# AN EXPERIMENTAL AND CLINICAL RESEARCH
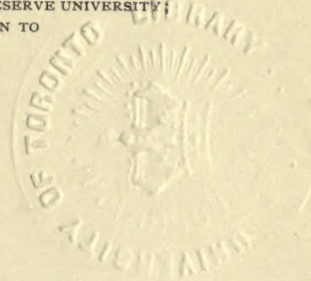
INTO

## CERTAIN PROBLEMS

RELATING TO

# SURGICAL OPERATIONS

*AN ESSAY AWARDED THE ALVARENGA PRIZE FOR 1901
BY THE COLLEGE OF PHYSICIANS OF
PHILADELPHIA*

BY

## GEORGE W. CRILE, A.M., M.D., Ph.D.

PROFESSOR OF CLINICAL SURGERY, MEDICAL DEPARTMENT, WESTERN RESERVE UNIVERSITY;
SURGEON TO ST. ALEXIS HOSPITAL; ASSOCIATE SURGEON TO
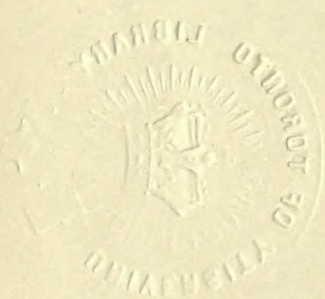LAKESIDE HOSPITAL, CLEVELAND

# PREFACE

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I TAKE this opportunity of acknowledging my indebtedness to my associate, Dr. W. E. Lower, who rendered most valuable assistance in both the experimental and the clinical parts of this work, to whom much of the credit for what merit this volume may have is due. My thanks are rendered my former assistant, Dr. Guy H. Fitzgerald, for making the histologic studies of the arteries and of the spinal cord, as well as rendering other assistance in the experimental research. I also thank my assistant, Dr. A. Cudell, for valuable assistance in the laboratory.

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COLLEGE OF PHYSICIANS OF PHILADELPHIA.

DR. GEORGE W. CRILE,

      Cleveland, Ohio:

MY DEAR SIR,—I have the honor to inform you that the Committee on the Alvarenga Prize has awarded the prize for this year to you for your essay entitled "An Experimental and Clinical Research into Certain Problems Relating to Surgical Operations," entered in competition under the motto: "*Renga*."

\*     \*     \*     \*     \*     \*     \*     \*     \*

      Very truly yours,

          THOMAS R. NEILSON,

               *Secretary.*

# AN EXPERIMENTAL AND CLINICAL RESEARCH

INTO

# CERTAIN PROBLEMS RELATING TO SURGICAL OPERATIONS

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## INTRODUCTION.

THE several subjects comprising this research were suggested by practical experience in the operating-room. As most of our exact knowledge of human functions has been gained by animal experimentation, it would seem to be safe to apply the laws thus obtained to surgical practice. This is more particularly true of the vascular and the nervous system. Upon the ready and the exact application of such laws depend the immediate results of many operations.

This research extended over three years, during which time the results were clinically compared and applied in an active operative practice. It was exceedingly gratifying to note the close correspondence between the phenomena observed in the operating-room and in the laboratory.

While surgical anatomy occupies a conspicuous place in literature, surgical physiology, though almost as important, is all but unknown. Unknown, because the physiologic laboratory is a comparatively recent creation, whose important surgical relations are scarcely appreciated.

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The experimental data, tracings, specimens, etc., have been preserved, and there is no statement made that may not be verified. A sufficient number of illustrations have been added to elucidate the text. Unless otherwise specified the experiments were made on dogs, taken unselected as they were supplied by the laboratory servant. Every precaution was taken to inflict as little pain or distress as possible. No more animals were used than seemed necessary to collect sufficient data from which useful and reliable deductions might be made.

## MODES OF INVESTIGATION AND ANNOTATION.

In all cases the animals were anesthetized, usually by ether, occasionally by chloroform, either alone or with ether or A. C. E. In a few cases curare and morphin were used. The first administration was facilitated and the process relieved of much of its disagreeable detail by thrusting cotton-wool into the apex of a conical-shaped hood of canvas, of sufficient capacity for receiving the dog's head and having a projection above for holding it in position, while the dog was held in a box allowing the forelegs to project over the top. On completion of anesthesia tracheotomy was usually performed, and a simple anesthetizing apparatus, consisting of a glass cannula, to which was attached a rubber tube connected at its one end with a funnel, was securely tied into the trachea. This arrangement not only facilitates the administration of the anesthetic and secures free and unimpeded breathing, but also serves, by merely disconnecting the funnel and attaching the rubber tube to a connection with a bellows, as part of a simple and efficient artificial respiration apparatus. The latter apparatus consists of a bellows fastened to the under surface of the table, having a rubber tube with a glass cannula for ready attachment

to the breathing-tube above described.  By means of adjusted weights for opening the bellows and a rope over pulleys carried to the front of the table and thence to a hinged footboard fastened to the floor, artificial respirations were easily maintained.

Respiratory movements were recorded by means of a broad canvas band encircling three-fourths the circumference of the dog's lower chest, to each end of which was clamped, under the necessary tension, the ends of strong threads fastened to a small circular disk on the inside of the rubber dam, which was snugly drawn over the oblique end of a three-inch, air-tight, brass tube.  The latter, by this tension on each end, was held upon the sternum or upon the anterior aspect of the abdomen. The ends were cut obliquely so as to make the respiratory actions operate more nearly at right angles to the plane of the elastic rubber.   To the small tube in the brass tambour was attached a rubber tubing, which acted upon a delicate recording instrument made on the principle and of the material of an organ key.   The rubber tubing was attached to a lead tube communicating with the interior of a wedge-shaped " key," which consists of a light wooden base and a like top, to which is cemented organ key leather, properly creased for expansion and contraction. On the upper surface of the wooden top is glued a small grooved piece of wood, and into the groove is pressed a long, slender, wooden writing style, armed at its one end with a thin tapering piece of Swedish spring steel.   This apparatus is so delicate as to record even the heart impulses against the chest.  The receiving apparatus was fastened to a light piece of board, which in turn was mounted on a burette-stand, making adjustment easy by pressing this board up or down in the grasp of the burette clamp.  The up-stroke represents expiration, the down-stroke inspiration.

## ON THE EFFECT OF SEVERING AND OF MECHANICALLY IRRITATING THE VAGI.

PRELIMINARY REMARKS.—In operations on the neck not infrequently the dissection is carried to the vagus, and occasionally, especially in a case of malignant disease, the question of removing a portion of this nerve or subjecting it to injury arises. In the literature of this subject the clinical reports of the effects of mechanically irritating, dividing, or resecting are much at variance.

*Review of Literature.*—Fontana resected a portion of the pneumogastric on twelve rabbits, three of which died.

Longet found that dogs usually survived this operation. He found that roughening of the voice followed and an increase in the frequency of respiration. There was emaciation and repeated vomiting, with diminution rather than increase of appetite.

Fano reported a case of the accidental resection of the right vagus in a case of malignant disease adherent to the larynx. During the operation the patient was inclined to cough. In the evening of the operation nothing in particular was observed except that the voice was a little muffled. The following day there was difficulty in respiration and a cough. On the third day there was an increase in the cough and the voice had become more muffled. Five days after the operation there was chill, followed by fever and delirium. Respiration was normal. Upon auscultation no congestion of the lung was discovered. Coma succeeded the delirium: the pulse was full and frequent. During this time the dressings were torn from the wound, causing hemorrhage. Death occurred on the sixth day. At the autopsy no metastatic abscess was found. Both lungs were a little engorged at the base and posteriorly. The stomach was of

normal volume. The vagus on the right side had been removed in the course of the operation. The right hemisphere of the brain presented a vascularization more pronounced than the left. On the right side of the larynx there were some portions of the cancer that had not been removed. The exact cause of death is not stated.

Keppler reported the following case: H. K. Weaver, aged thirty; diagnosis, sarcoma of the neck. Some difficulty was experienced in removing the tumor from its capsule, involving by extension considerable healthy tissue. Lying external to the common carotid artery a strand, about the thickness of the vagus nerve, whose position could not be ascertained owing to displacement of the parts as a result of the growth, was observed. This was carefully dissected away, and proved to be the obliterated jugular vein. After removal of the growth search was made for the vagus, which was found to have been severed. One hour after the operation the pulse was 112, regular; respiration 36; temperature 38 C. At five P.M., seven hours after the operation, the pulse was 128; respiration 24. Eleven hours ofter the operation pulse was 112; respiration 30. The following day pulse was 96; respiration 24–26. Patient made a recovery without any untoward symptoms. Laryngoscopic examination showed epiglottis and aryteno-epiglottidean folds to be slightly red, but free movement of the epiglottis returned four weeks after the operation. The pulse and respiration showed nothing anomalous.

Arthand and Butte severed the vagi in seven experiments, and report as a consequence that there was increased respiratory action, followed by a return to normal condition.

Langendorff experimented on this subject, showing that severing one vagus caused long and deep respiration.

Cruenhogan claims that the section of one vagus either

produces no change in respiratory movements, or if so, the movement is but slightly lessened in frequency.

Widmer, in nineteen cases of one-sided vagus sections, states that in eight cases there was no change in respiratory movement; in one there was a slight change; in another feeble respiration and an increase in an already cyanotic condition.

Svehla found in a series of operations that the section of one vagus slows the respiration with deep inspiratory action, and that after several days respiration became more rapid until it reached its original frequency.

Von Anrep, experimenting with warm-blooded animals, found that they could not withstand bilateral vagotomy. The animals died of pulmonary complications.

EXPERIMENTAL RESEARCH.—*Protocols.*—1. Vagal experiment. February 14, 1899.—Cur dog; weight, twenty-six pounds; ether anesthesia. While washing out a clot some magnesium sulphate solution ran into the carotid. The dog immediately had several convulsions. The blood-pressure dropped to the abscissa line and respiration ceased. Artificial respiration was immediately instituted, and one-thirtieth grain of strychnine sulphate injected into the external jugular. After the lapse of a few minutes shallow respirations began, which gradually became stronger, the blood-pressure correspondingly rising. On manipulation of the left vagus there was a great temporary fall in the blood-pressure followed by a slight rise.

2. Vagal experiment. February 15, 1899.—Cannula in femoral artery. Brown cur dog; weight, twenty-seven pounds, ether anesthesia. Pulling up and dissecting out the left vagus and carotid caused a rise in blood-pressure with irregularity of the strokes (Fig. 1). Separating the

vagus from the carotid caused a further slight rise in the blood-pressure and additional irregularity of the heart's action. On making traction on the left vagus, respirations immediately slowed, the blood-pressure rose and the strokes became irregular. On severing the left vagus, the
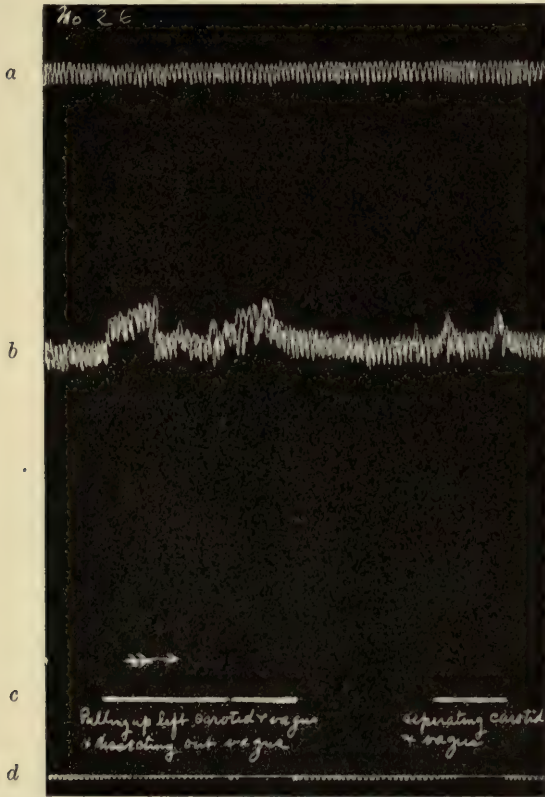


FIG. 1.—VAGAL EXPERIMENT.—*a*, respiration; *b*, blood-pressure; *c*, signal; *d*, seconds. Note the variation in the blood-pressure during raising and dissecting the vagus and the carotid. The second signal designates the dissection of the nerve from the artery. Note the irregular blood-pressure curve.

blood-pressure immediately rose and respirations became slow. On severing the right vagus, respirations became deep and slow, showing quite an interval at the end of each expiration. The heart's action during this time was rapid and the blood-pressure became slightly elevated.

3. Vagal experiment.   February 16, 1899.—Black cur dog; weight, eighteen pounds; ether anesthesia.   While separating the right carotid from the vagus by sharp dissection a slight rise in the blood-pressure was noticed.



This dissection together with other manipulation caused a marked rise in the blood-pressure and a slowing of the respiration.   Severing the vagus caused a rise with no perceptible change in the respiration.   The same experiment on the opposite vagus showed a like result as far as manipulation was concerned, but on severing the vagus the respirations immediately became slow.

4. Vagal experiment.   February 17, 1899.—Yellow cur dog; weight, twenty-one pounds; ether anesthesia.   Cannula in right carotid.   Pulling and manipulating the right vagus caused an immediate rise in the blood-pressure and a slowing of the respiration.   After one-half minute the blood-pressure returned to the point it occupied previous to the stimulation.
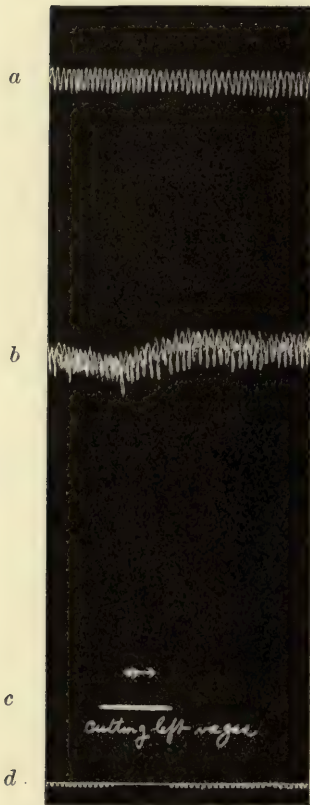
FIG. 2.—*a*, respiration; *b*, heart's action; *c*, time of experiment; *d*, seconds.  Left vagus severed with a snip of a sharp scissors.  Note the slowed respiratory action and gradual rise in the blood-pressure.

After four minutes of manipulation of the carotid and vagus, similar to that produced by dissecting out a tumor, there was a slight rise in the blood-pressure but no change in the respiration.   On severing the left vagus there was an immediate gradual

rise (Fig. 2) and a slowing of the respiration. Severing the right vagus caused an increased rapidity of the heart's action, producing a slight rise in the blood-pressure with a slowing of respiration. There was a long pause at the end of each expiration.

5. Vagal experiment. February 17, 1899.—Mongrel dog; weight, twenty-six pounds; ether anesthesia. Can-
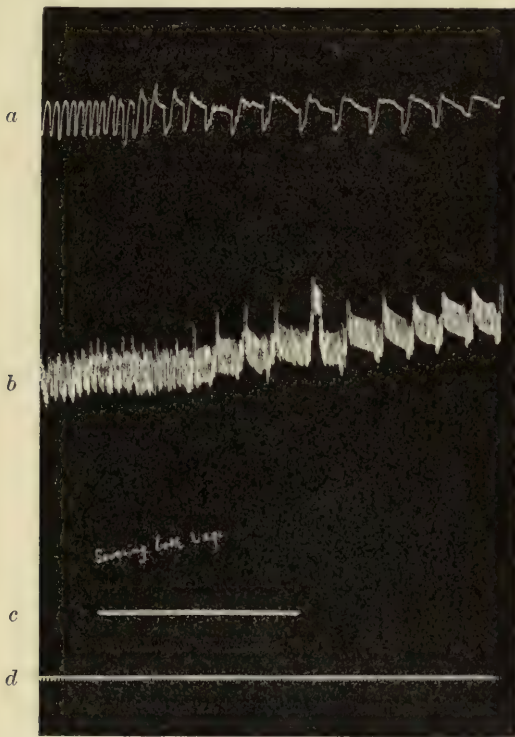


FIG. 3.—a, respiration; b, heart's action; c, time of experiment; d, seconds. Severing both vagi. Note the slowed respiration and the gradually rising blood-pressure. The respiratory effect upon the blood-pressure is well marked.

nula in right femoral artery. Dissecting the left vagus from the artery caused a slight fall in blood-pressure, but no change in respiration. Separating the right vagus

from the carotid produced an immediate slight rise in blood-pressure. The experiment was made as nearly alike as possible on both sides. Severing the right vagus caused a rise in blood-pressure and a slowing of respiration. On severing the left vagus an additional rise in blood-pressure followed and there was a marked slowing of the respiration.

6. Vagal experiment. February 18, 1899.—Black mangy cur dog; weight, thirty-two pounds; ether anesthesia. Cannula in right carotid. Separating the right vagus from the carotid produced a rise in the blood-pressure. Both vagi severed by quick snips of a scissors. Respiration was much slowed and soon ceased. Heart-beats increased in frequency and the blood-pressure gradually rose. (See Fig. 3.)

7. Vagal experiment. February 18, 1899.—Long-haired yellow mongrel dog, fair condition; weight, sixteen pounds; ether anesthesia. Cannula in right femoral. On pulling up the right carotid and vagus and roughly manipulating them there was a slight rise in blood-pressure, which fell to the control as soon as manipulation ceased. The same was repeated several times with like result. On roughly manipulating the left vagus there was an immediate rise in the blood-pressure. (Fig. 4.)

8. Vagal experiment. February 20, 1899.—Black mongrel, good condition; weight, twenty-two pounds; ether anesthesia. Delicate manipulation of left side of neck caused a slight rise in blood-pressure. Dog not entirely under anesthetic. Repeating the same for about fifteen seconds again caused a slight rise. Applying

vigorous traction and rubbing the left vagus with artery forceps caused a marked irregular rise in blood-pressure, and a slowing of respiration, with a lengthening of the amplitude of the respiratory excursions. On cessation of manipulation the blood-pressure remained high, but the
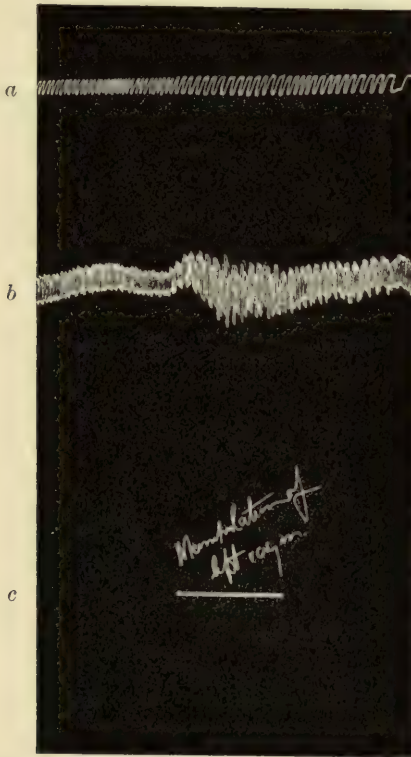


FIG. 4.—*a*, respiration; *b*, heart's action; *c*, time of experiment. Tracing showing the effect of mechanical irritation of the vagus. Note the slowed respiration during and following irritation, also the slowed heart-beat and irregular blood-pressure curve.

respiratory amplitude was lessened. Repeating the experiment caused an additional steady rise in the blood-pressure and a marked slowing of respiration. Upon a repetition of manipulation the pressure readily fell and the respiration remained slow. When the blood-pressure had reached the level of the control the respiration im-

proved, after which there was a slight rise. Roughly manipulating the right vagus caused a marked rise in the pressure, but not so marked as in the left. Respirations were not appreciably altered.
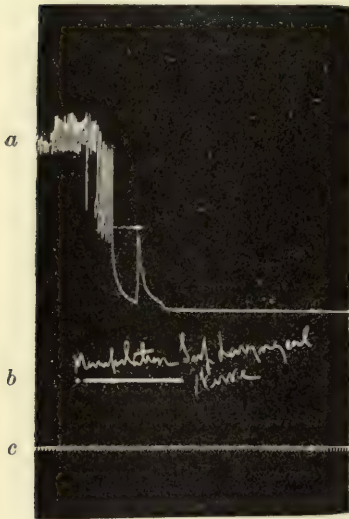


FIG. 5.—*a*, blood-pressure; *b*, signal; *c*, seconds. Note the sudden fall of the blood-pressure to the abscissa line on manipulating the trunk of the superior laryngeal.

