the occurrence of some tragic event seems to arouse his interest in the drama of life. The character of the methods used and the nature of the instruments employed in making a physical examination are always suggestive of the possibility of the introduction of some unexpected element to stimulate the interest of the examiner. On the other hand, in analyzing emotional reactions or intellectual adjustments the examiner is thrown back upon his own intellectual resources and there is little opportunity to manipulate apparatus and stimulate the flagging imagination by the suggestion of reality associated with purely objective signs.

While physicians appreciate that the circulatory and respiratory functions represent mechanisms essential for the successful adjustment of life, they seldom stop to consider that feeling and thinking are also equally important in securing the adaptation of human beings to the environment in which they live.

V

Having reviewed some of the sins of omission of the medical man we shall probably not be considered prejudiced if reference is made to the sins of commission of psychologists. If the physician stopped short of the goal he might have reached had he extended his field of exploration to include the study of the personality, the psychologist has been guilty of trying to build a house without paying very much attention to the foundations. The latter in practice has followed the lead of Descartes and has discussed the "res cogitans" as separate and distinct from the "res extensa." Emotions and mental processes are described as if they were not directly modified by physiological processes. The phenomena of intelligence have often been referred to without any suggestion of the relation of these very complicated adjustments to mouth-breathing, visual, or lung capacity, or to the supply of hæmoglobin and other physiological functions.

It is unfortunate that more psychologists do not take time to equip themselves to carry on work in fields into which they have been drawn by their enthusiasm. Although excellent work has been done by the psychologists in determining the mental fitness of individuals for their task, there is no doubt that many of the results should be accepted only after they have been carefully criticized by members of the medical profession who possess a practical knowledge of the different parts of the human machine and their reciprocal activities.

Once the decision has been made by the physician to explore a personality, he should not allow himself to be coerced by any fear of being thought unscientific into submissively abandoning terms which are of value in recording the data collected. The mystics of a certain school of materialists object to the use of the word "consciousness," and state that the word behavior is sufficiently comprehensive to describe the highest as well as the lowest forms of adjustment. There has been, as Kempf * has pointed out, "a sleight-of-hand movement in psychology to drop the term consciousness." If I slip on an orange peel, bump my head on the sidewalk, and remain unaware of what has happened, common sense will confirm the diagnosis that self-consciousness and not behavior was lost.

A reference is permissible to the use of the word behavior in this paper to include conduct. The word behavior is often used to describe those higher forms of response conduct in which some guiding motive is present. The retention of the word conduct in our vocabulary is desirable. There can be no doubt that we convey a better idea of the functions of the conductor of an orchestra by the use of this word than we should do if he were described as the leading behaviorist.

It seems to be the general consensus of opinion that during the period of the war many new facts of fundamental importance for the study of human behavior were not discovered. We have, however, acquired considerable skill in spreading out in a very thin layer the small stock of knowledge we possess. The neurologists who have had active service in the army know to what good use this information has been put in improving treatment as well as in preventing the occurrence of the symptoms of mental disorders. Progress has also been made in securing increased industrial efficiency, and last but not least, in assisting us to acquire a new and broader outlook upon life in general. After reading the clinical histories of persons suffering from nervous or mental diseases, the scientist with a reflective turn of mind is ready to sympathize with the French philosopher's lament that there are not more intelligent doubters in the world. "Sensations," "instincts," "conflicts," and "compensatory mental reactions" are discussed in many of these records with a degree of

* Kempf, E. J.: The Autonomic Functions and the Personality, Nerv. and Ment. Dis., Monogr., Series No. 28, 1918, p. 11.

assurance which suggests a great deal of attention has been given to analyzing these phenomena; an inference, however, which is not justified.

VI

One example may be cited of the desirability of extending our knowledge beyond the present stage in which vague conceptions and approximate definitions form the basis from which most of our investigations start. We often hear it said that in soldiers under fire for the first time, the old instinct to preserve life gets the better of the recently acquired central reactions associated with a special sense of duty and an understanding of the desirability of facing the enemy, with the result that an unfortunate conflict is precipitated At once the question is suggested what phenomena should be included under the term instinct and what is the nature of the conflict.