9. Vagal experiment. February 20, 1899.—Fox terrier, fair condition; weight, fourteen pounds; ether anesthesia. On rubbing the left vagus between the thumb and finger an immediate rise in the blood-pressure occurred and the respiration was much slowed. Dissecting out and vigorously rubbing the right vagus between the fingers caused a rise in blood-pressure but no alteration in the respiration. This was repeated several times with like results. On roughly manipulating the trunk of the superior laryngeal, the blood-pressure fell to the abscissa line; the heart was reflexly paralyzed. (Fig. 5.)

### SUMMARY OF EXPERIMENTAL EVIDENCE.

In the dog the sympathetic fibres run in a common trunk with the vagus proper. Therefore this nerve has been designated the vago-sympathetic, so that allowance must be made for the sympathetic factor. Picking up the artery and nerve together and bringing them up in the wound, making an ordinary blunt dissection, and separating these structures from their surrounding tissues, produced slight effect upon the circulation and res-

piration.   On separating the nerve from the artery by means of blunt dissection comparatively slight effects were noted.   Grasping the nerve with the forceps produced, in most instances, a rise in the blood-pressure and a slowing of the respiration.   Dragging down upon the nerve produced more marked effect.   Picking up the nerve and rubbing it up and down between the fingers, producing as much irritation as possible, caused a very distinct slowing of the respiration, and in most instances a rise in the blood-pressure.   Occasionally, however, there would be a temporary fall with a marked increase of the length of the heart strokes, indicating an inhibitory effect. In no instance was the heart completely inhibited. Grasping the nerve with two hemostatic forceps and so manipulating and irritating it, by sliding the forceps up and down, as to finally wear the nerve in two, produced in most instances a rise in the blood-pressure, and usually a very decided slowing of the respiration.   Not only was the respiration slowed, but the amplitude was diminished. It required some time before the normal rapidity and amplitude were regained.   No amount of mechanical stimulation, even to the extent of mechanically destroying the vagi produced an arrest of the heart's action. Severing one vagus was attended by comparatively little effect upon either respiration or circulation.   Usually there was a slight rise in the blood-pressure, and a slight decrease in the frequency of respiration with an increase in the amplitude.   The blood-pressure curve remained regular, and no particular effect upon the amplitude of the excursion of the manometer was noted.   However, on severing both vagi the blood-pressure rose considerably, ran an uneven course, the frequency of the heart's action was much increased and the length of the stroke shortened.   Respirations were greatly *decreased* in frequency, and the *amplitude* of the respiratory excursion was

markedly *increased*, so that, as nearly as could be esti-
mated, the loss occasioned by the slowing of the respira-
tory action was about counterbalanced by the increased
amplitude of the excursion.   The respiratory mechanism
was much more affected than the circulatory, and ex-
hibited early signs of exhaustion.

CLINICAL.—*Case* 1.—Excision of right vagus, together
with all the venous and arterial trunks on that side, in
operation for malignant disease; respiratory failure after
the operation; recovery.

John W., aged thirty years and eleven months, had
had a very large median epithelioma of the lower lip
removed.   He returned to the hospital because of tumors
on both sides of the neck; the glands were extensively
involved; those on the left side were first removed at a
separate operation.   The dissection was extensive, in-
volving the removal of the external jugular vein, the ex-
ternal carotid artery, the submaxillary and the parotid
glands, exposing by close dissection the common carotid
artery and the vagus nerve.   Two weeks later the right
side was operated.   A chain of glands along the inter-
nal jugular vein was so extensively involved that on
reaching this point it was found necessary to sacrifice both
jugular veins, the common carotid artery and its branches.
The artery was separated from the vagus, but on carrying
the dissection higher it was found that the vagus was so
directly involved in the growth that it was necessary to
sacrifice it.   A consultant made a pulse-count both before
and after severing the nerve.   The heart became accel-
erated four beats per minute.   No other effect was noted.
Respirations were not affected.   A hypodermic injection
of one one-hundredth grain of atropin had previously
been given.   The dissection was then carried up behind
the angle of the jaw, including the submaxillary and the

parotid glands, the facial artery and nerve, and all the soft parts. The vagus was again severed just below the point at which the superior laryngeal is given off. This nerve and the lingual were laid bare in the dissection. The dissection was carried on far behind the angle of the jaw, and the vessels were so deeply severed as to leave an insufficient length for applying a ligature. By means of a small full curved needle, armed with silk, the deep structures around these vessels were picked up, forming a close purse-string, which when tied closed them. During the latter part of the operation respirations were considerably slowed and the patient became somewhat cyanotic. The wound was then closed after completely arresting the hemorrhage. The sympathetic nerve was laid bare throughout most of its course, the superior cervical ganglion lying upon the floor of the wound was wholly exposed. After closing the wound by bringing together as far as possible its deeper portions by means of catgut sutures the patient was sent to the ward. Directly after he was reported to be in a critical condition due to respiratory failure. Upon arriving at the bedside, I found the house-surgeon maintaining artificial respiration. While observing the patient I noticed fresh blood on the dressings, indicating a dangerous hemorrhage. Hastily cutting away the dressings and laying open the wound, I thrust my hand into the upper angle from which the hemorrhage came. Although this was quickly done there was great loss of blood. With my hand grasping his throat he was replaced upon the ward ambulance and taken to the operating-room, the house-surgeon maintaining as well as he could artificial respiration on the way. On returning to the operating-room the large vessels were clamped and the forceps allowed to remain. The patient was removed from the ward to the operating-room on account of want of light. Ice

and heat were alternately applied, which helped to re-
store the respiratory action. He was given subcutane-
ous injection of saline solution and one two-hundredth of
a grain of strychnine every half-hour. At the end of
twenty-four hours the forceps were removed, and at no
time after recovery from the immediate effects of the
operation were there observed any unusual respiratory
or circulatory symptoms. The patient made a good
recovery. The microscopic examination of the growth
showed a large number of inclusion cells, indicating a
marked malignancy. There was considerable hoarseness
for two weeks, after which it gradually disappeared. The
respiratory failure in this case was in full accord with the
experimental evidence.

*Case* 2 (*Abstract*).—In removing glandular metastases,
following total laryngectomy for carcinoma, the left carotid
artery and vagus were involved. The pulse and respira-
tions were observed during the excision and after it. A
hypodermic injection of one one-hundredth of a grain of
atropin was given twenty minutes before the operation
was begun. The nerve was severed by a quick snip of
a scissors. There was some hoarseness for several days,
after which it gradually disappeared. No other effects
were noted. Patient made a good recovery.

*Case* 3.—See report under closing the carotid artery.
In this patient the vagus was resected. One one-hun-
dredth of a grain of atropin was administered prior to
operation. No immediate effects were noted. The voice
could not, for obvious reasons, be observed.

*Case* 4 (*Abstract*).—A full charge from a shot-gun
whose muzzle was within a few inches of the patient's
neck when discharged, entered the neck in the upper part

of the carotid triangle. The artery was torn off and the nerve lacerated. The wadding and shot were firmly packed upon and driven into the torn nerve and other structures of the neck. The pulse was reduced to 42 beats per minute. Respirations were slow, exhibiting quickened respiratory action with lengthened pause and a prolonged expiratory action. The slow pulse continued more than two hours, after which the " vagal" mechanism went into resolution and an extremely rapid cardiac action followed.

*Case* 5 (*Abstract*).—In removing a mixed tumor of the parotid the dissection was carried for some distance upon the carotid and the vagus. While freeing the nerve near the level of the tip of the styloid process the pulse dropped from 90 to 56. The wound was almost bloodless, exhibiting the various structures in plain sight. A four per cent. solution of cocain was applied upon a piece of cotton and the dissection continued elsewhere. After three minutes the dissection of the vagus was again resumed. Meanwhile, the pulse had returned to 86. During the remainder of the dissection of the vagus there was no appreciable alteration in the heart's action, in spite of a more severe manipulation than had before been given. The depth of the tumor not having been anticipated no atropin had been administered. This case illustrated the effect of stimulation of the upper portion of the vagus, notably near the point at which the superior laryngeal is given off. This nerve-trunk, though not seen at the time, might have contributed to the cardiac phenomena from indirect violence.

*Case* 6 (*Abstract*).—*Emergency removal, without anesthesia, of a large goitre in unconsciousness from asphyxia. Vagus clamped. Recovery.*

Preliminary administration of one one-hundredth grain of atropin ; inclusion of vagus nerve in large forceps ; no cardiac inhibition ; artificial respiration.

Female, aged forty-six ; had had a goitre twelve years, which during the six months preceding the operation had rapidly developed. The tumor was large, quite firm, deeply situated in the neck, extending well down behind the sternum and clavicle, displacing the apex of the lung and producing a compression of the trachea against the vertebral column. The tumor was so firmly fixed as to be scarcely movable. During two months she had been obliged to make use of the extraordinary muscles of respiration. The development of the platysma was remarkable. In each inspiratory effort the contraction of this muscle was so powerful as to draw down the angles of her mouth, lower lip, and the integument of the lower part of her face, to throw in vertical folds the entire surface of her neck and upper thorax, and to entirely change the aspect of the neck and face. The lower jaw, meanwhile, was carried fixedly forward and upward. By this means she was able to so slightly relieve the pressure upon the trachea as to accomplish a stridulous though scant exchange of air. It was planned to expose the tumor under local anesthesia, then try to relieve the obstruction by elevating the tumor while administering general anesthesia. She was placed upon the table, but was absolutely unable to breathe in a lying posture. She struggled for breath, sprang up into a sitting posture, then gasping, turned cyanotic, became unconscious, and fell apparently lifeless on the table. At a single stroke with a scalpel the tumor was laid bare, then literally torn out, while the blood from the many torn vessels flooded her face and neck. Artificial respiration was in the mean time begun. The hemorrhage was first controlled by firm gauze packing, then with a large forceps the common carotid, jugular vein,

and vagus nerve were grasped *en masse* below and like-wise above, completely controlling the hemorrhage. The operation was performed in about forty-five seconds. The patient had been given one one-hundredth grain of atropin previous to the operation, which prevented any cardiac inhibition, although the vagus was crushed at the point of clamping. The operation was completed without her knowledge. She said afterwards that she believed she was dying and was conscious that something was done, but had no pain. Patient made a good recovery.

### RESEARCH INTO THE EFFECT OF INTRAVENOUS INFUSION OF SALINE SOLUTION.

*Protocols.*—1. October 10, 1898.—Mongrel dog; weight, nineteen pounds. Saline solution at 39° C. was allowed to flow into the left femoral vein. After a lapse of a few seconds there was a gradual slight rise in the blood-press-ure which was well sustained. Eleven hundred cubic centimetres were injected during nineteen minutes. The abdomen soon began to enlarge, becoming more tense, while the respirations became shortened, diminishing in frequency. The color of the blood changed to a dark red. The abdomen rapidly became more tense and distended. the respirations slower and shorter, mucus flowed from the nose, and the animal died of respiratory failure.

*Post-Mortem.*—Immediate autopsy revealed all the veins widely distended and tense; the liver full and hard; the intestines and stomach pale, their walls thickened with free fluid in their cavities; the kidneys somewhat edema-tous; the urinary bladder full; the gall-bladder distended with bile, its walls edematous; the spleen slightly enlarged and the pancreas somewhat edematous, though not much enlarged. The walls of the bladder were not altered. The parietal peritoneum was normal. The stomach and small intestines had absorbed the greater amount of fluid.

On incising the liver, large quantities of pale blood escaped. This blood showed an early tendency to clot. There was no fluid in the pleural cavity, but some edema and ecchymosis at the base of the lungs. On incising the lungs frothy fluid escaped, and on dropping a piece into water it floated low. The heart was in diastole and the pericardium and the heart-tissue were normal. The brain was normal. The tissues of the extremities were more wet than usual. The soft parts of the trunk and abdomen were more edematous than those of the extremities. The smaller veins underneath the skin were enlarged. The arteries were not so.

2. October 12, 1898.—Spaniel; weight, sixteen pounds; chloroform anesthesia. The animal died after the beginning of the experiment, from excessive inhalation of chloroform. After death twelve hundred cubic centimetres of saline solution were allowed to run into the left femoral vein. The abdomen was considerably distended, the heart chambers were dilated, and the liver was full of water, as were also the intestines and the stomach. The inferior vena cava was enormously distended. There were clots in both sides of the heart. The tissues were wet and soggy.

3. October 15, 1898.—Weak, sickly dog; weight, fourteen pounds; chloroform anesthesia. The animal was unpromising and he was chloroformed to death.

4. October 20, 1898.—Bitch; twenty-one pounds; ether anesthesia. Experiment began at 10.30 A.M., dog died at 10.37. The cause of death was an inadvertent opening of the pressure-bottle containing saturated solution of magnesium sulphate. The animal died in less than a minute of simultaneous paralysis of both the heart and the respiration. Two thousand three hundred cubic centime-

tres of salt solution were allowed to flow into the left femoral vein during and after death. The abdomen was distended, the skin and other tissues wet. There was superficial bleeding. All the veins were distended. A considerable amount of fluid was in the peritoneal cavity. Bladder partially full; large amount of water in the walls of the intestines; stomach greatly dilated and filled with water; liver hard, and on section quantities of fluid escaped; gall-bladder pale and tensely filled with bile. On making an incision in one lobe of the liver thin blood spurted out and the entire organ diminished in size, becoming softer. Blood from the liver quickly clotted. The large venous trunks were full, especially the vena cava inferior. No fluid was in the pleura, but a considerable amount in the posterior lobes of the lungs. The heart was empty; the kidneys apparently normal, though on section they were found slightly edematous. The spleen was normal; the intestinal mucosa pale and swollen.

5. October 23, 1898.—Dog, seventeen pounds; ether anesthesia. Saline solution was allowed to flow into the femoral vein until death occurred. The abdomen enlarged and became tense. The blood-pressure was slightly raised with the first flow, remaining at the same level until the beginning of death. The respirations became slow and shortened as the abdomen enlarged. As the abdominal tension increased, the lower ribs were fixed in their position and there was only diaphragmatic breathing. As the respirations were more and more interfered with, the blood became cyanotic, the heart-beats less frequent, the amplitude of the stroke markedly lengthened, and the blood-pressure sank gradually but continuously, as in asphyxia experiments, until death. As the end approached the heart-beats became shorter and slower. Death was due to respiratory failure.

*Post-Mortem.*—Abdomen enormously distended; superficial veins full; tissues very wet and bled freely; the field of dissection in preparing the animal was covered with dark clots. The tissues of the right hind leg comparatively dry, air found in the connective-tissue spaces. This condition obtained in all the extremities. There was some air in the subcutaneous tissue over the abdomen and thorax and a large quantity of free fluid in the peritoneal cavity; the gastro-intestinal tract was pale, soggy, and heavy. There was a large quantity of water and air in the stomach, and a large amount in the intestinal tract. On making an incision into the wall of the distended stomach, there seemed to be an unusually well-marked separation of its coats. The same was observed in the intestines. The urinary bladder was full; the gall-bladder was tensely filled with bile and its walls edematous. The kidneys were pale, not enlarged, but there was some ecchymosis underneath the capsule. The lungs were ecchymosed, the shade of coloring becoming intensified towards the bases, where the ecchymosis was most intense. On incising the posterior lobe, frothy, bloody fluid escaped. Heart in diastole and blood not coagulated. Vessels of mesentery dilated; patches of ecchymosis in the intestines and the stomach; pancreas somewhat enlarged and edematous; the veins of the brain full, nothing in the medulla. Some ecchymosis on the surface of the brain.

6. October 28, 1898.—Dog, sixteen pounds; ether anesthesia. The saline solution was placed at an elevation of seven feet ten inches above the dog. The flow into the left femoral vein was begun at 3.40 P.M. At 3.55 the abdomen was markedly distended, and at 4.04 death occurred. Blood-pressure rose a trifle more than in the preceding experiments, in which the saline solution flowed

from a height of three feet six inches.  The death phenomena were the same as in the preceding.

*Post-Mortem.*—The post-mortem findings were similar to the preceding, with the exception of a greater amount of ecchymosis underneath the capsule of the kidney and on the surface of the brain.  There was a decided increase in the amount of bloody edema in the bases of the lungs.

7. February 16, 1899.—Black cur dog; weight, nineteen pounds.  Ether anesthesia administered at 3.14 P.M.  Blood count was six million.  Rectal temperature 100° F.  Cannula in right carotid.  Saline solution at 57° C.  Injection into left femoral vein at 3.25.  At 3.26, a slight steady rise in blood-pressure, temperature of dog 101° F.  At 3.28, blood-pressure still rising steadily but slightly, rectal temperature 101° F.  Up to this time seven hundred cubic centimetres had been injected.  At 3.28½, blood-pressure fell slightly and the strokes became long and sweeping.  Immediately the blood-pressure was restored.  At 3.34, temperature 102° F.  Fourteen hundred cubic centimetres at 57° C. had been administered.  At 3.35, artificial respirations became necessary.  On tilting the dog four ounces of bloody fluid ran out of the tracheal tube.  At 3.38, blood-pressure had somewhat recovered.  A second count was made, the dog having had sixteen hundred cubic centimetres.  Rectal temperature was 101½° F.  Blood-count showed four million two hundred and seventy-two thousand.  At 3.40, blood-pressure was again falling, the strokes long and sweeping.  At 3.41, on retilting the dog-board, about three ounces of bloody fluid was discharged from the tracheal tube.  At 3.41½, artificial respiration was of no further avail, blood-pressure dropped to the abscissa line.  Total amount of saline, seventeen hundred and fifty cubic centimetres.  Intra-abdominal temperature 103° F.

*Autopsy.*—The general condition of the animal was the same as in the previous experiments with the exception that the bloody edema of the lungs was much more intense. The urine contained an excessive amount of urea and albumin.

8. February 20, 1899.—Bull-bitch puppy; weight, twenty-six pounds, in good condition; ether anesthesia. Saline solution temperature 51° C. in left external jugular. There was a steady but slight rise in the blood-pressure until sixteen hundred cubic centimetres had been given, when bloody watery mucus flowed from the dog's nostrils in profusion. The respirations became shallow and the animal began to fail. After eighteen hundred cubic centimetres had been given, the dog died of respiratory failure.

*Autopsy.*—Marked increased tendency to clotting. No free fluid in the abdomen. Intestines dark red in color. The stomach and the intestinal walls were thickened, but those of the intestines rather more than the stomach; intense bloody edema of the pulmonary bases; heart in diastole; no clots; pancreas dark red in color and somewhat edematous.

*Note.*—In this and the preceding experiments with hot saline the animal, although under surgical anesthesia, struggled.

9. February 20, 1899.—Black crossed hound, young and in good condition; weight, forty-two pounds. Anesthetized at 3.40 with ether. Rectal temperature 101° F. Saline solution allowed to flow into the external jugular vein at the rate of six hundred cubic centimetres per minute. Temperature of saline 40° C. There was a slight temporary fall, followed by a marked steady rise in the blood-pressure. As the saline flowed respirations

became slowed, the amplitude of the strokes increasing. The blood-pressure kept steadily rising during five and a half minutes. After the introduction of three thousand five hundred cubic centimetres of saline the abdomen was perceptibly enlarged. There was considerable oozing at the points of dissection in the neck. Respiration at this time became more slowed. At 4.40, a one-half dram of chloroform was placed upon the inhaler, after which there was an immediate fall in the blood-pressure and the respirations became much more slowed. At 4.41½, an ounce of ether was placed upon the inhaler, but the pressure did not change; respirations soon ceased. At 4.42, the blood-pressure fell to the abscissa line. Four thousand eight hundred cubic centimetres of saline solution were used. Death resulted from respiratory failure.

*Autopsy.*—The tissues of the somatic area were not edematous. No free fluid in the abdomen. Stomach and intestines thick, edematous, and white. Large quantities of fluid in the alimentary tract. Liver enormously enlarged ; kidneys pale and watery ; pancreas very edematous ; spleen rather dry. The somatic area was dry as compared with the splanchnic. Great amount of pulmonary edema, especially of the right base, which seemed to be considerably disintegrated.

10. February 20, 1899.—Crossed fox terrier and beagle, fair condition ; weight, fourteen pounds ; ether anesthesia. During the administration of the anesthetic respirations ceased. Artificial respirations with bellows were of no avail. Stretching the sphincter ani was followed by several shallow spasmodic respiratory efforts. At 5.55, saline at 37° C. was injected into the left external jugular vein. The heart showed longer, more sweeping strokes ; the respirations became faster. Six hundred cubic centimetres had been given during five minutes. Eighteen

minutes later a cold solution at 10° C. was administered in the left femoral vein. Blood-pressure steadily rose. One minute later fifteen minims of chloroform was dropped on the inhaler. This was followed by a marked fall in the blood-pressure, which immediately returned on removing the chloroform a half-minute later. Five hundred cubic centimetres of cold solution had been used. The dog felt distinctly cold. Fifteen minims of chloroform were again dropped upon the inhaler, followed by an immediate fall of blood-pressure. On removing the anesthetic there was a rise. The autopsy revealed conditions similar to the preceding, but the pulmonary bases were not so edematous and there was less ecchymosis. No bloody fluid escaped from the nose or tracheal tube during the operation.

11. February 22, 1899.—Mongrel bitch puppy, fair condition ; weight twelve pounds ; ether anesthesia. Ether administered at 3 10. During the administration the animal stopped breathing ; cannula introduced into the trachea and artificial respiration supplied by means of the bellows. The dog revived rapidly. Rectal temperature, 100° F. At 3.30 saline at 0° C. was injected into the right jugular. There was an immediate rise in blood-pressure and a marked lengthening of strokes. At 3.31¾, on stopping the saline, there was an additional rise in the pressure. At 3.32, saline at 64½° C. injected in left external jugular vein. A marked temporary fall followed, after which a rise with shortening of the strokes. At 3.32¾, saline stopped. An immediate fall took place until it reached the previous point. The hot saline flowed twice as fast as the cold. At 3.33, saline at 0° C. injected in right external jugular vein. There was a slight temporary fall, then a steady gradual rise until saline was stopped at 3.34, when there was an abrupt rise.

The strokes were longer while cold saline flowed. At
3.35, saline at 64° C. injected into left external jugular
vein. The dog struggled somewhat, the blood-pressure
rose markedly, the strokes became shorter, and on stop-
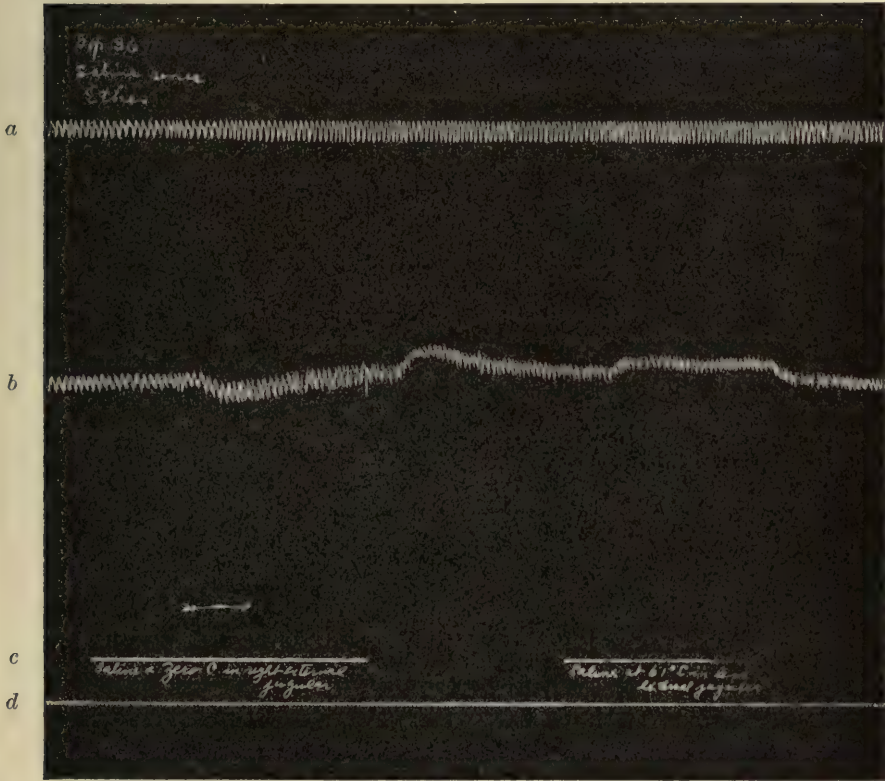


FIG. 6.—*a*, respiration; *b*, blood-pressure; *c*, signal; *d*, seconds. Note the contrast between the
effect of injecting cold and warm saline solution. The first effect after injecting the cold is a fall in
blood-pressure and an increase in the length of stroke, the pressure quickly rising after cessation
of the flow. The hot solution caused an immediate rise, followed by an equal fall on cessation of
flow. The final effect the same.

ping at 3.35½, the pressure fell abruptly but not to the
control level. There was an increase in the amplitude
of the respirations. At 3.37 a clot formed in the can-
nula. Dog's rectal temperature, 100½° F. At 3.45,
saline at 62° C. in left external jugular vein. At 3.45¼,

there was a slight temporary fall and then a marked, quite abrupt rise in blood-pressure and the strokes became shorter. The dog again struggled vigorously. At 3.46, the infusion was stopped and there was an immediate fall. At 3.47, solution at 0° C. was injected into right jugular vein. There was a temporary fall, then a steady rise, the strokes becoming longer. At 3.47½, saline stopped. An additional abrupt rise occurred, the strokes becoming shorter. At 3.48½, saline at 61° C. Slight rise in blood-pressure; strokes shorter; amplitude of respiration slightly increased. At 3.49¼, saline off; an immediate fall in blood-pressure. While the hot saline was running the dog struggled somewhat. At 3.51, saline at 0° C. There was a slight temporary fall, then a slight steady rise with marked lengthening of strokes. At 3.52½, saline was stopped. An additional abrupt rise followed, the strokes becoming shorter. At 3.54¼, saline at 60° C. An immediate rise in blood-pressure occurred with a shortening of the strokes,—the rise being steady and marked. At 3.55, saline stopped and there was an abrupt fall in blood-pressure. At 4.07½, saline at 0° C. Temporary slight fall, followed by a steady rise with marked lengthening of strokes. At 4.08, saline stopped. An additional rise took place and the strokes became shortened. At 4.09½, saline infusion at 51° C. Temporary fall, then a rise with slightly shortened strokes. At 4.10, saline off. An abrupt fall in blood-pressure. At 4.11, saline at 0° C. Slight fall, the strokes then becoming longer and the pressure maintaining its level. At 4.12, saline stopped. An immediate rise followed. At 4.12½, saline at 54° C. No appreciable effect. At 4.12¾, applied one-half drachm of chloroform on inhaler. At 4.13, marked fall in blood-pressure; slight slowing of respirations. At 4.13½, chloroform taken away; blood-pressure immediately rose to previous level. At 4.13¾, saline off. Slight fall in

blood-pressure.   At 4.14¼, saline at 0° C.   Slight rise
with marked lengthening of strokes.   At 4.14¾, chloro-
form, one drachm.   Fall in blood-pressure not so marked
as during the hot infusion.   At 4.15½, chloroform and
saline off; blood-pressure rises.   At 4.22, saline at 62° C.
Respirations slow and blood-pressure tracing showed
respiratory curve.   At 4.29½, saline stopped, and dog died
a typical asphyxia death at 4.32.   Nineteen hundred
cubic centimetres of hot saline and nine hundred and
thirty cubic centimetres at zero had been used.

*Autopsy.*—Cellular tissues and muscles were edema-
tous.   There was but one litre of free fluid in the abdo-
men.   The bladder was empty, the stomach and intestines
edematous, and the alimentary tract contained a large
amount of fluid.   All the viscera were engorged and
edematous.   The veins were distended and the pulmo-
nary bases congested and edematous.

12. Dog ; weight, thirty pounds ; ether anesthesia.   Five
thousand five hundred cubic centimetres saline solution
used.   The thyroids were hypertrophied.   At 4.40, began
saline infusion.   After three thousand cubic centimetres
had been introduced a considerable amount of fluid began
to flow from the mouth, evidently coming from the
stomach.   Burning the right hind foot caused a slight rise
in the blood-pressure and the abdomen became greatly
enlarged.   Coarse râles could be heard over the chest.
The pulmonary bases were dull on percussion.   Ten
minims of chloroform upon the inhaler produced in a
few seconds a decided fall in the blood-pressure.   The
curve described in the fall was a gradual descent.   The
animal died of respiratory failure, the blood-pressure
having remained at an even height until the final decline
began, when it was continuous until it reached the ab-
scissa line.   The heart beat slowly until death.

*Autopsy.*—Superficial vessels very full; urinary bladder greatly distended; gall-bladder edematous and full of bile; the heart in diastole, its chambers greatly distended; the lungs exhibited extreme bloody edema.

13. July 12, 1899.—Male dog; weight, forty-three pounds; hemoglobin, ninety-seven per cent.; red cells, five million. Bled from the external jugular veins, taking eight hundred cubic centimetres from the left side in five minutes, and in eleven minutes five hundred cubic centimetres from the right side. The veins were widely opened and allowed to bleed without interference. Twelve minutes after cessation of bleeding the femoral artery was opened, but no blood flowed. Nine minutes later the dog was apparently dead, all motion having ceased. Upon the injection of two thousand cubic centimetres of saline solution at 48° C. respirations were re-established, but a large quantity of water was accidentally introduced into the vein, and the animal died in convulsions.

14. July 13, 1899.—Male dog; weight, ninety-four pounds; hemoglobin, ninety-seven per cent.; red cells, five million. Bled from the right external jugular vein, running saline into left simultaneously. After bleeding to the amount of five hundred cubic centimetres, the blood became a bright cherry-red, showing that the saline was in the circulation. As it progressed it became thinner and redder. This fluid did not coagulate, and what little blood there was in the solution quickly settled, leaving clear fluid above. It had been the intention to bleed the dog to death, but at this point the experiment was terminated, as the apparatus failed to work properly. The amount of blood withdrawn was four thousand four hundred cubic centimetres; amount of saline introduced, three thousand seven hundred cubic centimetres; tem-

perature of saline, 52° C.    Dog able to move about in a
few minutes.    After five hours he was still unable to eat,
though drank water frequently.    Twenty-four hours later,
hemoglobin, thirty per cent.; red cells, two million;
weight, ninety-one pounds; animal ate and drank well.
Six days later the hemoglobin was twenty-two per cent.;
red cells, two million one hundred thousand; weight,
ninety-three and three-fourths pounds.    Several tests
were made to confirm the percentage of hemoglobin.    On
the eleventh day there was a marked leukocytosis; red
cells very pale, irregular in shape, and of different sizes.
On the seventeenth day the hemoglobin was forty-three
per cent.; red cells, three million three hundred thou-
sand; weight, ninety-three pounds.    Dog apparently in
good health.

15. July 15, 1899.—Female dog; hemoglobin, eighty
per cent.; red cells, four million; weight, thirty-three
and one-half pounds.    While bleeding the right external
jugular vein saline solution was introduced into the left
more rapidly than the blood escaped, for the purpose of
raising the blood-pressure.    Right external jugular vein
ligated on cardiac side of wound to prevent regurgitation
from opposite side.    The flow of blood was noticed to
increase and decrease with raising or lowering the bottle
of saline.    The amount of blood withdrawn, three thou-
sand cubic centimetres; amount of saline introduced, five
thousand six hundred cubic centimetres; temperature of
saline, 52° C.

16. July 18, 1899.—Male bull-dog; hemoglobin, eighty-
nine per cent.; red cells, four million seven hundred
thousand; weight, thirty-four pounds.    Bled from right
external jugular vein, at same time injecting saline on other
side.    Bleeding continued for ten minutes.    Amount of

blood withdrawn, two thousand six hundred and fifty cubic centimetres ; amount of saline introduced, three thousand cubic centimetres ; temperature of saline, 55° C. At about eighteen hundred cubic centimetres the fluid withdrawn began to darken and soon became the color of port wine. The dog died in a convulsion while the bleeding continued. The pressure of the column of saline in the bottle forced the stream through some time after the cessation of the heart's action and the respiration.

17. July 19, 1899.—Female dog ; hemoglobin, ninety per cent. ; red cells, four million seven hundred thousand ; weight, thirty-four pounds. Bled from right femoral artery, at same time running saline into left external jugular vein. Bled seven and one-half minutes. Amount of blood withdrawn, one thousand cubic centimetres ; amount of saline introduced, eighteen hundred cubic centimetres ; temperature of solution, 54° C. Color of blood modified by the saline, becoming much brighter. The last of the fluid withdrawn was but slightly colored. The dog died in a short convulsion.

*Autopsy.*—Lungs collapsed ; heart in systole ; fluid in veins cherry-red ; bladder full of urine.

18. July 20, 1899.—Male dog ; hemoglobin, eighty-five per cent. ; red cells, three million eight hundred thousand ; weight, thirty-seven pounds. Dog thin and in poor health. Bled from right jugular vein and simultaneously injected solution into left jugular vein. Color of the blood was soon modified, the cherry-red disappeared, and the fluid became dark throughout. Amount of blood withdrawn, thirteen hundred and fifty cubic centimetres ; amount of saline introduced, sixteen hundred and seventy-five centimetres ; temperature of saline, 48° C. Upon completion of the operation the dog was in so bad a con-

dition that he lived but twenty-five minutes, the heart ceasing to beat several minutes before cessation of respiration.

*Note.*—Every dog has died when the bleeding has been carried to the point at which the fluid appears dark, like diluted port wine.

19. July 21, 1899.—Male dog; hemoglobin, seventy per cent. ; red cells, four million one hundred thousand; weight, forty-five pounds.   Bled slowly from left jugular. Heart ceased to beat in five and one-half minutes.   The heart and the respirations were irregular from the first, remaining so for hours.   After seven hundred and fifty cubic centimetres had been withdrawn the dog, with the exception of an occasional gasp, seemed to be dead. Amount of blood withdrawn, seven hundred and fifty cubic centimetres; amount of saline injected, nine hundred cubic centimetres ; temperature of saline, 50° C.

*Note.*—After the operation the dog lay stupid for some time.   The respiration was very bad, at times ceasing entirely.   The conjunctival reflex was present throughout. Forty-five minutes after the operation the dog walked about, but very unsteadily.   About one hour later he had a severe chill, which lasted three hours.   He drank considerable water.   July 23, hemoglobin, thirty-four per cent. ; red cells, two million two hundred thousand; weight, forty-four pounds; marked leukocytosis.   In ten days' time the dog was normal.   The count was up to four million and hemoglobin eighty per cent.

20. July 25, 1899.—Male dog; hemoglobin, seventy-four per cent.; red cells, four million two hundred thousand; weight, thirty-seven and one-half pounds.   Bled from right jugular, at the same time saline was infused into left jugular.   Bleeding continued nine minutes.   Amount

of blood withdrawn, thirteen hundred cubic centimetres ; amount of saline injected, eleven hundred cubic centimetres ; temperature of saline, 48° C.

*Note.*—Whenever the respirations became very weak, oxygen was given by forcibly distending the lungs with oxygen gas. The effect of the oxygen was very pronounced, soon causing the respiration to become strong and full. Five gallons of gas were given, all we had prepared. The dog lived about three hours after the last inhalation of oxygen, and undoubtedly could have been kept alive by constant inhalation of gas.

21. July 28, 1899.—Male dog; hemoglobin, eighty per cent. ; red cells, four million five hundred thousand ; weight, thirty pounds. Bled from right external jugular vein. In three minutes heart-beats could not be felt and bleeding had ceased. Respiration jerky and shallow. The amount of blood withdrawn at this time was six hundred cubic centimetres. Seven hundred cubic centimetres of saline were rapidly introduced and oxygen was given by means of a bag fastened around the head. The dog made a rapid recovery. In less than three minutes he was struggling, and it was soon necessary to re-anesthetize him in order to proceed with the experiment. The left jugular was then opened and two hundred cubic centimetres of blood withdrawn. The dog became weak and the blood darker. Oxygen was then given, together with three hundred cubic centimetres of saline at a temperature of 44° C. In three minutes the dog was again struggling. In five minutes he walked about and was quite lively. July 29, hemoglobin, thirty-three per cent. ; red cells, one million eight hundred thousand ; weight, twenty-eight and one-quarter pounds. Rather weak, but eats and drinks well. August 3, hemoglobin, thirty-three per cent. ; red cells, two million two hundred thou-

sand; weight, twenty-nine pounds.   Dog made perfect recovery.