At present we have only the vaguest sort of notions in regard to the synthesis of reactions described collectively as an instinctive response and we are also very much in the dark as to just what mechanisms are involved in the conflict. In a very general way we are correct in saying that the instinct activities may be referred to mechanisms in the cord, medulla, and mid-brain. Ontogenetically as well as phylogenetically these nerve tracts are known to be much older than those concerned in voluntary responses. Here within a very small area we see the connections between the circulation, respiration, internal secretion, movement and the general sensibility, which all play a part in the instinctive reactions. The majority of physicians adhere conservatively to their determination to study only the objective reactions connected with the activities of the lower brain centres. A glance at any diagram illustrating the relation of parts in the mid-brain and medulla is sufficient to refresh our minds in regard to the proximity of all the great nerve tracts radiating from these centres to higher ones and suggests the need of more active coöperation in research between psychiatrist and internist who have arbitrarily separated functions which nature has united.

Think of what valuable information could be obtained by intelligent coöperation between the psychiatrist and internist intent upon studying together the physical and mental symptoms associated with the vagaries of feeling, thinking and acting occurring in every patient admitted to the wards of a general hospital. This entente would be of assistance, not only in laying the foundations of an exact knowledge of the psycho-neuroses, but as an aid in understanding human nature. A pooling of clinical interests is needed in order to conduct a successful attack upon the problem of the psycho-neuroses which are probably a greater menace to civilization than are all the hostile military forces in the world.

In the vertebrate embryo there is an excellent opportunity of tracing the development of the different nervous tracts in relation to the rapid elaboration taking place in responses as higher centres modify and inhibit more primitive impulse; an important relation to understand in its bearing on the psycho-neuroses. We are accustomed to talk quite glibly without possessing any definite knowledge of the subject about the rebellion of these lower centres in "shell-shock" against the control imposed by the autocracy assumed by the new brain.

Professor H. H. Lane, at my suggestion, studied some of the earliest reactions in the embryos of guinea-pigs with a view to correlating as far as possible the progressive changes taking place in the nervous system during growth with the increasing complexity of reaction and the assumption of control by the new brain. He demonstrated that "avoiding reactions" took place in response to olfactory stimulation before the olfactory lobe was connected by differentiated nerve tracts with the cerebral cortex. The fact that an "avoiding reaction" does occur without the intervention of the cerebral cortex suggests the interesting question as to what extent in fear the subsequent responses take place without the participation of the higher centres. An interesting study could be made to determine in what manner these primitive responses are modified as the cortex gradually assumes control. A number of years ago I suggested that light would be thrown upon this problem by correlating the earliest reactions of the human embryo and the progressive structural changes taking place in the nervous system; and pointed out the excellent opportunity there is in the obstetrical wards of a hospital for extending these observations to the human subject. Studies of this character are needed to assist in determining what factors are introduced as the higher begin to dominate the lower centres, and when this is known then the way is open to analyze the conditions responsible for "a conflict."

Hughlings Jackson,* in a remarkable series of lectures, called attention to the control exercised by the "higher nervous arrangement" over the lower forms from which they had been evolved, and compared it to the action of a government directing the nation from which the government had been evolved. When any disturbance in the coördination of function in the higher and lower centres take place we have to consider not only the effect of "the taking off" of the control, but also the "letting go" of the lower functions. The sudden removal of the governing body of any country gives reason for lamenting, "(1) the loss of service of eminent men, and (2) the anarchy of uncontrolled people." This distinguished representative of the medical profession recognized the value of that fundamental knowledge of man which it is not inconceivable that some day we shall require our statesmen to possess.

When we come to consider the question of how instincts are inherited, we begin to be confronted with serious difficulties. The physician is too much inclined to assume that biological inheritances are transmitted in the same way that psychological inheritances are passed on from one generation to another. There are two forms of heredity, says Professor Ward; "the one with which the biologist deals and this which he leaves to the psychologist—who usually leaves it alone."