22. July 29, 1899.—Male dog; hemoglobin, ninety-seven per cent.; red cells, five million; weight, thirty-four pounds.   Bled slowly from right external jugular.   Blood ceased flowing in twelve minutes, eight hundred cubic centimetres being withdrawn.   The heart-beats could not be felt; respiration spasmodic and weak.   Waited ten minutes and then opened the left external jugular, from which there oozed one hundred cubic centimetres of blood. The time consumed in obtaining this was ten minutes. With the exception of an occasional diaphragmatic spasm the dog was apparently dead.   Saline solution was infused into the veins and oxygen was given by inhalation.   The heart began to beat strongly by the time five hundred cubic centimetres were introduced.   In one minute from the time the saline and oxygen were started the respira-tion and heart's actions had become fairly good.   The dog had regained consciousness before the dressings were applied.   Two hours later he drank large quantities of water, but ate nothing during the day.   At the end of the first day hemoglobin was thirty-five per cent.; red cells, three million five hundred thousand; weight, thirty-four pounds.   Dog stupid and weak; laid down most of the time; refused to eat; drank water, but refused milk. At the end of the second day he was forced to take milk, but was still very weak.   On the third day he was some-what improved, but refused to stand.   On the fourth day he seemed quite sick.   Gave four hundred and fifty grains of Rochelle salts.   On the sixth day the bowels moved for the first time.   Began to eat.   Has lost weight and is very weak.   Seventh day, hemoglobin, thirty-eight per cent.; red cells, two million five hundred thousand; weight not noted.   The dog made a complete recovery.

23. August 21, 1899.—Male dog; hemoglobin, ninety-seven per cent.; red cells, five million one hundred thousand; weight, thirty-five and one-half pounds. Bled from right external jugular vein, and at the same time saline was introduced into the left. The amount of blood withdrawn was nineteen hundred cubic centimetres; the amount of saline injected, two thousand cubic centimetres; temperature of saline, 43° C. Oxygen was given at the same time the blood was withdrawn. Bleeding continued fifteen minutes until the escaping fluid was nearly pure saline. Color remained bright red. The experiment was discontinued, as the supply of oxygen was exhausted. The apparatus was working unsatisfactorily, and several bubbles of air went into the circulation with an audible sound. An hour and a half later the attendant found the dog was dead.

24. November 10, 1899.—Dog; weight, eighteen pounds. After the blood-pressure had been arranged and the cannula for the saline infusion had been attached; the animal was killed by an excess of chloroform anesthesia for the purpose of determining the disposition of the saline solution when administered after death. The solution was then allowed to flow until two thousand five hundred cubic centimetres were introduced. During this time a gradual increase in the size of the abdomen was noted, as in the experiments on the living animal.

*Autopsy.*—The tissues were everywhere wet, excepting in the extremities. The larger portion of the fluid had accumulated in the abdominal viscera. There was a large amount in the stomach and in the intestinal tract. The liver was much enlarged, hard, and cold, and on incising it large quantities of bloody fluid escaped. The post-mortem findings were about the same as in the animals in which the saline solution was introduced during life.

25. Dog; weight, seventeen pounds; ether anesthesia. The manometer was attached to the carotid artery. Salt solution was introduced into the left femoral vein from a height of seven feet ten inches. A slight rise occurred in the blood-pressure which was sustained. The abdomen enlarged rather rapidly; the lower ribs became fixed; respirations short and slow, finally failing, but the circulation up to this point maintained a steady line. When the blood-pressure began to fall it continued until death, while the heart executed slow beats until the end.

*Autopsy.*—The autopsy in almost every respect revealed conditions similar to the preceding with the exception that there was some ecchymosis in the walls of the intestines and of the stomach.

26. Mongrel dog; weight, twenty pounds; ether anesthesia. The manometer was connected with the left carotid artery, the saline solution introduced into the left femoral vein. A rather abrupt rise of the arterial pressure followed. After five hundred cubic centimetres had been administered one-thirtieth grain of strychnin was injected into the vein. Both the arterial and the venous pressures fell, it being about fifteen seconds before they regained the lost pressure; the abdomen enlarged; râles were heard over the chest and both pulmonary bases were dull on percussion. Burning the paw produced but a slight rise in the blood-pressure.

*Autopsy.*—The somatic area not especially wet; the splanchnic area saturated with water; no free fluid in the thorax. The lungs on section were found to be markedly edematous and a large amount of bloody fluid escaped. The pericardial sac was normal, the heart-muscle was somewhat edematous, and the chambers were filled with recently clotted blood. The pancreas was enlarged and edematous.

27. Dog; weight, thirty-four pounds; ether anesthesia. At 5.23 P.M. right hind paw was burned, producing a sharp rise in the blood-pressure. At 5.32, saline solution at 20° C. was injected into the iliac vein from an elevation of seven feet ten inches. This caused no rise in the pressure. The animal received one thousand cubic centimetres of saline solution at 5.38. The right paw was again burned and the arterial pressure rose, but not so markedly as before. One minute later the blood-pressure maintained the height to which it had been elevated, but on again burning the paw it rose still higher. At this point the animal was subjected to further burning, which was followed by an additional slight rise in pressure. After the introduction of three thousand cubic centimetres the neck began to swell and large quantities of watery fluid escaped from the mouth, coming evidently from the stomach. Tetanic spasms followed, and after four thousand seven hundred cubic centimetres had been given the animal died of respiratory failure.

*Autopsy.*—The usual conditions were found. The splanchnic area was filled with fluid, though there was not much free fluid in the peritoneal cavity, from which area about one thousand cubic centimetres were recovered. All of the veins were tense and full.

28. Dog; weight, twenty pounds; ether anesthesia; saline infusion at 12° C. There was a momentary fall at the beginning of the flow, followed by a slight rise. At this temperature one thousand cubic centimetres were administered. After this fifteen hundred cubic centimetres were given at 42° C. This produced a slight rise, then a gradual fall. Fifteen minutes later a solution at 12° C. was given, producing a slight rise, which was followed by a gradual fall. The animal was killed by injecting fifteen minims of chloroform.

*Autopsy.*—The autopsy revealed conditions almost identical with the preceding.

29. Dog; weight, twenty-eight pounds; ether anesthesia. Experiment began at 4.30 P.M. Four thousand cubic centimetres of saline solution was allowed to flow into the left femoral vein. Fluid finally began to escape from the mouth, later from the anus. Râles were heard over the lower lobes of the lungs, and on percussion there was dulness over the pulmonary bases. The dog died of asphyxia at 5 P.M.

*Autopsy.*—Venous system full; arteries comparatively empty; accumulation of fluid in the splanchnic area; stomach distended with air and water; bloody edema of the lungs; considerable fluid in the trachea and the bronchial tubes.

30. December 1, 1898.—Mongrel bitch; weight, twenty pounds; ether anesthesia. Saline experiment. While adjusting the cannula on the respiratory apparatus a clip from the pressure-bottle was inadvertently opened and a quantity of solution of magnesium sulphate passed into the carotid artery. The animal was seized with a clonic convulsion. All the extremities became rigid and death ensued instantly. The normal saline was then allowed to flow and fill the venous system. There was so much leakage from the field of dissection that the experiment was no more than suggestive. The liver and entire splanchnic circulation were much distended.

31. December 5, 1898.—Spaniel dog; weight, twenty-four pounds; ether anesthesia. Two hundred and twenty cubic centimetres were given. The recording cannula was attached to the right carotid, the cannula for saline infusion into the right femoral vein. The animal

was in good condition. At 3.18 P.M., after being re-
duced to surgical anesthesia, the saline was allowed to
flow. The blood-pressure rose steadily but slowly for
about ninety seconds, when it remained at that level,
whether or not the solution was flowing, almost until the
close of the experiment. Elevating the infusion-bottle
caused no perceptible change in the blood-pressure. The
temperature of the saline was 40° C. After fifteen min-
utes the abdomen began to enlarge, and at the end of
thirty minutes the respirations were somewhat embar-
rassed. This was manifested by the shortness of the
respiratory excursions and the decrease in their rapidity.
The infusion cannula at this time was not serving its pur-
pose well, so it was transferred to the left femoral vein,
where the solution flowed more rapidly. Temporarily
the blood-pressure was slightly raised, but after a rounded
curve it dropped to the previous level. Forty-two min-
utes after beginning the saline infusion fluid began to
flow from the mouth and nostrils. There seemed to be
an increased flow of saliva. There was also an accumu-
lation of fluid in the breathing apparatus. The abdo-
men became extremely tense and there was free oozing
wherever dissection had been made. The percussion note
over the lower abdomen was flat; over the stomach it was
more tympanitic. The respirations now became extremely
embarrassed; extraordinary muscles were called into
action; the blood became darker; coarse moist râles
were heard over the lobes of the lungs, especially on the
posterior aspect. On percussion there was flatness on the
posterior inferior region of the thorax. The respiratory
cannula was filled with water and mucus. Death from
complete respiratory failure occurred sixty-two minutes
after the beginning of the saline infusion. In all six thou-
sand one hundred and fifty cubic centimetres were infused.

*Post-Mortem.*—The tissues of the somatic area were

wet and soggy, especially the walls of the abdomen and chest. At all the points where dissection had been made there was oozing. On opening the abdomen free fluid escaped ; the intestines were white, even translucent, and solid to the touch,—picking them up they were heavy. The stomach also was heavy, soggy, and white ; on incising it as well as the intestines large quantities of clear fluid escaped. There was a considerable quantity of air in the stomach. The mucous membrane of the gastrointestinal tract was very much swollen and pale, imparting a velvety touch. The large intestines were less pale and less involved than the small. From the ileo-cecal valve to the anus the involvement diminished and the lower portion of the rectum was more nearly normal. The urinary bladder was much distended. The liver was greatly increased in size and imparted a sense of unusual resistance to the touch, the lobes being quite rigid ; it was paler than normal, and on incising it large quantities of blood escaped. The kidneys were much less swollen than the liver or the gastro-intestinal tract, and upon incising them some free fluid escaped. On opening the thorax the lower lobe of the lung was found congested and edematous. There was some free fluid in the pleural cavity. The inferior vena cava imparted to the finger the sense of considerable tension. The superior vena cava was very much dilated and under less tension. The muscles of the extremities were quite firm, not especially wet, and some air was noted in the connective tissue between them. Thirteen hundred and sixty cubic centimetres of fluid were collected from the gastro-intestinal tract, the peritoneal cavity, and the urinary bladder. About six ounces were collected from the pulmonary tract.

32. January 30, 1899.—Crossed setter dog ; weight, forty-seven pounds ; ether anesthesia. At 4.10 P.M. carotid

blood-pressure was taken.    At 4.25 a blood-count was
made with a Thoma-Zeiss instrument, showing three mil-
lion two hundred thousand red cells per cubic millimetre.
At 4.45, normal saline at temperature 37° C. was intro-
duced into the left femoral vein.    The blood-pressure
rose immediately, but only temporarily.    In a few seconds
there was a secondary slight fall, followed by a steady
gradual rise.    In five minutes' time two thousand two
hundred cubic centimetres of fluid had been introduced
and the blood-pressure  remained at  the  same  height.
There was then an increased bleeding in the entire field
of  dissection.    During the next ten minutes five hundred
cubic  centimetres  were  introduced.    A  few  drops  of
chloroform  were  given  instead  of  ether, the blood-press-
ure  falling  immediately.    During  the  subsequent  five
minutes one hundred cubic centimetres of saline were in-
troduced,  making  three  thousand  one  hundred  cubic
centimetres introduced during twenty minutes.    Blood-
count at this time showed  four million four hundred and
seventy-six  thousand  red  cells  per  cubic  millimetre.
Thirty minutes after the beginning of the saline and after
three thousand one hundred cubic centimetres had been
given, one-thirtieth grain of strychnin was injected into
a vein.    In about seven seconds the blood-pressure rose
slightly.    After a few minutes several drops of chloro-
form were again administered, a marked fall following.
At the end of fifty-five minutes four thousand six hun-
dred cubic centimetres of saline and one-thirtieth grain
of strychnin had been administered and no change was
produced in the blood-pressure.    At this time the pul-
monary bases were dull and numbers of moist râles were
heard.    The abdomen then became perceptibly enlarged.
At 5.24, one hour after the beginning, one-fiftieth grain
of digitalis was given intravenously, producing no change
in the blood-pressure.    At 5.25, four thousand eight hun-

dred cubic centimetres had been given.    Blood-count at
this time showed five million four hundred and seventy-
six thousand.    At 5.29, one-half dram of chloroform
was given on the inhaler, producing gradual fall in the
blood-pressure.    On removing the chloroform the blood-
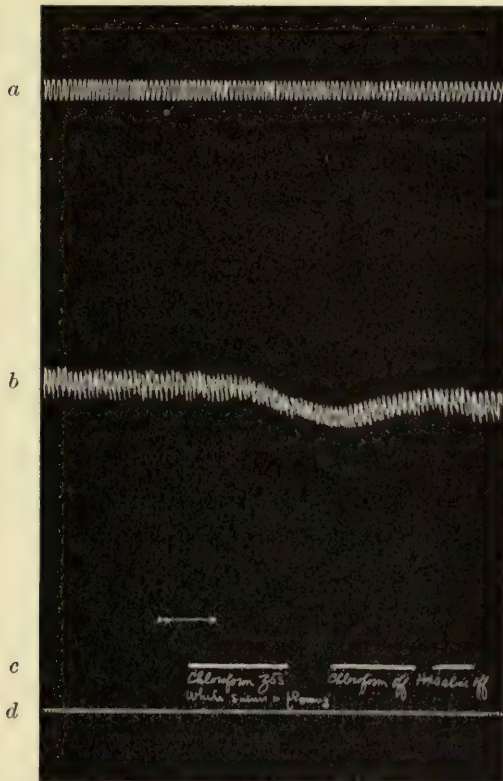


Fig. 7.—*a*, respiration; *b*, blood-pressure; *c*, signal; *d*, seconds.  While the saline solu-
tion was flowing into the jugular one-half dram of chloroform was administered.  Note
the marked fall in the blood-pressure during the inhalation and the compensatory rise
following the removal.

pressure recovered.    (Fig. 7.)    At 5.30, the saline flow
was stopped, five thousand two hundred cubic centimetres
having been introduced.    Eye reflex not gone.    At 5.36,
anesthesia removed.    Slight rise in blood-pressure fol-
lowed.    Reflexes not abolished.    At 5.38½, a dram of

chloroform was put upon the inhaler. Slight fall in blood-pressure followed. Chloroform inhaler then removed and four drams of ether administered. No fall in blood-pressure followed. The individual strokes became shorter. At 5.41, while adjusting the apparatus, some saturated solution of magnesium ran back into the heart. The dog died almost instantly of cardiac and respiratory failure. The abdomen had become very greatly enlarged.

*Autopsy.*—Most of the tissues were quite wet, but on cutting across muscles they did not seem to have an unusual amount of fluid. There was but little edema of the limbs. There was a small amount of clear fluid in each pleural cavity, but none in the pericardial sac. The bases of both lungs were intensely edematous and congested, and on section there was squeezed out a relatively large quantity of frothy, bloody fluid. A quantity of free fluid was in the abdomen. The bladder was immensely distended. The stomach was filled with clear fluid and its walls were greatly thickened. The mucosa was especially stiff and edematous. The same condition was present throughout the intestinal tract, but to a less degree towards the anus. The pancreas was enlarged and edematous. The liver was greatly enlarged and firm, and on section large quantities of bloody fluid escaped. All the veins were full and resistant. The heart was firm, containing some recent clots. The urine obtained from the bladder contained a small amount of albumin and an excess of urea. There were no organized elements in the sediment.

33. February 3, 1899.—Cur dog; weight, twenty-two pounds; ether anesthesia. At 2.35 P.M. the rectal temperature was 99° F. The cannula for recording the blood-pressure was placed in the carotid artery, and that for saline infusion in the femoral vein. Blood-count at this

time, four million one hundred and seventy-five thousand. At 2.40, saline solution at a temperature of 60° C. was injected. There was a slight fall in the blood-pressure at 2.43. At 2.45, the saline stopped running. At 2.48, it was again started and a slight rise in the blood-pressure occurred. At 2.55, the rectal temperature was 100° F. At that time the animal had received six hundred and fifty cubic centimetres. At 3.08, the temperature was 101° F. and eleven hundred cubic centimetres had been given. At 3.15, the saline was at 48° C. The dog's temperature was then 102° F. and two thousand cubic centimetres had been given. The blood-count at 3.15 showed three million eight hundred and seventy-nine thousand. At 3.16½, a dram of chloroform was applied on the inhaler. No effect was produced. At 3.30, the dog had had three thousand four hundred cubic centimetres at 48° C. Rectal temperature, 102° F. Blood-count showed five million one hundred and seventy-six thousand. At 3.38½, a dram of chloroform was applied on the inhaler. At 3.38⅞, there was a fall of blood-pressure. At 3.40, one dram of chloroform was given, and at 3.40$\frac{1}{10}$, there was a fall of blood-pressure to the abscissa line. At 3.41, respiration ceased. Three thousand eight hundred cubic centimetres had been given. The abdomen was considerably enlarged and respirations had become embarrassed.

*Post-Mortem.*—Free fluid was found in the peritoneal cavity; the gastro-intestinal tract pale and edematous; free fluid in the stomach and intestines; urinary bladder greatly distended; all the veins engorged; the liver enlarged and hard, and when incised quantities of bloody fluid escaped. The pulmonary bases were congested and edematous, and on being incised there was a considerable amount of frothy fluid. The vena cava inferior was especially engorged and tense. The heart had a few recent clots in the cavities.

34. February 4, 1899.—Cur dog; weight, thirty-six pounds; A. C. E. mixture for anesthesia. The animal was in poor condition and there was considerable delay in adjusting the apparatus. The blood-count gave three million five hundred and eighty thousand. While separating the carotid artery from the vagus nerve the latter was mechanically stimulated by rough handling and respiration ceased. In spite of efforts, such as artificial respiration and normal saline injection, the animal died. The autopsy showed the presence of a supernumerary thyroid, but was otherwise negative.

35. February 5, 1899.—Spaniel cur; weight, twenty-one pounds; ether anesthesia. The dog was anesthetized at 3.40 P.M., at which time its rectal temperature was 101.4° F. At 4.17, blood-count showed four million two hundred and eighty thousand. Salt solution at 58° C. was introduced in the left femoral vein. The arterial pressure was registered by means of a carotid cannula. The blood-pressure rose immediately, then fell slightly, after which it rose slowly but steadily until 4.20, where it remained fairly constant. Four hundred cubic centimetres of saline at 58° C. had been given. Rectal temperature, 102° F. At 4.25, the trachea and lungs were filling with frothy mucus. The dog had one thousand cubic centimetres of saline, and his temperature was 103° F. Inverting the dog and taking away the anesthetic caused a rise in blood-pressure. At 4.28, increase in length of strokes and shallow breathing; trachea full of bloody and frothy mucus. Again inverting the dog caused a rise in blood-pressure. At 4.30, each stroke fell lower, and at 4.32, the dog died, having had two thousand three hundred cubic centimetres saline at a temperature of 58° C. Intra-abdominal temperature, 104° F.

*Autopsy.*—All the organs were found edematous, but

the pulmonary bases were markedly congested and filled with frothy, bloody liquid.  Each of the kidneys contained about one ounce of fluid.  The gall and urinary bladders were distended, as were also the large venous trunks.  Section of the lung showed macroscopically an emphysematous appearance, as if the alveolar walls were destroyed, also numerous spots of free hemorrhage, probably from broken-down capillaries.

36.  February 7, 1899.—Black cur dog; weight, twenty-two pounds; ether anesthesia.  Experiment began at 5.16; temperature by rectum, 100° F.  Blood-count, five million five hundred and eight thousand.  Blood-pressure in right carotid; normal saline at temperature of 62° C. injected into left femoral vein.  Blood-pressure rose immediately. Anesthetic changed to chloroform on account of mucus in trachea.  After the first few drops there was a slight temporary fall in the pressure, but it returned almost immediately to the previous height.  Temperature, 100° F. Blood-pressure rose gradually, then declined slightly, and again rose.  At 5.44, four hundred cubic centimetres saline at temperature 68° C.; slight decline in blood-pressure; temperature, 101° F.  Upon the administration of one-half dram of chloroform the blood-pressure fell almost to the abscissa line.  Artificial respiration.  Blood-pressure gradually returned.  Chloroform stopped and ether administered.  At 5.55, fifteen hundred cubic centimetres saline at 58° C. had been administered.  Blood-pressure steadily fell; temperature, 101° F.  At 6.00, two thousand one hundred cubic centimetres saline had been injected; temperature, 102° F.  Blood-count showed three million six hundred and sixty-six thousand.  At 6.10, there was a sudden collapse.  Blood-pressure fell to the abscissa line.  Dog was raised and frothy, bloody mucus escaped from the cannula.  Artificial respiration was con-

tinued, but resuscitation was impossible. The entire quantity of saline injected was two thousand five hundred cubic centimetres.

*Post-Mortem.*—There was considerable edema of all the tissues and bloody emphysema at the base of both lungs. The urinary bladder was distended and the urine showed an excessive amount of urea and a trace of albumin.

37. Bitch; weight, twenty-four pounds; ether anesthesia; three thousand four hundred cubic centimetres saline were infused. Immediately upon beginning the infusion into the left femoral vein a steady but gradual rise in the cannula was noticed. The animal enlarged in the usual way. After the abdomen began to increase a few drops of chloroform upon the cone caused, after the lapse of a few seconds, a fall in blood-pressure. The application of a relatively large quantity of ether produced no effect. The animal died of respiratory failure in much the same manner as in the preceding. The autopsy showed the relatively normal condition of the somatic area, and the water-logged condition of the splanchnic area, together with the ecchymosis and edema of the lungs and edema of the bronchial pulmonary tract. Urinary analysis: specific gravity, 1030; no sugar; albumen, trace; color, light amber; reaction, acid; urea, great excess; precipitate, flocculent.

38. Bitch; weight, thirty-six pounds; ether anesthesia. Death after three thousand eight hundred cubic centimetres were used. On beginning of the saline infusion at the temperature of the body, in the left jugular vein, there was no rise in the blood-pressure. This experiment followed precisely the same line as the preceding. The inhalation of fifteen minims of chloroform, after the ani-

mal's abdomen began to enlarge, produced a very marked
fall in the blood-pressure, while six drams of ether, after
the blood-pressure had recovered itself, produced no effect.
Urine analysis revealed nothing unusual excepting an ex-
cess of urea.

39. Black spaniel puppy ; weight, sixteen pounds.  Can-
nula for blood-pressure in the carotid.   Mesenteric artery
and vein closed.   Following this the respirations ceased,
but were resumed on the infusion of hot saline in the ex-
ternal jugular vein.   The animal struggled as the saline
flowed.   The drum was started at 4.15, at which time the
rectal temperature was 101° F.   At 4.17, the saline was
allowed to flow into the left femoral vein, producing a
marked rise in the blood-pressure, the curve of which was
somewhat irregular.   The amplitude of respiration was
increased.   The animal had attacks of panting.   One
minute later there was a slight decline in blood-pressure,
but recovery took place in half a minute.   In another
minute respirations became slow and the blood-pressure
was steadily falling.   Saline was allowed to flow two
minutes longer.   The blood-pressure continued to fall and
respirations were slowed.   Artificial respirations were be-
gun five minutes after the beginning of the flow of the
saline into the femoral vein, but resuscitation was impos-
sible, and one minute later death ensued.   During this
time sixteen hundred cubic centimetres of normal saline
flowed into the animal.   The temperature at the close of
the experiment was 101½° F.   Some bloody fluid appeared
at the abdominal incision.   The intestine and mesentery
were cyanotic.   The spleen was enormously engorged,
tense, and full of dark, bluish blood.   The urinary blad-
der was partially filled.   A small amount of free fluid was
in the abdomen.   The kidneys were bloodless and the
stomach dark and congested except at the pyloric end,

which was normal.  The lungs were edematous, but the edema was not especially marked at the bases  The skeletal muscles were normal.

40.  Mongrel puppy in good condition ; weight, twenty pounds ; ether anesthesia.  The abdominal aorta was closed at 5.02 P.M.  At 5.11½, the saline at 34° C. began to flow into the left external jugular vein.  A slight but steady rise in blood-pressure occurred.  One minute later the flow was stopped, which was followed by a steady fall. After a minute the saline was again allowed to flow and the decline in the blood-pressure ceased.  In half a minute the flow was stopped, when there was a slight fall, after which the infusion was again begun and a slight rise occurred.  Seven minutes after the beginning of the saline flow there was marked edema of the tissues of the neck.  On repeating the infusion there was a marked rise in the blood-pressure.  This lasted two minutes, during which time the bases of the lungs became dull.  One minute later there was oozing from the wounds in the neck.  The blood-pressure began to decline.  After nineteen and one-half minutes the respirations became slow, ceasing at the end of twenty-three minutes.  The heart executed slow, sweeping strokes, indicating asphyxia. The heart stopped one and one-half minutes after the cessation of respiration.  Total saline, two thousand four hundred cubic centimetres.

*Autopsy.*—The intestines and mesentery were dark. The stomach and intestines contained only a small amount of dark, gelatinous-like bloody fluid, which was adherent to the mucous membrane.  The spleen was quite large, dark, and contained a considerable amount of fluid. There was but a small amount of blood in the large veins of the abdomen.  The veins of the extremities were nearly empty.  With the exception of the liver, which

was engorged, but little fluid was in the abdominal organs. The tissues of the thoracic region were edematous and saturated with thin blood. The tissues of the forelegs were more moist than those of the hind. There was marked edema of the soft parts around the larynx and esophagus. Free fluid was in both pleural cavities, also in the pericardial sac. The general edema of the lungs was not limited to the bases. The mucous membrane of the esophagus and trachea was markedly edematous. The back pressure in the carotid was very high. The heart was pale, having a washed-out appearance. No blood-clots were in the chambers, only a watery, blood-tinged fluid.

41. February 27, 1899.—A spaniel in good condition; weight, thirty-two pounds; ether anesthesia. Blood-pressure taken in right carotid. Abdominal aorta clamped at 11.16. One minute after closing the abdominal aorta respirations failed. Artificial respirations were supplied for a few minutes, during which time the small vessels of the neck bled freely. At 11.19, saline solution at 37° C. was allowed to flow into the external jugular vein. This produced a slight rise in the pressure, the curve being rather irregular. A minute and a half later there was a sudden and decided rise, after which, during one moment, a slight but steady fall. Eleven minutes after the beginning of the saline infusion the blood-pressure remained at the same level, watery fluid dropping from the nose. Four and a half minutes later there was free bleeding from all points of dissection in the neck. On crushing the left testicle there was an increase in the frequency of respirations and a fall in the blood-pressure. On cessation of manipulation there was a partial recovery of the fall. Later, rubbing and stretching the sciatic nerve produced a slight but temporary rise in blood-

pressure, it being lost before the cessation of mechanical stimulation.   After the lapse of twenty-six minutes the pulmonary bases became dull.   Respirations gradually became slower, during which time the heart beat more slowly, executing long strokes.   The respirations became labored, and in thirty-four minutes the animal died of asphyxia, the heart continuing to beat two minutes after the cessation of respiration.   Total amount of saline administered was two thousand five hundred cubic centimetres.

*Post-Mortem.*—There was very high back pressure in the carotid artery.   All the veins in the forepart of the body were distended with thin, bluish blood.   The muscles of this part were edematous.   There was a large amount of cellular edema, especially of the neck.   Both the pleural cavities and the pericardium contained free fluid.   Very marked edema of both pulmonary bases was noted.   The heart-muscle was pale, containing no clots, but a small quantity of diluted blood.   The liver was dark and contained but little fluid.   There was but a small amount of bile in the gall-bladder.   The kidneys were large, blue, and intensely congested.   The pancreas was bluish on dissection and filled with dark blood.   The spleen was large and hard, containing a large amount of dark, bluish blood.   The intestines were cyanotic, containing dark, gelatinous-like fluid.   There was no urine in the bladder.   The large veins of the lower extremities were empty and the tissues of the hind extremities dry.

42. March 1, 1899.—Cur ; weight, twenty-six pounds, fair condition ; ether anesthesia.   Blood-pressure in carotid artery.   Abdominal aorta closed.   Saline solution at 37° C. allowed to flow into the left jugular vein.   Blood-count at the beginning of the flow was three million five

hundred thousand red corpuscles.   On allowing saline to flow into the jugular vein there was a slight but temporary fall in the blood-pressure, which was followed by a steady rise with irregular but shortened strokes.   The blood-pressure curve remained irregular for two minutes. After six minutes the sciatic nerve was stretched, which produced a rise in blood-pressure.   The pulmonary bases were dull at the end of twenty-seven minutes, at which time two thousand nine hundred cubic centimetres had been administered.   The blood-count showed one million four hundred thousand.   In each instance the count was taken from the vessels of the neck.   Total saline, three thousand one hundred cubic centimetres.

*Post-Mortem.*—The tissues of the lower extremities were dry, the veins empty, while those of the upper extremities were moist.   The muscles and cellular tissues of the thorax were edematous.   The intestines were dark blue in color and empty, with the exception of a small amount of dark, gelatinous-like blood, which was adherent to the mucous membrane.   There was no edema of the intestinal walls.   The stomach was empty and the kidneys very pale.   The spleen was enlarged and contained dark thin blood.   The pancreas was normal.   The liver was engorged with dark, thin blood.   The gallbladder was partially filled and the urinary bladder distended.   There was free fluid in the pericardial cavities. The lungs were edematous, their bases almost black. There was free fluid in the pleural sac.   The heart was pale and contained a few small clots.   The esophagus was edematous, containing quantities of stringy mucus. The cellular tissues around the thyroid and around the glottis were especially edematous.

43. Bull puppy ; died before he was reduced to surgical anesthesia.

44. March 1, 1899.—Cur; weight, thirty-eight pounds; ether anesthesia. Blood-pressure taken in right carotid. Abdominal aorta closed. Saline solution at 37° C. allowed to flow into left external jugular vein. Blood-count, four million one hundred thousand. The saline infusion caused a slight but temporary fall in blood-pressure, which was followed for a short time by a steady rise, after which it remained at the same level. After administering three thousand six hundred cubic centimetres saline, the blood-count showed one million two hundred and eighty thousand. The animal died of respiratory failure after receiving four thousand cubic centimetres.

*Post-Mortem.*—The tissues of the forepart of the body were soggy; those of the hind part comparatively dry. No free fluid was found in the abdomen. The stomach contained a quantity of watery fluid and its walls were slightly thickened. The intestines were dark in color, containing a small amount of bloody fluid. The liver was engorged. There was free fluid in the pleural and pericardial sacs. The veins of the thorax were full and tense. The heart was pale, presenting a washed-out appearance, and was distended with diluted blood. There were no clots. No abnormal change had occurred in the brain, except that it appeared pale. Lungs edematous; free fluid in the pleural cavity.

45. March 2, 1899.—Mongrel, in good condition; weight, twenty-four pounds; ether anesthesia. A cannula delivering saline solution at 57° C. was inserted into the left femoral vein, and one delivering saline at 0° C. into the left jugular vein. After allowing the hot solution to flow, there was a fall in the blood-pressure which continued about twenty seconds, after which it rose again. The respirations were panting. On stopping the flow of the

hot saline no appreciable effect was observed.   On turning the cold infusion into the jugular vein an immediate fall occurred in the blood-pressure to the abscissa line, and in spite of artificial respirations the animal died.   The total amount of hot and cold saline injected was six hundred cubic centimetres.

*Post-Mortem.*—The dog's neck was exceedingly cold to the touch.   The intestines were dark blue, the walls somewhat thickened.   There was no fluid in the stomach or the intestines.   The veins were engorged and tense. The muscles of the thorax were soggy, but those of the extremities were dry.   The lungs were cold, the left colder than the right, the temperature being almost as intense as that of the saline at zero.   There was bloody edema of the pulmonary bases.   The heart contained some diluted blood and a few small clots.   The autopsy was made directly after death.

46. March 3, 1899.—Mongrel dog; good condition; weight, twenty-eight pounds; ether anesthesia.   Cold and hot solutions infused.   Solution at 0° C. infused into the external jugular vein.   The first effect noted was an increase in the length of the stroke and decrease in rate. The blood-pressure gradually rose.   On cessation there was a rise in the pressure and the stroke assumed the previous rate and length, after which the pressure fell to the previous level.   On introducing the hot saline the strokes became greatly slowed and lengthened and the blood-pressure abruptly fell.   Following this there was a rapid rise, higher than the previous level.   The strokes became short and the rate increased.   The pressure gradually fell to the previous level, remaining about the same until the animal was killed by an overdose of chloroform.

47. March 4, 1899.—Yellow cur dog; weight, twelve pounds, young and in good condition.   Blood-pressure can-

nula in right carotid.    Abdominal aorta was closed ; blood-count then showing four million five hundred thousand. On allowing the saline solution at 30° C. to flow into the jugular vein there was a slight rise in blood-pressure,
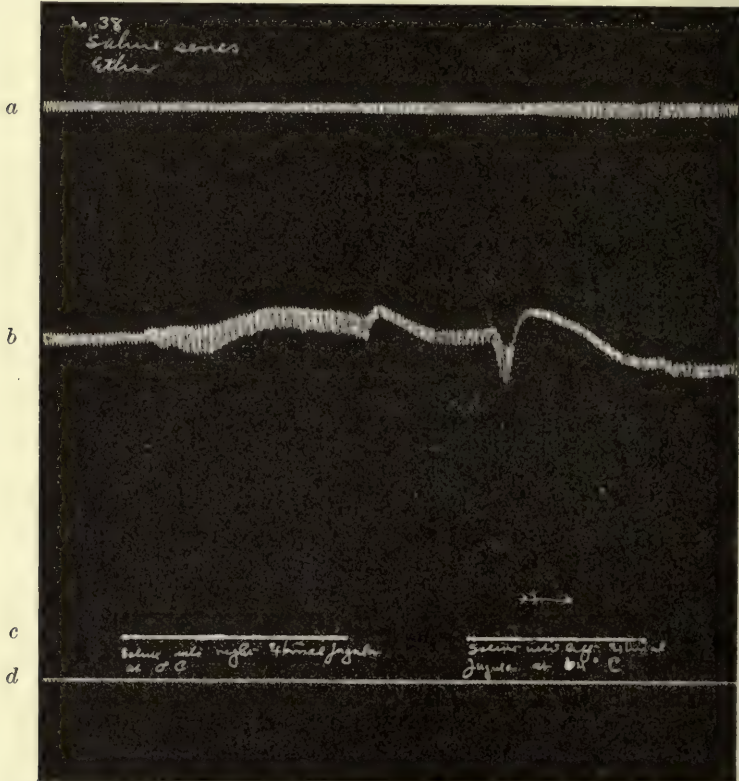


Fig. 8.—*a*, respiration; *b*, blood-pressure; *c*, signal; *d*, seconds. Note the diminished rate and the increased length of stroke following the infusion of saline solution at 0° C. On cessation the blood-pressure rose above the previous level, finally taking about the former level. Infusion at 64° C. there was an immediate fall with temporarily slowed beat and elongated stroke, after which there was rapid rise, short strokes, followed by a compensatory fall to the previous level.

followed by a compensatory fall, after which there was some irregularity. The respirations were somewhat slowed. After one thousand cubic centimetres had been introduced there was a marked fall in the blood-pressure, with irregular, sweeping strokes. The blood-count was

two million five hundred and fifty thousand.    The back pressure in the carotid was marked.    After eleven hundred cubic centimetres of saline were introduced  death occurred from respiratory failure.

*Autopsy.*—Heart was pale.    A small amount of free fluid was found in the pleura and pericardium.    There was edema of the pulmonary bases, the thorax, and of the neck.    No free fluid was found in the abdomen and none in the intestines, the latter being dark.    The walls of the intestines were not edematous.    The liver was engorged.    The tissues of the hind legs were dry in comparison with those of the forelegs.    The brain apparently was normal.    The autopsy was made immediately after death.

48. March 6, 1899.—Yellow cur dog, in good condition ; weight, twenty pounds.    Blood-pressure in right carotid. The abdomen was opened and a clamp put supposedly upon the abdominal aorta, but was afterwards found to close only the renal.    Saline solution at 37° C. was made to flow into the external jugular vein.    An immediate rise in blood-pressure followed.    Later there were some irregularity.    After the administration of two thousand nine hundred cubic centimetres death occurred from respiratory failure.

*Autopsy* revealed conditions the same as in the other experiments, in which the aorta was not closed, with the exception that the kidneys were pale and the urinary bladder empty.

49. March 6, 1899.—Pug dog, in fair condition ; weight, twenty-four pounds ; ether anesthesia.    Cannula in right carotid.    In this experiment it was discovered, after twelve hundred cubic centimetres had been introduced, that the aorta was not effectually closed.    On clamping this vessel, one thousand cubic centimetres were introduced, after

which death occurred. The error in the technique invalidates this experiment.

50. March 7, 1899.—Terrier; weight, twenty-seven pounds; fair condition, ether anesthesia. Cannula in right carotid. Saline allowed to flow from different heights. This experiment was made for the purpose of determining what difference, if any, would be produced. It was found that the rise of blood-pressure varied with the height to which the bottle was raised. The ratio, while it could not be expressed, did not seem to represent a direct ratio, as it varied greatly. These tests were made several times in the same experiment, in each instance with a similar result, though usually in a different degree. The animal died of asphyxia after three thousand two hundred cubic centimetres had been introduced.

51. March 8, 1899.—Black and tan dog, old and in poor condition; weight, eight pounds. Blood-pressure in right carotid. Saline introduced into the femoral vein. This experiment was performed to determine the effect of allowing the saline to flow from different elevations, and corroborated in almost every respect the preceding experiment. The animal died of respiratory failure after one thousand cubic centimetres had been introduced.

52. March 8, 1899.—Pointer; weight, twenty-one pounds, good condition; ether anesthesia. Blood-pressure in carotid. Saline solution at 38° C. was introduced into the femoral vein. This experiment was made similar to the preceding, which it corroborated in almost every detail. The animal died of respiratory failure after administering three thousand two hundred cubic centimetres.

53. March 9, 1899.—Cur dog, in fair condition; weight, eleven pounds; ether anesthesia. Blood-pressure in right

carotid. Saline solution at 38° C. was introduced into the left femoral vein. The experiment was similar to the preceding, which it also corroborated. Death ensued from respiratory failure after two thousand five hundred cubic centimetres had been introduced.

54. March 9, 1899. Cur; weight, sixteen pounds; ether anesthesia. Blood-pressure in right carotid. Saline solution at 38° C. was introduced into the left femoral vein. This experiment was conducted on the same line as the preceding, which it verified. The animal died of respiratory failure after two thousand five hundred cubic centimetres had been introduced.

55. March 11, 1899.—Cur; weight, ten pounds. Cannula for blood-pressure in right carotid. Normal saline was introduced into the left jugular vein and the experiment was made upon the blood-pressure by allowing the saline to flow from different heights. The results were the same as in the preceding cases. The animal died of respiratory failure after two thousand two hundred cubic centimetres had been introduced.