VII

Reference to the methods used in the Air Service for studying the personality of the aviator † indicates the possibility of utiliz-

* Croonian Lectures, 1884.

† Manual of Medical Research Laboratory, U. S. War Department, Air Service, 1918, pp. 200–212.

ing even our very limited store of knowledge for conserving both energy and life. These examinations are conducted with a view to determining the emotional and mental fitness of an aviator to fly. It is also interesting to note that far more attention is paid to-day in analyzing the predisposition of an aviator and determining his fitness for his task than in selecting a President. Is it unreasonable to believe that some day we shall judge our rulers by their "predispositions," and not by their arguments? The efforts made to safeguard the mental hygiene of the aviator unquestionably prevented many accidents.

MEDICAL RESEARCH LABORATORY

Hazelhurst Field, Mineola, L. I., N. Y.

Examined .... date ....
Name .... Rank .... Organization......
Residence ....

I. *Aviation:*

Enlistment—date, place, sworn in, Assigned to (branch of service)—Active Service—Entrance or Transfer to Air Service. —Aviation School work—Repeats.—Aviation—active service—date of commission, dates and places of training.—Hours of flying.—Maximum Altitude. Duration.—Accidents.—Reasons for selecting aviation.

II. *Personal History:*—Age—S. M. W.
Diseases (children's and adult).
Injuries, operations.
Education, School and College.
Athletic training.
Occupation of Civil Life—Success.
Tobacco—Alcohol—Sleep—Family.

III. *Physical Examination:*—
Ht.—— Wt.—— Gain or Loss.
Pupils—Reaction to light and accommodation,
Secondary dilatation.
Knee Jerks.
Psycho-motor Tension.—

Tic—Tremor.

Extension in fingers and hands.

Tongue.

Drawing parallel lines.

Writing slowly.

Dermagraphia before and after rebreathing.

Appearance—Tired.

Evidence of anxiety or of stress.

IV. *Personality study:—*

Observation, good or bad—Resourcefulness—Forcefulness.

Frankness (Does he seem to be genuine?).

Spontaneity—Emotivity.

Temperament (mood), even, lively, dull, unsteady, tendency to unburden, stable.

Contentment.

Alertness.

Aggressiveness.

Mental Reactions, quick, slow, deliberate, degree of mental energy, dull, well balanced, high tension.

Coöperation—Sportsmanship—Self-possession.

Remarks:

Rating:

This study of the aviator's personality judged from the medical standpoint alone is not sufficiently comprehensive for all purposes, but the lines of inquiry followed were suggested by the experience gained from examinations made on the field. The initial mental symptoms of fatigue have a special interest.

MENTAL SIGNS OF STALENESS

1. Lack of pleasure in the work.
2. Lack of confidence.
3. Disgust at the whole business.
4. Nervousness in attacking the task; technique goes to pieces; he analyzes every part of it and sees his task too minutely.

When these are present the aviator should not be allowed to fly.

Personality studies properly made could be used to great advantage in laying the foundations for a rational education.

The Qualification Card for use in schools and colleges was suggested to me as the result of examining students, and trying to assist them in some of their difficulties in adjusting life. The need for this kind of work both in schools and universities is far greater than had been imagined. The information asked for can be obtained by any intelligent teacher, and it is of such a character that special technical knowledge on the part of the examiner is not necessary in gathering the data. Important results have followed the introduction of even such brief personality studies and already have led to more frequent and sympathetic coöperation between parents, teachers and physicians. A number of years ago we suggested that a training in pedagogics should aim to give teachers some practical insight into the methods of exploring a personality; in order that they might appreciate the beginning of the pathological tendencies which are responsible for so many failures in life.* The present alarming incidence of nervous and mental diseases calls for more active efforts on our part to secure reliable information in regard to the genesis of these disorders and the methods of preventing their development.