56. Bull terrier; weight, twenty pounds. Died of ether anesthesia before experiment began.

57. Cur dog; weight, twenty pounds, good condition; ether anesthesia. Blood-pressure in the carotid. In this experiment it was found that the rise in the blood-pressure in the first of the tests was very slight, later on it became more marked; that is to say, in this experiment the ratio between the rise in blood-pressure and the elevation of the saline-bottle was not so great as in the

preceding experiment. The animal died of respiratory failure after four thousand three hundred cubic centimetres had been introduced.

58. March 15, 1899.—Hound; weight, fifty-two pounds; ether anesthesia. Cannula for blood-pressure in right carotid. After eighteen hundred cubic centimetres had been introduced the bottle was raised five feet without apparent effect. On lowering it five feet, no effect was noticed. On stopping the saline flow, there was a slight fall. After two thousand five hundred cubic centimetres had been introduced the bottle was raised five feet, after which there was a very slight rise, with an occasional intermission of a heart-beat. On lowering the bottle five feet there was a slight decline exactly equal to the previous rise. On again elevating the bottle five feet, an additional slight rise occurred. This was repeated several times, and in the main exhibited similar effects. After introducing eight thousand seven hundred cubic centimetres the animal died of respiratory failure.

59. March 16, 1899.—Terrier; weight, fifteen pounds; ether anesthesia. Blood-pressure in the carotid. Abdominal aorta closed just below the diaphragm. On introducing saline solution the usual effects were noticed, and the animal died of respiratory failure after the admission of nine hundred and fifty cubic centimetres.

*Autopsy.*—There was no edema of the tissues excepting around the thyroid glands, and none of the lungs; there was, however, about one hundred and fifty cubic centimetres in each pleural cavity. The heart was pale and full of diluted blood; the intestines were dark blue

in color and empty; the stomach was normal; the spleen rather dark in color; the liver large and engorged; the urinary bladder empty, and the brain pale and bloodless.

60. March 18, 1899.—Cur; weight, fourteen pounds; ether anesthesia. Blood-pressure in the carotid. Abdomen clamped just below the diaphragm. The animal died of respiratory failure after two thousand cubic centimetres had been introduced. The esophagus, trachea, parotid gland, and lungs were edematous. The pleural cavities filled. There were blood-clots in the frontal sinus.

61. Dog; weight, fifty-six pounds; A. C. E. anesthesia. Saline solution at temperature of 100° F. was allowed to flow into the jugular vein at the rate of one thousand cubic centimetres in five minutes. There was a rise in the blood-pressure and slowing of the heart-beats, the writing style executing long excursions. The blood-pressure regained its normal level, but the character of the heart-beats continued the same. After ten minutes there were distinct intermissions. On stopping the flow the heart resumed its normal action. On re-establishing the flow the heart-beats were again markedly intermittent. Animal died of respiratory failure.

The following table shows the ratio between the weight of the animal and the amount of normal saline solution introduced to cause death, in eighteen experiments:

*Table of Fatal Dosage of Normal Saline Solution.*

| | Weight in Kilograms. | Cubic Centimetres of Solution causing Death. |
|---|---|---|
| First . . . . . . . . . . . . . . . . . . . . . | 9.51 | 23.00 |
| Second . . . . . . . . . . . . . . . . . . . | 15.41 | 47.00 |
| Third . . . . . . . . . . . . . . . . . . . . | 17.22 | 40.00 |
| Fourth . . . . . . . . . . . . . . . . . . . | 13.59 | 55.00 |
| Fifth . . . . . . . . . . . . . . . . . . . . | 10.87 | 34.00 |
| Sixth . . . . . . . . . . . . . . . . . . . . | 16.31 | 38.00 |
| Seventh . . . . . . . . . . . . . . . . . . . | 21.30 | 52.00 |
| Eighth . . . . . . . . . . . . . . . . . . . | 9.97 | 38.00 |
| Ninth . . . . . . . . . . . . . . . . . . . . | 23.93 | 74.00 |
| Tenth . . . . . . . . . . . . . . . . . . . . | 9.06 | 29.00 |
| Eleventh . . . . . . . . . . . . . . . . . . | 12.23 | 32.00 |
| Twelfth . . . . . . . . . . . . . . . . . . . | 3.62 | 10.00 |
| Thirteenth . . . . . . . . . . . . . . . . . | 9.51 | 32.00 |
| Fourteenth . . . . . . . . . . . . . . . . . | 4.98 | 25.00 |
| Fifteenth . . . . . . . . . . . . . . . . . . | 9.51 | 26.00 |
| Sixteenth . . . . . . . . . . . . . . . . . . | 4.53 | 32.00 |
| Seventeenth . . . . . . . . . . . . . . . . . | 9.06 | 43.00 |
| Eighteenth . . . . . . . . . . . . . . . . . | 23.56 | 87.50 |
| | 224.17 | 717.50 |
| Average . . . . . . . . . . . . . . . . . . . . . 3.2 + | | |

The following gives the ratio in animals with their abdominal aorta clamped, in eight experiments :

| | Weight in Kilograms. | Cubic Centimetres of Solution causing Death. |
|---|---|---|
| First . . . . . . . . . . . . . . . . . . . . | 7.24 | 16.00 |
| Second . . . . . . . . . . . . . . . . . . . | 9.06 | 24.00 |
| Third . . . . . . . . . . . . . . . . . . . . | 14.50 | 25.00 |
| Fourth . . . . . . . . . . . . . . . . . . . | 11.78 | 31.00 |
| Fifth . . . . . . . . . . . . . . . . . . . . | 17.22 | 40.00 |
| Sixth . . . . . . . . . . . . . . . . . . . . | 5.43 | 11.00 |
| Seventh . . . . . . . . . . . . . . . . . . . | 6.79 | 9.50 |
| Eighth . . . . . . . . . . . . . . . . . . . | 6.34 | 20.00 |
| | 78.36 | 176.50 |
| Average . . . . . . . . . . . . . . . . . . . . . 2.2 + | | |

SUMMARY OF THE EXPERIMENTAL EVIDENCE.—*On the Circulation.*—The intravenous introduction of saline solution at or near normal temperature into the circulation of the animal from a height producing a pressure

greater than that of the blood usually caused a rise in the blood-pressure. The beginning of this rise appeared as soon as the force of the stream was added to that of the circulation. The rise was sometimes abrupt, sometimes gradual, appearing at once or after a lapse of a short time. In almost every instance a point was soon reached above which no amount of saline solution, irrespective of the height to which the bottle was elevated, could raise it. As a rule, the increase in the height of the blood-pressure was but slight, varying from two to six or eight millimetres of mercury. The cases in which there was no immediate rise after the beginning of the infusion were mostly those in which there had been some previous alteration in the blood-pressure. In a small number of experiments there was immediate temporary fall. This was usually rather abrupt, and in every instance a recovery to the previous level was made or the pressure went even higher.

The character of the heart-strokes in many instances was not altered; but in cases in which it was, an increase in the length of the stroke occurred. The frequency of the heart-beats was usually diminished. The general characteristics of the blood-pressure appeared from the time at which it reached its maximum height, after the beginning of the flow, to the time when the beginning of the final decline occurred. The curve was remarkably even. If at the beginning of the flow the curve was irregular, the saline injection usually prevented its continuation, establishing a mean level. When, as a result of the continuous flow, death was produced by an excessive amount, the beginning of the death phenomena was marked by the gradual decline in the blood-pressure, and in no instance was it possible to stop this downward tendency. The heart-beats composing this curve were characterized by their becoming for a time increasingly longer, then gradually shorter, until

the last beat. The frequency was generally diminished from the beginning of the final decline, and if, during this descending curve, the animal executed a respiratory movement, even though it were but a gasp, a very marked alteration in the blood-pressure curve was produced. That is to say, the final descending curve presented the essential characteristics of death from asphyxia.

The preceding remarks apply to the experiments in which normal saline solution at the temperature of the body was given to normal animals in a continuous injection until death occurred. If at any time after a sufficient amount of saline had been administered to raise the blood-pressure to the maximum the animal's foot was burned, or other injury inflicted, an additional rise would follow. This rise, however, was not so high as in the cases in which no infusion had previously been given. It was also observed that chloroform, even the inhalation of a few drops, caused an immediate but gradual fall in the blood-pressure, in many instances the fall being marked. Ether, as a rule, produced no change upon the blood-pressure. The effect of chloroform was the more marked the greater the amount of saline that had been previously given.

As to the effect of administering the saline at different rates of flow, the more rapidly it was introduced the more quickly the blood-pressure reached the highest point in that particular case, but the final height would be the same. When introduced with great rapidity the animal, though under full surgical anesthesia, would respond in a peculiar subconscious way, showing a tendency to struggle.

*The Effect upon the Blood itself.*—On making blood-counts by means of a Thoma-Zeiss instrument before and during the saline infusion a decrease in the number of red cells was usually shown. The blood-counts, however, exhibited a great variation in the different experiments.

In two, they showed an actual increase in the number of red cells, but, as a rule, the number fell, generally about one-fourth to one-fifth. The blood-counts, though very carefully made, in the same experiment at different stages showed varying results, and in some instances after considerable diminution there would be a secondary increase. The blood-count was not proportional to the amount of infusion.

The tendency to clot seemed to increase in the progress of the experiment. This was especially marked in the blood from the liver.

The color of the blood grew darker from the time of the beginning of the final descent of the blood-pressure until death. Earlier its color was lighter red. There was a very marked increase in the tendency to hemorrhage, especially from the small vessels. Wounds made before the introduction of the saline and which had become dry began to ooze soon after the beginning of the infusion. The temperature in many instances was slightly raised.

The foregoing applies to a dog under surgical anesthesia in which normal saline solution at the temperature of the body was allowed to flow into a vein from varying heights and at different rates of flow until death occurred.

*On Respiration.*—The respirations were increased or diminished according to circumstances. If saline was introduced rapidly the alteration both as to increase in frequency and in the amplitude of the stroke was more decided. This increase did not continue, but after a period of time corresponding fairly well with that allowed for the circulatory changes to reach their maximum the respiratory rhythm returned nearly to the normal. As the animal became increasingly under the effect of the infusion, the respirations decreased in frequency, while the amplitude of the excursion increased.

The abdominal factor of respiration gradually diminished until it was lost, and the costal factor alone assumed the burden. This factor soon began to fail,—death ensuing. When once this tendency was inaugurated, it continued until the end. In every instance after the appearance of these phenomena death ensued. There was not even a temporary improvement. During the latter part of this period the extraordinary muscles of respiration were brought into action, the respiration becoming gasping. The respirations always failed before the heart. All the animals died of respiratory failure. The characteristic decline of the blood-pressure curve, referred to under the heading, " Effects upon the Circulation," were inaugurated after respiration had ceased, *pari passu* with the development of the later saline phenomena. Coarse, moist râles of varying intensity developed. They were first heard most distinctly over the pulmonary bases, then over the entire chest, and later could be heard when standing near the dog-board. During this stage of the experiment dulness over the pulmonary bases developed, extending later over other portions. In the greater number of the experiments the tracheal cannula became filled with fluid having a consistency varying from a tenacious to a watery fluid. Sometimes it seemed to consist of bloody serum, at other times of a frothy mucus. In some cases this fluid collected in such quantities as to materially interfere with the respiratory action, making it necessary to tilt the dog-board and turn out the fluid.

*The Effect upon Tissues and Organs.*—There was an increased amount of fluid in the skin. The muscles of the extremities contained a slightly increased amount of fluid and those of the trunk and neck were decidedly more edematous. The connective tissue was more moist than normal and occasionally was emphysematous. The heart was always in diastole, the chambers widely dis-

tended and usually filled with clots. No fluid was in the pericardium. The heart-muscles were somewhat edematous. The venous trunks were everywhere distended, imparting to the touch the sense of a decidedly increased tension. The smaller veins also were distended, especially the mesenteric and the subcutaneous. The capillaries and smaller vessels of the gastro-intestinal tract almost disappeared. In the lungs, underneath the capsule of the kidney, and in the walls of the stomach there was in many cases capillary hemorrhage. The same was noticed, in some instances, under the coverings of the brain. The arterial system was not distended. The portal circulation was greatly engorged.

*Respiratory Tract.—Nose.*—The mucous membrane of the nose was edematous and usually bathed in mucus. During the latter stages mucus discharged freely from the nose.

*Trachea.*—The mucous membrane of the trachea was edematous, being more or less filled with clear, though more frequently a bloody fluid.

*Lungs.*—In almost every instance the lungs were edematous and ecchymosed. The edema and ecchymosis were most marked in the bases, diminishing over other portions. The ecchymosis varied from small points of a diffused color up to an ecchymosis so intense as to resemble the liver. In some instances the bases were extremely dark, soggy, and heavy, and when fragments were thrown into water they floated very low. On incising them, quantities of frothy, bloody fluid escaped, but in some the fluid was quite clear. Frequently fluid was found in the thoracic cavity. This in many instances was bloody.

*The Alimentary Tract.—Mouth.*—The mucous membrane was thickened and edematous. There was free discharge from the mouth consisting of a mixture of

watery fluid and mucus. In some instances there was a free discharge of fluid, probably from the stomach.

The pharynx, esophagus, and stomach were edematous and the mucous membrane was thickened. The stomach in every instance was much distended with watery fluid. The wall of the stomach was considerably thickened, and at times both the mucous membrane and the serous surfaces were pale, though more frequently white. The wall was so edematous that on incising it its histologic layers were to a considerable extent separated and watery fluid oozed from its cut surface. Its cavity was more or less filled with watery fluid.

*Intestines.*—The small intestines were white, their walls much thickened and edematous. On incising them the histologic layers were well separated and fluid oozed from the cut surface. Usually their lumen was filled with watery fluid. The large intestine presented like conditions, decreasing towards the anus. There was free fluid in the peritoneal cavity and in some instances a large quantity. In many of the experiments the intestines were so filled with fluid that it escaped from both the anus and the mouth.

*Liver.*—The liver in every instance was hard and greatly enlarged. On making incisions, large quantities of diluted blood escaped, at times spurting. Even when the incision was made at one point the entire liver decreased in size *pari passu* with the flow, and the hardness disappeared.

*Gall-Bladder.*—The gall-bladder was usually full of bile.

*Spleen.*—The spleen usually contained more fluid than normal.

*Pancreas.*—The pancreas was in most cases enlarged and edematous.

*Urinary Tract.*—The kidneys were but slightly enlarged, and on incising them considerable pale fluid escaped, es-

pecially from the pelves. Occasionally there was ecchymosis underneath the capsule. The ureters were somewhat enlarged. When the experiment was continued for a length of time the urinary bladder was usually extremely distended, but its walls were not thickened. In shorter experiments there was no distention.

*Experiments in which the Abdominal Aorta, including the Splanchnic Arteries, or in which the latter alone, were closed.*—In this series of experiments, in which either the abdominal aorta or at least some of the splanchnic vessels were closed before the saline solution was allowed to flow, death ensued before an equal relative amount of the solution had been given; that is to say, the normal dog could take relatively much more saline than an animal whose splanchnic area had been excluded by closing the supplying vessels. Pulmonary edema developed. The animals died of respiratory failure, the blood gradually becoming cyanotic. In most cases the heart showed the effect of asphyxia by beating more slowly but very strongly. The circulatory phenomena were virtually the same as in the experiments in which the aorta or the splanchnic arteries had not been clamped. The respiratory changes occurred first. On making blood-counts at the beginning of the experiment, it was found that in the cases in which the splanchnic circulation had been modified by clamping one or more of the supplying vessels, the number of red blood-cells was strikingly diminished. This was in marked contrast with the comparatively slight change occurring in the experiments in which such exclusion had not been made.

At the autopsy in this series of experiments no alterations were found in the abdominal viscera. There was no free fluid in the abdominal cavity. Usually the intestines were cyanotic. The stomach, when its blood-supply had been excluded, remained normal, but it was noted in those

cases that there was in the stomach and in the intestines a peculiar dark, bloody, gelatinous fluid which adhered closely to the mucous membrane. The walls of the hollow viscera were not thickened as in the other experiments. In comparison with the fore extremities, the hind were quite dry. The heart was pale, the pericardium containing some fluid. The heart stopped in diastole; the chambers were filled with diluted blood and there was considerable pressure in the aorta. In almost every instance the lungs were extremely edematous, much more so than in the experiments in which the splanchnic blood-supply had not been excluded. Death in every instance was due to asphyxia, as in the first series.

*Effect of Varying Height of the Saline Column.*—A series of experiments was also made upon the effect of allowing the solution to flow from different heights. It was found that increasing the height of flow usually raised the blood-pressure. Great irregularity was noted in the change in blood-pressure. In some instances there was but a slight rise, in others considerable. In the same experiment, at different times, the rise in the blood-pressure might not be equal to that produced by an elevation made earlier or later; that is to say, there was no direct ratio between the elevation and the rise in the blood-pressure, neither was there any ratio between the rise and the amount of saline the dog had received previous to the elevation of the bottle.

*Some Drug and other Effects.*—After a considerable amount of saline had been infused, the inhalation of chloroform, even in small dosage, produced a very marked depression upon the circulation.

Upon the administration of strychnin or nitroglycerin, their usual physiologic action was noted, though to a lesser degree.

Thermal, electrical, and mechanical stimulation of the

tissues produced the usual effects,—*e.g.*, burning or crushing the paw caused a rise in blood-pressure and an increased respiratory rhythm ; manipulation of the larynx, a reflex inhibition of the respiration and the heart, etc.

*Effect of Varying Temperature, etc.*—No matter what the temperature, the effects were eventually about the same. When the solution was cold, the heart-beats were diminished and the strokes became longer. Frequently at the beginning there would be a fall in the blood-pressure, after which in many cases the usual rise observed in all saline infusions would occur. If the lost pressure was not regained during the flow, it was immediately on cessation of flow, with a return to the previous rapidity and length of strokes. Hot saline produced the opposite effect,— viz., an increase in the rapidity and a diminution of the length of the strokes, with a rise in the pressure. On cessation of the infusion the strokes would resume their former rate and length and the blood-pressure would fall to its previous level. The results then were ultimately almost alike. Even extreme variation in the temperatures of the solution produced but minor alterations in the temperature of the body. The effects of saline infusion were almost wholly mechanical and physical,—within a reasonable range they were independent of variation in the temperature, the rate of flow, the height above the animal, and the vein into which it was introduced. The mechanical factor consists in adding the force of the infusion to the force of the venous blood-stream which raises the venous pressure, thus increasing the output of the heart. The amount of the output has been proved to be dependent upon the venous blood-pressure.

One of the reasons why the infusion did not raise the pressure indefinitely was the escape of the solution from the circulation at a rate corresponding to the rate of the infusion. The escape occurred principally through the

structures that normally absorb fluids,—viz., the gastro-intestinal tract, to a much less extent through the mouth and respiratory tract, and still less into the tissues of the somatic area. The rate of escape of the saline solution through these channels almost equalled any rate of intro-duction we were able to devise. This was substantiated by numerous blood-counts, showing that after a certain dilution had been reached the count remained about the same. A secondary increase of blood-corpuscles was shown, although an enormous amount of saline was in-troduced during the observations, but in the experiments in which the splanchnic area had been previously ex-cluded, by closing the splanchnic vessels, the dilution increased *pari passu* with the flow, strikingly diminishing the number of red blood-corpuscles. In these cases, the broncho-pulmonary tract eliminated larger quantities than it did in the experiments in which the "leaky" gastro-intestinal tract had not been excluded.