VIII

The problem of human behavior cannot be discussed without some reference being made to the emotional and mental symptoms indicative of the unrest which is appearing in all parts of the world. These disorders are part of the price man is paying to-day for his neglect in making adequate provision for the study of human nature. Various epidemics of bodily disease during the middle ages seriously menaced the progress of civilization. Since that time the progress in medical science has lessened this danger; but unfortunately relatively little attention has been given to limiting the spread of mental disorders. As the result of the greatest war in history and the present unsettled social conditions, our attention is now being forcibly directed to the

* Paton, S. Psychiatry, 1905. J. B. Lippincott Company, p. 197.

urgent need to remedy this defect. While we are waiting as patiently as possible for additional information in regard to the fundamental qualities of human nature, we should let our statesmen realize that the data already in our possession could be used to advantage in assisting to restore the emotional and mental balance essential to the establishment of peace and order.

The emotional disorders sweeping over the world to-day seem to have a common basis; although the symptoms are modified by the local conditions existing in the different countries. There is no more room for believing that the emotional instability appearing in Russia, France, or the United States is traceable in each country to independent causes than there was for believing that the extraordinary action of the flagellants, the dancing manias, and various forms of psychotic disturbances appearing in the middle ages were the result of diseases differing specifically from each other.

Doctor Johnson in defining the word insanity anticipated some of our modern psychiatric conceptions when he stated that "all power of fancy over reason is a degree of insanity." Just as soon as fancy begins to supply the data upon which we base our plan for the conduct of life, the condition we call insanity is present. This is the biologic conception of insanity and not the one generally given in the court room. The sane man faces squarely the plain facts connected with living and does so under all ordinary circumstances without developing a feeling of insecurity or inadequacy. He reviews calmly the fact that life is a struggle for existence and the progress of civilization is necessarily very slow. Having faced these facts, reason, not fancy, then prepares and elaborates his program for living. The psychoneurotic, driven by a sense of inadequacy and insecurity, dodges the main issues. To him the idea of struggle and the slowness of progress are harrowing thoughts. Concrete, well-defined situations are extremely harassing as the possibility always exists of being forced to meet an unwelcome intruder in the guise of some unsolved personal question. General theories and abstractions take the place of facts, and if the truth cannot be avoided, to quote from Huxley, "its fair face is varnished with the pestilent cosmetic rhetoric." Just as soon as confidence in self is shaken various ruses are adopted to restore the emotional equilibrium. Different degrees of egotism may represent the compensatory efforts to effect a satisfactory readjustment. The aggressive forms of egotism are protective reactions useful in keeping intruders off the premises; thus reducing the danger of the sudden exposure of the real personality. In preparing these defenses the power of fancy over reason is often clearly in evidence.

Society has unconsciously made it increasingly difficult for the psycho-neurotic to face his own problems. We have been socialized in thought to the extent of avoiding a great many personal questions, and the word individual has almost been dropped from our vocabulary.

Feelings and thoughts as well as our living quarters are shared with our friends and acquaintances. Such a very keen interest has been developed in what other people are doing there is seldom time to put our own house in order. It is a great comfort to the psycho-neurotic intellectual to forget temporarily the difficulties of the individual citizen and to discuss class privileges, class distinctions, class rivalries and class judgments. He is also enthusiastic in discussing general social conditions, a method of diverting attention from the galling recollections of personal defeat and personal disappointment. A form of competitive notoriety in championing the cause of the people serves to divert attention from personal failure. Any suggestion in regard to making the facts derived from the study of individual cases of human behavior the basis for a science of character is received with scant consideration. The psycho-neurotic dreads to be left alone with himself but loves to pose in public as a martyr. He runs away from unsolved personal problems and develops fanatical enthusiasms in studying general social questions; and tries to put democracy on the patent-medicine shelf as a universal remedy hoping thereby to avoid the irritation and mortification associated with the recollection of personal insufficiency.

Numerous illustrations selected from actual life could be cited as evidence of the skill acquired in camouflaging the bitterness of personal defeat and disappointment by resorting to semi-rationalization.

There is the familiar case of the neurotic mother exhibiting such an abnormal degree of solicitude in reforming the entire educational system, while subjecting her own children to such distracting influences in the home that the natural difficulties of acquiring good mental habits are immeasurably increased. Then there are the men and women who are continually declaring their interest in the "brotherhood of man" or in the "cause of the common people" who in the inner circle of the home exhibit peculiarly exasperating qualities of both temperament and character.

An interesting illustration of the substitution of general terms to describe a concrete situation is exemplified by the person who is afraid to apply the tests suggested by reason to determine whether his own life has been a success, and suddenly surprises his friends by announcing his conviction that there is a great deal of good in the present Bolshevist movement. This statement, which at first may be as much of a surprise to the person making it as to his friends, exposes a side of the personality which was carefully hidden from the public view until the cat jumped out of the bag. Such a person does not think pertinently nor through any of the real issues in his own life. Extreme solicitude in concealing personal defects generally results in the exposure of the real personality.

The present widespread emotional instability gives rise to many and strange repugnances. In one class of persons where there is little intellectual capacity to effect a partial compensation, the symptoms of ennui and boredom express the general dissatisfaction with self. If there is sufficient mentality to effect a compensation of even temporary value there is apt to be a rapid multiplication of wish-directed thoughts diverting attention away from the skeleton in the closet. The ineffectual character of the compensation may be indicated by attacks of mental depression and these are followed by a period in which great zeal is shown in elaborating plans for the general improvement, not of the individual, but of society. The various plans proposed run the gamut from parlor socialism to Bolshevism. We need to be reminded constantly of the fact, and reminded by a psychiatrist, too, that we can remain sane only if we begin by setting our own house in order before starting out to reform the world. And the first step in this direction is to learn to face life as it is, and not as we should prefer or wish to have it. "Better the sight of the eyes than the wandering of desire" is an old Hebrew maxim based on the recognition of a very sound principle of mental hygiene which was formulated a great many centuries before Freud redirected attention to the danger of uncontrolled wishing.

IX

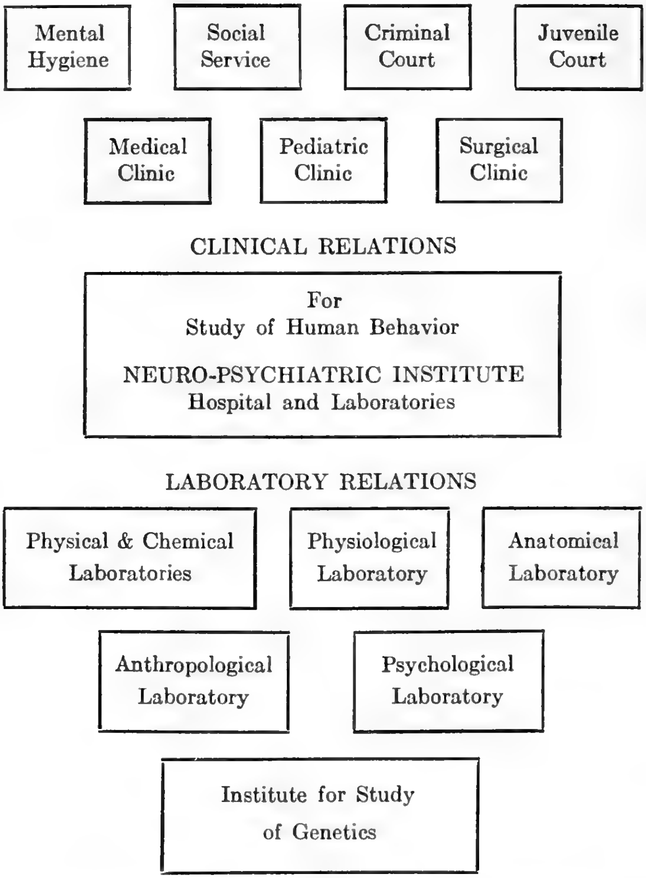
It is fortunate for Society that the physician is still interested in individual cases, and has not yet shown any indication of studying disease or treating his patients as the average social reformer attempts to do, *en masse.* His work compels him to attempt to make a diagnosis of each person's malady, and his generalizations as a rule summarize the definite findings of specific cases. His practice is based on at least the tacit recognition of the principle that human beings are independent autonomous organisms, each requiring special study and no two are exactly alike.