It might be supposed that in the experiments in which the great channel of elimination—viz., the gastro-intesti-nal—had been excluded by closing the supplying vessels the blood-pressure would be raised higher than in the other experiments, but this was not observed. Neither was it found that the administration of an excessive amount of saline materially interfered with the response of the heart or the vasomotor mechanism to stimuli, as proved by the reflex inhibition from laryngeal manipula-tion, or crushing and burning the paws, by the adminis-tration of strychnin and nitroglycerin, as well as by the compensation that occurred on tilting the dog-board.

CONCLUSIONS.—The foregoing applies to the normal dog under surgical anesthesia. In experiments in which the blood-pressure had been lowered by a reasonable hemorrhage alone, saline infusion promptly restored the lost pressure. If the pressure had been lowered by the

exhaustion of the vasomotor nervous system by afferent impulses set up from injury of the cerebro-spinal or the sympathetic nervous system, the infusion would restore the pressure in proportion to the vasomotor exhaustion ; that is to say, normal saline solution is effectual in shock in proportion to the impairment of the vasomotor mechanism. If this mechanism has gone into resolution, infusion is without curative effect. If the impairment is considerable, the infusion will partially restore the pressure, etc. Taking into consideration all the facts, the reason why the blood-pressure is raised but little, if at all, higher than the normal is due to the rapid escape from the vessels and the action of the automatic mechanism in the medulla, which when the pressure rises above the normal diminishes the force and the frequency of the heart-beats and lessens the vasoconstriction in the area of peripheral resistance to reduce the pressure to the normal level. The peripheral resistance determines the height of the blood-pressure, no matter how swift the stream nor how great the volume of blood. The limitations of the effect of normal saline infusion must now be apparent. If the peripheral resistance is lost (break-down of the vasomotor mechanism ; that is to say, fatal " shock"), no amount of infusion can do more than temporarily or partially restore the lost blood-pressure, and death is inevitable. If the shock is much increased by regional accumulation of blood (so-called intravascular hemorrhage), as in operations on the splanchnic area, infusion may be effective because the peripheral resistance is still present ; that is to say, the vasomotor mechanism has not gone into resolution. If hemorrhage complicates shock and the vasomotor mechanism is still intact, infusion is effectual. Such propositions may be multiplied.

The foregoing deductions explain why injuries of the somatic area, such as mangling of limbs in railway acci-

dents, are frequently but little, if at all, benefited by saline infusion. It is true that in almost every case an artificial pulse may be produced, even a pulse of considerable volume, but it is without resistance. It will disappear almost as quickly as it came, and no amount of infusion will sustain the circulation in such a case because the vasomotor mechanism has gone into resolution, destroying peripheral resistance, hence no blood-pressure can be created.

ILLUSTRATIVE CASE (*Abstract*).—Brakeman, aged twenty-five, in previous normal health, as proved in autopsy, was thrown under the trucks of a railway-carriage, losing both legs above the knee. There was considerable hemorrhage.

*Circulation.*—Pulse, 152, small volume, rhythmic, slight tension. Nails, bluish; small superficial veins of chest and abdomen prominent; blood-vessels of the lips and face distended and of venous color, giving a " cyanotic pallor;" pulsation in the neck marked, indicating toneless vessels; surface moist and cold, presenting bluish tinge.

*Respiration.*—Rate, 39; inspiratory phase quickened and shortened; expiratory phase, relatively lengthened; pause increased; extraordinary muscles in light action; slight rhythmic movement of the larynx and alæ nasæ.

*Nervous System.*—Mind clear and alert; special senses acute; complains but little of pain; is restless and begs for water.

*Discussion of the Physiologic State.*—The massive mechanical irritation and exposure of the nerve-endings and nerve-trunks produced an excessive action of the vasomotor and cardiac centres, especially the first, leading to exhaustion. Proportionately to the degree of exhaustion the " peripheral resistance" is diminished. Proportionately to the diminution of peripheral resistance the general blood-pressure is lowered and the venous return

diminished.    Proportionately to the diminution of the venous return the output of the heart is diminished, and proportionately to the diminished output of the heart the volume of the pulse and the general blood-pressure is diminished.    This "toneless" state of the vascular system, then, is due to the loss of "peripheral resistance," which in turn is due to the exhaustion of the vasomotor mechanism, which is due to the excessive stimulation, owing to massive mechanical irritation of the nerve-supply of the lower extremities, by the wheel of the car.

In this toneless state the larger arterial trunks are relatively empty, so that the blood thrown into the arterial trunks with each contraction of the heart produced a high but short wave accounting for the marked pulsation in the arteries of the neck; the wave, then, when it reaches the extremities (e.g., radial pulse) is proportionately diminished or lost, is abrupt in ascent, is not sustained, and has proportionately lost its resistance. The capillary circulation is correspondingly diminished, producing the pallor which, together with the loss of heat by perspiration, produces the cooling of the skin.    The diminution of the capillary pressure proportionately lessens the venous flow, thereby causing an accumulation of blood upon the venous side, which accounts for the prominence of the small superficial veins and the bluish tinge of the skin,—"cyanotic pallor."    The acceleration of the blood-pressure is reduced, the heart-beat is increased in frequency and in force; and, other things being equal, when its intake is diminished it beats with increased force and frequency.    (There are many important questions that this discussion has opened, but as they are not pertinent to our present inquiry they will not now be discussed.)

The respiration is increased in frequency in accordance with a well-known law governing its automatic centre,—

viz., the diminution of oxygen in the blood causes an
increased respiratory action, and when the blood reaches
a certain degree of cyanosis the extraordinary muscles of
respiration are brought into action whether obstruction is
or is not present. There being no obstruction present
and the extraordinary muscles having no resistance to
overcome, their work is so light as to give but little evi-
dence of their action,—the inauguration of their action
being rather an indication of the degree of cyanosis,
which in turn indicates the degree of circulatory failure.
The amount of blood under these conditions actually cir-
culating through the lungs is proportionately diminished,
which would be in effect a hemorrhage, an intravascular
hemorrhage. The effect upon the respiratory mechanism
is essentially the same as in an actual external hemor-
rhage. Owing to diminished nutrition and excessive
action the respiratory mechanism becomes fatigued, the
earlier indications being an increased pause and a quick-
ened inspiratory phase. During twenty minutes two
thousand cubic centimetres of normal saline solution at
100° F. was infused into the median basilic vein (other
features of the case will not be discussed). The pulse
was reduced in frequency to 124. The volume was fully
as large as normal, the ascent of the wave was abrupt,
the fall equally so. The tension remained low. Patient
perspired freely and was less restless. Cyanosis dimin-
ished. Superficial veins remained about the same. The
pulsations of the neck were more marked than before.
The patient was not so restless. There was an improve-
ment in most of the symptoms, but what of the vaso-
motor system ? The ascent and descent of the wave was
as sharp as before. There was enormous increase in the
volume but only slight in tension. The arterial trunks
in the neck oscillated even more than before. The super-
ficial veins were even still more prominent. The skin

continued to have a "cyanotic pallor." These several phenomena show that the vasomotor impairment and impending break-down still existed. Though a large pulse was artificially created the patient's chances for recovery were virtually what they were before. The effects of the saline solution gradually passed away, and an hour later another saline infusion of fifteen hundred cubic centimetres was given. This time the effects were not so marked and were less sustained than in the preceding. All of the symptoms rapidly grew worse and the patient died at the end of four hours. After the first infusion had been given oxygen was administered. During the administration the respirations were diminished in frequency and the cyanosis was lessened. The participation of the extraordinary muscles of respiration was diminished. This discussion has been extended for the purpose of defining a well-marked and fairly characteristic group in which saline infusion is of but temporary aid and in which it does not alter the essential conditions present. The vasomotor break-down is an impairment that cannot be relieved by saline infusion.

Drugs are equally ineffective in these cases for the same reason that although the heart may be stimulated, there being no peripheral resistance, no blood-pressure (pulse) can be created, and death is inevitable. Drugs having action upon the vasomotor mechanism are equally powerless, because this mechanism having become exhausted, it cannot respond. This also gives a clear reason for the benefits of infusion in cases of hemorrhage alone or hemorrhage with shock, by restoring the normal volume of fluid and adding force to the venous stream.

In "shock" (vasomotor impairment,—*i.e.*, lowered peripheral resistance) the benefit is due to the force added to the venous circulation. The venous pressure falls *pari passu* with the diminution of the peripheral resistance

(vasomotor impairment, shock), so that the saline infusion supplies to the venous pressure force which the decreasing peripheral resistance does not ordinarily supply. It must be borne in mind that the output of the heart is wholly dependent upon the venous pressure; that is to say, the infusion may merely tide over a circulatory crisis during which other means for restoring the circulatory equilibrium and tone must be employed. In cases of dangerous hemorrhage the combination of oxygen inhalation with infusion is beneficial, because the reduction in the number of corpuscles so diminishes the amount of oxygen carried, that it should be supplied in concentrated form, which, by virtue of the law of diffusion of gases, increases the volume's per cent. of oxygen in the blood.

## ON THE PHYSIOLOGIC ACTION OF COCAIN AND EUCAIN WHEN INJECTED INTO TISSUES.

*Review of Literature.*—Cunningham, in a series of experiments on the Physiologic Action of Cocain on the Lower Animals and Man, concludes that cold-blooded animals are much more susceptible than warm-blooded animals. Experimenting on a frog's heart, he found that on the application of cocain the heart became slower and more forcible, the force of the pulsations diminishing until the action became so feeble that the heart was arrested in diastole. On making observations on the tongue of a frog to determine what effect both injection and local application had upon the calibre of the vessels, he found that by the former there was little or no effect, but applied locally there was a distinct contraction of the vessels. Upon respiration there was an immediate increase in the frequency, and the respiratory phase was deepened. Larger doses after a short increase of respiration produced a great decrease with difficulty of breathing. Respirations were variously altered, and in an overdose

they were arrested. Upon the nervous system, small doses were found to increase reflex irritability of the cord, and large doses shortened the period of heightened reflexes and decidedly diminished reflex action. Administered hypodermically to dogs, they grew excited, and if the dose was rather large the whole demeanor of the animal was changed. They did not seem to recognize the persons around, becoming restless and trembling violently. There were continual pendulous movements of the head, the pupils were dilated, and the skin quite hot. After fifteen or twenty minutes this condition suddenly changed to a state of measurable excitement. Later muscular weakness became apparent and the animal grew feeble. This finally wore away. Small doses caused an acceleration of the heart, the pulse in some cases becoming three times that of the normal. The heart usually continued to beat after arrest of respiration. Blood-pressure was raised in medium doses, and in large doses, after a temporary rise, there was a rapid fall, almost to the zero point. Medium doses provoked movements of the small intestines, and increased those of the large intestines.

Giuseppe Cepriani, on experimenting with cocain, found that when blisters were applied and the skin divested of its epidermis and subjected to an application of cocain, complete anesthesia followed. On injecting two per cent. solution of eucain, there occurred in a short time slight complications,—viz., hurried respirations, lessening of heart contractions, and finally decrease of general sensation and motion. In all experiments the author was able to demonstrate that eucain completely paralyzed the nerves of sensation and lessened the excitability of motor nerves.

Verebily and Horvath made an investigation into the effect of local anesthesia upon tissue structure, especially the terminal filaments of the nerves of sensation.

It was found that the connective-tissue envelope of the corpuscles of Herbst were of sharp contour, of compact appearance, and intensely tinged, whereas that covering the normal corpuscles was scarcely to be distinguished from the circular fibres of the surrounding tissues and showed a looser fibre. The circular fibres of the surrounding ground-tissue showed, departing from the normal picture, a loose "joining," and presented an appearance suggesting that they had become separated by pressure and removed from each other as a result of their own elasticity. The corpuscles showed themselves by a higher power to be composed as follows : the peripheral lamellæ were retracted from the membrane and envelope, and the central closely adherent to one another. In the neighborhood of the puncture all the Herbst corpuscles were altered. The altered corpuscles formed a circle above the point of puncture, which from the stand-point of physiologic working he would name "anesthetic cicle."

The Vater Pacini corpuscles showed, both in the material treated according to Benz as also in the sections which were taken from the cocainized material of cats, the following : the contour of the corpuscles were irregularly nitched ; the lamellæ run parallel with the envelope, were separated at many places and a little swollen and nitched. The corpuscles were in general smaller, the inner knob or nucleus and the nerve-fibres were sharply defined and unchanged. The entire process which brought these changes about they could observe directly upon examination of fresh material. In three or five minutes after the cocainizing the contour of the corpuscles became irregular and contracted, while at the same time they seemed to draw to them the surrounding loose connective tissue. Application of cocain then shows that Herbst corpuscles of duck-bills, as also the Vater Pacini corpuscles of the mesentery of the cat, undergo anatomical changes. The

causal connection of the cocain is proved by the fact that the metamorphosis resulted only in those places where cocain had worked, and constantly there. These changes they saw in the periosteal and superficial layers lying under the latter,—in places therefore where the anesthesia could easily reach. The anatomical changes were, in short: (a) Mild grades: envelope sharply defined; body in both diminished in size; envelope elevated from ground-tissue; lamellæ separated from envelope and nearer each other. (b) Changes of stronger degree: the envelope everywhere elevated is disposed in deep irregular folds and entirely retracted; lamellæ closely adherent show an irregular course, but parallel with the envelope; inner nucleus and nerve unchanged, perhaps a little flat; between the bodies and circular fibres of ground-tissue a wide gap is formed; circular fibres separate from each other and relaxed. (c) No changes observed in the Gandry corpuscles; the coloring capacity of tissue and corpuscles normal.

Charles Netzberg reviews the subject. Eucain was discovered by Merling in 1896. It was found to produce hyperemia of the tissues with the invasion of the wound by blood, while cocain, on the contrary, is a vasoconstrictor. Pouchet believes that the toxic qualities of eucain are equal to that of cocain, and that the effects produced by eucain are more sudden and pronounced. Vinci holds that eucain is less toxic than cocain.

Dr. L. Poplieski, in experiments performed in 1896 to determine the changes in conductivity and excitability of nerves under the influence of cocain, concluded that the conductivity is proportional to the strength of the current. He found that the excitability was diminished by applying a strong solution to the vagus, then stimulating it above that point, the blood-pressure was not effected, but upon applying it below the point of applica-

tion of cocain, blood-pressure was lowered. He also found that on cocainizing the vagi the blood-pressure was raised, as in cases in which the vagi had been severed. After convincing himself that irritation of the chorda tympani produced copious salivary flow, he painted the nerves with a five per cent. cocain solution. After one minute the irritation with a certain strength of current produced no secretion, but the secretion occurred when the strength of the current was increased. After two minutes no secretion occurred after the application of the stronger current.

Professor B. Damlewsky, in experiments carried out upon various kinds of invertebrate animals, arrived at the following conclusions,—viz., that cocain was an active anesthesia for all animals, being a general protoplasmic poison ; that the general physiologic action of cocain is more pronounced upon the highly organized animals ; that strong concentration of cocain was shown to have a paralyzing action upon pure contractile structures, and that the return of the function after this shows that the paralysis was not necessarily connected with the destructive operation upon the protoplasmic structure.

F. A. J. N. Hernette, investigating the subject of eucain, arrived at the conclusion that the toxic properties of this drug are about the same as those of cocain.

Von Anrep and Danini conclude that the reflexes are heightened only after small doses of cocain. From medium doses even they were paralyzed. Respirations, according to Von Anrep, are hurried, later slowed. The heart-beat is quickened by cocain, due to irritation of the accelerating apparatus, and the blood-pressure is elevated. In toxic doses it is lowered.

Rosenthal believes that large doses of cocain lowers the blood-pressure.

Berthold concluded that an injection of weak solution

caused a sinking followed by a short rise of pressure, then a return to normal. After moderate doses, diuresis. After injection of cocain and after large doses there was a decrease of urine.

The temperature effects were studied by Mosso, Danini, Nekolky, Von Gurep, Reichert, and others, who were agreed that there was a rise in temperature after the injection of cocain. On applying this drug to the nerve-fibres there is direct paralytic effect upon the peripheral nerves, first on the sensory and later on the motor fibres. The action of cocain extends in centrifugal direction.

Tumass, on the other hand, could cut through the femoral nerve at a point touched by cocain without pain, but could not convince himself of the extension of the anesthetic to places not touched.

Professor Gennaro Scoguamiglio, after a research to determine the relative effect of eucain, concludes that anesthesia is more marked and lasts longer than from cocain. It was found that on all experiments on small animals the lesser poisonous action of eucain was manifest.

Professor Charteris, in a series of experiments on the physiologic action of eucain and cocain, concludes that the lethal dose of eucain per kilogram of body-weight was 0.09 gram, and the lethal dose of cocain per kilogram of body-weight was 0.068 gram. He also found that the mode of death by the two substances varied. With cocain there were more rotary movements of the head, more opisthotonos, more salivation, and more labored breathing than with eucain, while the action of eucain is slower in the onset and less in intensity.

Biggs, in a lengthy article on the physiologic action of cocain, concludes that it is a powerful local anesthetic; that it has a depressant action on the heart; that in small doses it increases respiratory action, then decreases them; that large doses diminish this action

rapidly from the first ; that it first heightens then greatly depresses the reflex action of the spinal cord ; that it has a depressant action on the motor nerves with a paralysis of the vagi ; that it diminishes the excitability of the sciatic nerve ; that applied to any of the more highly constituted organs or tissues it causes cessation of their function.

Von Eecke, after a series of carefully conducted experiments, concludes that the hydrochlorate of eucain produces in the frog successively excitation, convulsions, and paralysis. The lethal dose is 0.16 per kilogram. In warm-blooded animals eucain produces sometimes excitation, sometimes convulsions, finally death by asphyxia. The organism may accommodate itself to increasing doses. Intracardiac centres of the heart were paralyzed by eucain, and the function of the muscle of the heart was diminished. It excites directly the bulbar respiratory centre and in large doses paralyzes it. Eucain increases diuresis.

François Frank has studied the paralytic action of cocain upon nerves and nerve-centres, finding that loss of activity of nerve is complete and loss of conductivity equal to section. This effect does not extend more than one to two centimetres above or below the zone placed in contact with the cocain. Injecting cocain in the sheath of the vagus produced sympathetic paralysis of the nerve.

Vinci, after a series of experiments, compares the local action of eucain and cocain as follows : duration and intensity is the same for both ; while cocain is ischemic in action, eucain congests the conjunctiva. In warm-blooded animals, the toxicity of eucain is less than that of cocain.

*Protocols.*—*Eucain and Cocain in Two per Cent. Solution.*—1. April 11, 1897.—Frog. Injected twenty minims of two per cent. solution of cocain underneath the skin of the back. In less than a minute muscular weakness was noticed in all the limbs, and in three minutes the animal died. Respiration ceased first. The heart beat

on rhythmically for some time after the failure of the respirations.   Cocain was injected into the pericardium, coming into contact with the beating heart with no effect upon the beat.   Some solution was then injected into the circulation.   At first there was no effect.   Later the heart beat more slowly, then stopped.   The sciatic nerve responded to electrical stimulation after the death of the animal.   The injection of cocain " blocked" such stimulation.   Eucain was substituted for cocain in "blocking" the alternate side.   It was as effectual as the cocain. There was complete muscular paralysis.