The average American could profit a great deal by taking lessons in the art of balancing his personal accounts, emotional as well as mental, and adopting a rational plan for finding out whether the debit and credit columns tally. There is sufficient evidence to show that as a nation we are untrained in this art. Our personal feeling of insecurity, our fear of finding superiors is revealed in the emphasis placed on the word "equality" while relatively little is said about justice. We are driven to take this position by promptings from the subconscious field reminding us continually of our inadequacy and unfulfilled ambitions. It would be a great comfort to many to feel that there were no physical or mental or social inequalities. Marked solicitation characterizes our plans for developing some form of government in which the biological inequalities of individual citizens will be carefully concealed. As a people we are always afraid of finding superiors, and this unfortunate national characteristic is one result of the failure to cultivate an intelligent critical spirit. If we were satisfied that Democracy had accomplished all we claim for it, there would be less inclination to parade its virtues upon every occasion. The man who is honest at heart seldom makes any personal reference to his own particular virtues, and advertised virtues are rarely to be considered as pledges of good conduct.

We have just begun to realize the danger of wishful thinking. Most of our wishes are artfully concealed, not only from public inspection, but as a result of skilful self-deception even from our own recognition. As a wish from the biological standpoint is nothing more or less than an indication of the "motor set" determining the direction of all our activities, the elements composing it are found largely in our subconscious life. This is a fact of which we need to be constantly reminded as the wish when translated into overt action may be so easily reinforced by emotion that its genesis is soon hidden beneath a very complex series of compensatory responses.

Let us hope that the physician to-day will make the best use of the opportunity which the war has brought to him to acquire for himself and to assist others to acquire the art of intelligent self-criticism which is so essential in protecting individuals against the incidence of nervous and mental disorders as well as in compensating for a pronounced defect in our national life. Intelligent self-criticism is needed in this country in order to assist in repelling those disorganizing forces which now dissipate individual as well as national energy.

The physician, as has been indicated, should be better qualified than the member of any other profession to undertake the study of body-mind problems, and immediate action should be taken to provide adequate opportunities in our medical schools for studying the problems of human behavior. The future of our civilization depends first upon the realization of the need for training investigators competent to explore these special problems.



A neuro-psychiatric institute is the logical centre for this work. The institute should be in close and sympathetic connection with other clinics and laboratories, and also with other scientific departments in a university in order that there may be collaboration between investigators in related fields of study. When once these centres have been established then we may know that an intelligent effort is being made to go to the root of many of our social troubles. At the present time money and energy are wasted in the treatment of the last stage of disorders of adjustment found in workhouses, asylums, prisons, reformatories and various other institutions. The "down and outs" bear witness to our unpreparedness to attack directly the real enemies of our civilization. It is singularly unfortunate that in a republic it has never been possible, until very recently, to organize a centre well equipped for carrying on explorations in the field of human behavior.

In Newark, N. J., under the direction of Dr. C. C. Beling,* a Bureau of Mental Hygiene is now being organized as one of the divisions of the Department of Public Affairs.

The physician realizes probably to a greater degree than the members of any other profession that present social disorders as well as other diseases can be most effectively studied by beginning with the consideration of the facts in individual cases. His training as well as his practical philosophy of life should make it easy for him to appreciate the value of Socrates' advice, "Know thyself." Upon the success attained in assisting people to practice the precept which for so many centuries has been repeated automatically with academic precision, depends the stability and development of human institutions.

* Health Bulletin, May, 1919. Issued monthly by the Department of Health, Newark, New Jersey.