2. April 15, 1897.—Frog.  First, injected fifteen minims of two per cent. solution of eucain into the skin over the back of the frog.   The frog died before the expiration of the third minute.  Respiration failed first.  There was complete muscular paralysis after the injection of the solution.

Second, injected the sciatic nerve with two per cent. of the same solution.

Third, applied the electrodes of the Dubois-Reymond coil.   No muscular contraction was produced.   Applied the electrodes below the eucain "block" and sharp contractions followed.

Fourth, injected the opposite nerve with normal saline solution as a control.   Application of the electrodes caused sharp contractions.

Fifth, on applying them below the "block" the contractions were of equal vigor.

Sixth, moistening both nerves, one with saline solution and the other with eucain, and the electrodes applied to each, resulted in sharp contractions of the "saline leg;" —no contractions in the "eucain leg."

Seventh, applying a powerful current above the "block" caused some muscular contractions.

Eighth, injected cocain into the spinal cord in two

per cent. solution, after having made a control by inject-
ing normal salt solution, and finding that impulses were
not "blocked" and applying the electrodes, the eucain
"block" was found to be effectual.

3. April 15, 1897.—Dog; weight, twenty-one pounds,
young, lank, and playful. The object of the experiment
was to test the effect upon the afferent impulses con-
stituting sight. The animal was selected on account of
his being playful and active. Cocain was dropped into
both eyes. After a few minutes a long hypodermic
needle was passed into the conjunctiva at the inferior
angle of the eye. Step by step a painless path was co-
cainized to the posterior portion of the globe and con-
siderable quantity of solution injected, as near the optic
nerve as possible. While injecting the first eye slight
pain was caused, but in the second there was none. The
animal was then allowed to run about the laboratory.
At first he was exceedingly playful, then became rather
uncertain, appearing doubtful in his movements. An-
other injection of five minims of two per cent. solution
was injected in each orbit. This so impaired the sense of
sight that he was afraid to follow when called. He could
avoid the tables, but could not locate us at a distance.
When placed upon a table he was unable to assure him-
self of the safety of leaping down, though he had play-
fully and willingly done so several times previous to the
injection. We were finally obliged to lift him to the
floor. He then became staring, and when called would
look around wildly, apparently bewildered. He seemed
to have some muscular weakness and to have partially
lost the sense of sight. The effects passed off, however,
leaving no appreciable effects.

4. *Eucain and Cocain Experiments, each in One per
Cent. Solution.*—A middle-aged dog was reduced to sur-

gical anesthesia with A. C. E. mixture; a mercurial manometer was attached to the carotid artery. Eucain was injected into the sciatic nerve and the corresponding anterior crural was severed. Previous to this experiment a control had been taken by applying a Bunsen flame to the paw, which produced a rise in the blood-pressure and the usual contraction in the muscles of the leg, constituting a drawing away of the paw from the flame. On applying the flame to the paw after a solution of eucain had been injected into the sciatic and the anterior crural had been severed there was neither a rise nor a drawing up of the foot. On the opposite leg a similar experiment was performed by injecting cocain of the same strength, and on applying the flame the "block" was found to be complete. Neither muscular contraction nor alteration in the pressure was noted. In neither case was there respiratory change. Neither was there any change in the rhythm of heart-beat as represented by the tracings. The nerve-trunks were then isolated on both sides and the electrode applied above the " blocks." In the eucain and the cocain experiments there were no muscular contractions as a result of such stimulation, though the heart and the respiration were both affected in the usual way. As a control the brachial plexus was exposed and the electrode applied, causing a sharp contraction of the corresponding muscles. The vagi were then isolated and the electrodes applied, which produced inhibition of the heart and of the respiration. After securing this vagal control, a solution of eucain was injected into the right vagus and cocain into the left. Applying the electrode above the " blocks" produced no effect upon the heart in either case, but the respiration was again affected. On applying similar blocks above the points of stimulation and reapplying the electrodes, no effect was produced.

5. Eucain experiment.    April 21, 1897.—A cur dog, weighing fourteen pounds, was subjected to the following experiments :

First, the spinal cord was exposed and the electrode applied just above the lumbar enlargement.    This produced violent contractions of the lower extremities.

Second, a quantity of normal saline solution was injected under the membranes and the stimulation reapplied as a control.    The muscular contractions were as vigorous as in the first instance.

Third, injected a sufficient quantity of one per cent. solution of eucain into the cord, and after a few minutes applied the electrode above this block.    No contraction followed.    Allowing the animal to recover from the general anesthesia, he was found to be paralyzed in both hind extremities and unable to walk.    There was paralysis, both motor and sensory.    The animal was then given two drams of the one per cent. eucain solution, soon producing death by respiratory failure.

6. Eucain experiment.    April 14, 1897.—Healthy adult cat was placed under surgical anesthesia by thrusting its head into a Mason jar in which a piece of cotton, saturated with A. C. E. mixture, had been placed.

First, the medulla was exposed by making a median incision and cutting away the skull at the base.    On exposure some cerebrospinal fluid escaped.    Some normal salt solution was dropped upon the medulla.    This produced no effect upon the blood-pressure, the heart, or the respiration.

Second, an equal amount of two per cent. solution of eucain was then applied.    At the expiration of one minute the abdominal factor of respiration was abolished, but the costal remained.    The respiratory rhythm was much increased, becoming very shallow.    The excursions be-

came more and more shallow, ceasing at the end of five minutes. The heart continued in slow and regular beats until death.

7. Eucain experiment. April 21, 1897.—Large cat was placed under A. C. E. anesthesia, the medulla was exposed by the same method as in the preceding. An injection of normal salt solution was then directed into the medulla. No alteration upon the respiration, the heart's action, or the blood-pressure was noted.

Second, a few drops of two per cent. solution of eucain, injected in the same manner, rapidly diminished the amplitude of the respiratory stroke and increased the rapidity. The respirations soon failed and artificial respiration was supplied.

Third, the spinal cord was then exposed, into which a solution of normal saline was injected. The electrodes were then applied, causing vigorous contraction of the muscles.

Fourth, a one-half per cent. solution of eucain was then injected into the cord just below the point of injection of the salt solution, and upon immediate application of the electrode a considerable amount of muscular contraction was produced. After six minutes had elapsed there was but a trifling amount of contraction on strong stimulation. In eight minutes the "block" was complete.

Fifth, solution was again injected into the fourth ventricle. The respirations failed as before. Artificial respirations were supplied, and upon burning the paw with a Bunsen flame no effect was noted upon the circulation, and the foot was not drawn up.

8. April 21, 1897.—Eucain experiment in one-half per cent. solution. Under A. C. E. anesthesia, the testicle was

subjected to a considerable crushing, which produced a fall in the central blood-pressure.

Second, a solution of eucain was injected into the organ and into the spermatic cord.

Third, on repeating the experiment no fall in the blood-pressure occurred.

Fourth, the opposite side was subjected to a similar experiment, and though at first the block was not complete, at the end of eight minutes no amount of violence produced any effect upon the circulation or respiration.

Fifth, on applying marked mechanical stimulation upon the laryngeal mucosa there was a temporary arrest both of the heart's action and the respiration.

Sixth, this same area was then brushed over with a two per cent. solution of eucain and subjected to a like manipulation, which before was attended by respiratory and cardiac inhibition. After seven minutes had elapsed the manipulation was again applied to this area, but no effect upon either the heart or respiration was noted. The dog exhibited some convulsive action in a later manipulation. One dram of a two per cent. solution of eucain was then injected into the jugular vein. No effect was produced.

9. April 22, 1897.—Eucain in one per cent. solution. A half-grown kitten under A. C. E. anesthesia was subjected to the following experiment. The fourth ventricle was exposed, and in so doing there was a considerable loss of blood. The animal began to gasp, and a speedy death was threatened. An injection of the eucain solution in the fourth ventricle quickly abolished the remaining respiratory effort. The animal was too young to be of much value in the experiment, so was allowed to die.

10. April 24, 1897.—Eucain in one per cent. solution. A large adult cat was subjected to experiment upon the

spinal cord as described in the preceding, yielding similar results, and on exposing the fourth ventricle the animal was so much reduced by the dissection as to be unfit for a satisfactory experiment.

11. April 24, 1897.—Dog.   Blood-pressure and respiratory action recorded as in the preceding.   After complete anesthesia had been accomplished, on injury of the testicle there was a marked fall in the blood-pressure.

Second, injecting fifteen minims of eucain solution into this organ and repeating the experiment, after the lapse of five minutes, no effect was noted.

Third, severe manipulation of the larynx produced a temporary arrest of both the heart and respiration.

Fourth, on applying a two per cent. solution of eucain upon the mucous membrane of the larynx, then repeating the former manipulation, after a lapse of five minutes, no inhibition was produced.

Fifth, the fourth ventricle was exposed and a considerable quantity of the solution placed within it by means of a hypodermic needle.   Before one minute elapsed respiration was markedly slowed and their excursions diminished, while at the end of the second minute it had wholly ceased.   Artificial respiration was then supplied.   It was found that the corneal reflexes of both eyes had been lost.   On withdrawing the ether the animal was found to be under total anesthesia from the effect of the eucain in the fourth ventricle.   The animal was kept alive twenty-four minutes, during which time no general anesthetic was inhaled.   Complete general anesthesia was maintained by dropping eucain into the fourth ventricle from time to time.   Motor paralysis was also complete. The pupils were widely dilated.   The blood-pressure suffered a marked decline after the first application of the eucain.

12. April 25, 1897.—An adult dog, weighing twenty-four pounds, under A. C. E. anesthesia was subjected to the application of a two per cent. solution of eucain in the fourth ventricle as in the latter part of the preceding experiment. Immediately following the application there was a gradual decline in the blood-pressure and a failure of the respirations. The entire animal was anesthetized by the eucain alone, the ether having been withdrawn. The corneal reflexes disappeared, the pupils dilated, and muscular power was wholly lost. The abdominal feature of the respiration first disappeared, later the costal.

13. April 25, 1897.—A. C. E. anesthesia. Experiment upon the cortex of the brain. Uncovered the dura mater over the motor area and applied electrodes, but there was no response. Eucain was then injected into, or rather under, the dura mater, after which both hind paws were burned, both legs moving equally in consequence of the burning. The animal died of respiratory failure.

14. May 4, 1897.—Experiment upon the ventricle with cocain. Cur dog. The fourth ventricle was almost bloodlessly exposed, and a stream of normal salt solution was directed upon it. This produced no effect. A few drops of four per cent. solution of cocain were then placed by means of a hypodermic syringe upon the floor of the fourth ventricle, which rapidly abolished respiratory action. Ether was removed after the application of the cocain. The heart-beat was not affected, but the blood-pressure declined. After twenty-one minutes natural respiration was again resumed, soon becoming vigorous. The first intimation of the recovery of respiratory action were small twitchings, and the animal soon showed signs of coming out of the anesthetic. The floor was re-cocain-ized, and again the animal was rendered completely

anesthetized, respiration ceasing.    During this time no general anesthetic was administered.    The latter was removed after the first effect of the injection of cocain. In the first application the blood-pressure declined greatly though steadily.    The animal was kept alive by means of artificial respiration for fifty-four minutes, when finally the heart was allowed to run down without respiratory aid.    The heart-strokes did not become so extremely long and sweeping as usual in the state of asphyxia.    There were but few cardiac intermissions.    On applying Bunsen's flame to the feet they were not drawn up.    The corneal reflexes were abolished.

15. May 4, 1897.—Black cat.    A. C. E. mixture, two per cent. solution of eucain in fourth ventricle.

The application of a few drops of eucain upon the fourth ventricle arrested the respiration and produced a great decline in the blood-pressure.    Artificial respiration was maintained.    Corneal reflexes were abolished. A. C. E. removed.    Total anesthesia was maintained almost an hour by dropping a solution of eucain into the ventricle.    On burning the paws the foot was not contracted.

16. May 5, 1897.—Cat.    Eucain experiment upon the medulla.    A few drops were placed upon the fourth ventricle.    No aid was given the animal.    It died of respiratory failure.

17. May 6, 1897.—Healthy mongrel. Cocain. Medulla experiment.

Fourth ventricle was exposed.    The animal was then allowed to come out of the influence of the general anesthesia sufficient to make a slight struggle.    Cocain was applied upon the floor of the fourth ventricle, at first only a few drops.    The respirations became less fre-

quent and irregular but did not cease. The feet were burned just previous to the application of the cocain and both the blood-pressure and the respiration were increased. More cocain was then applied; the animal became totally anesthetized and the respirations ceased. The corneal reflexes were abolished, the pupils became widely dilated, and on applying a Bunsen flame to the paws no effect was produced upon either the respiration or the circulation. Neither was there exhibited the usual drawing up of the corresponding leg. The first intimation of the resumption of natural respiration was a slight twitching of some of the respiratory muscles, after which shallow, then full, respiratory action appeared. Cocain was again applied high up, following which there was an extraordinary acceleration of breathing, the respirations becoming as rapid as the heart-beat, an almost incredible rapidity. The heart continued to beat for some time after respiration ceased.

18. May 7, 1897.—Spaniel dog. The same line of experiment was conducted as in the preceding. The effect of the application of cocain was not so marked and the respirations were not entirely abolished.

19. May 7, 1897.—Mongrel dog. Medulla experiment with cocain. Results the same.

20. May 10, 1897.—A large strong dog was under ether anesthesia until the exposure of the medulla, when he was maintained an hour and a half under general anesthesia by applying a few drops of two per cent. solution of cocain every ten to twenty minutes. The blood-pressure suffered a great decline after the first application. In the subsequent applications the decline was approxi-

mately equal to the extent to which it had meanwhile risen from its lowered position.

21. May 12, 1897.—Cat, under chloroform anesthesia. The medulla was exposed by cutting the membrane between the first cervical and occipital bones. Through this opening a few drops of two per cent. cocain was injected directly into the substance of the medulla. Respiration ceased almost instantly and the blood-pressure suffered a very great decline. Twitchings of the respiratory muscles soon appeared, followed by shallow, then stronger, respirations. Further application of cocain upon the medulla was not followed by complete arrest, but by injecting the solution into the substance of the medulla complete arrest was secured, the paralysis being motor as well as sensory.

22. May 13, 1897.—The preceding experiment was repeated, the animal being kept under total anesthesia for an hour and a half by dropping at intervals a solution of cocain upon the medulla. All of the observations previously mentioned were again noted. Several times the animal was allowed to sufficiently come out from the influence of the anesthetic to struggle on the dog-board. Each time the application of the cocain promptly reduced it to complete general anesthesia.

23. May 16, 1897.—The various points in the preceding experiments were carried out by employing a one-half per cent. solution of eucain. While the effects were in the main the same, they were neither so prompt nor so decided.

24. Cocain experiment. April 6, 1897.—Frog. The animal was pithed, then a nerve-muscle preparation made without severing the thigh. Both sciatic nerves were isolated. Normal salt solution was injected into the right sciatic and a four per cent. solution of cocain into the

left. Both were faradized, proximal to the points of injection, with the same current supplied by a Dubois-Reymond coil. The cocainized nerve responded with a slight muscular twitching and the "salt" nerve with a marked contraction. The former twitching was observed only when the under surface was laid upon the electrode. This portion was then injected and the stimulation reapplied. No contraction then appeared. The application of the current in this experiment was made immediately after the injection. Applying the electrodes to the nerve below the "block" caused strong contractions. The spinal cord was next exposed and a normal saline solution injected under the dura mater. The cord was then faradized above the saline block. This was attended by a contraction of all the muscles supplied by this portion of the cord excepting those that had been blocked by injecting the cocain into the sciatic. After securing this control, a solution of cocain in smaller quantity than the saline solution used in the control was injected in the same area. On the application of the electrode to the cord above the block no muscular contractions were produced.

25. April 7, 1897.—Adult white cat was reduced to surgical anesthesia by the administration of A. C. E. mixture. Both of the sciatic nerves were exposed. The right was injected with a normal salt solution, the left with a two per cent solution of cocain. On applying the electrode, proximal to the points of injection, the cocainized nerve gave no response while the saline nerve responded in vigorous muscular contractions. On applying the electrode, peripheral to the cocain block, vigorous contractions were produced. Both vagi were then exposed and subjected to electrical stimulation, producing thereby a marked inhibition of the heart. After this, cocain was injected on one side into the sheath of the nerve and

normal saline on the other; when the electrodes were again applied the inhibition was marked on the saline side but did not appear on the cocain side.    On applying the electrodes on the cocain side, the respirations were slowed and deepened.    On injecting cocain above the point of application of the electrodes, so that the electrical stimulation was made between the two blocks, no respiratory disturbance was noted.    Finally the animal was given a toxic dose of the essential oil of absinthe, which produced violent convulsions.    In these convulsions it was noted that the muscle supplied by the blocked sciatic nerve did not participate.

26. April 7, 1897.—A large dog was reduced to surgical anesthesia by the administration of A. C. E. mixture. Both sciatic nerves were exposed and both anterior crurals severed.    In the control nerve, salt solution was injected; in the other, cocain.    Faradization of the control above the saline block produced sharp contraction of the muscle supplied.    On applying the electrode above the cocain block there was slight contraction of one or two muscles.    On examining the nerve and field of experiment, it was found that a small twig of a nerve branched just above the block, but below the application of the electrode.    This twig was severed and the electrode again applied at the same point.    No contraction then occurred, but when the full force of the Dubois-Reymond apparatus was applied some muscular contraction was noted. On making a cocain block above the point of application of the electrode, and repeating a like application, no contraction occurred.    The "cocain" paw was subjected to a Bunsen's flame until the paw was charred.    No effect was noted on the rhythm of the respiration, the height of blood-pressure, nor the muscles.    Marked contraction occurred upon applying a Bunsen's flame to the

"control" paw. This consisted in a deliberate drawing up of the leg as if to remove the paw from the flame. These contractions may appear though the animal be in a profound surgical anesthesia. The vagi were then exposed and the left faradized. There was slowing of the heart and a fall in the blood-pressure. Like results were obtained by repeating the experiment upon the opposite vagus. A cocain block was applied to the left vagus and this nerve was faradized above the block. No effect was produced. A "saline" block was applied to the opposite nerve, and stimulating the intact nerve both above and below the block produced the usual effect. The electric current was then tested by applying it to both nerves and muscles and found to be active. Finally the cortex of the brain over the motor area was exposed in order to determine whether or not by the injection of cocain into this portion of the brain the cortical discharges might be blocked during an absinthe convulsion. Fifteen minims injected into the jugular vein produced no effect. This quantity was repeated and an immediate fall in blood-pressure occurred. A slight muscular spasm passed over the extremities. The muscles of the neck twitched slightly. Finally a dram, making in all two drams, of injection into the jugular was given without causing any marked convulsions. One dram of two per cent. solution of eucain in the femoral vein caused a slight twitching, but the animal continued to live. A considerable quantity of cocain must have been absorbed by the injections in the sciatic nerve and in the vagus. The animal was finally killed by pouring a half-dram into the tracheal tube, which almost instantly arrested both the respiration and the heart.

27. A dog, good-natured and playful, weighing eighteen pounds, was subjected to an experiment as follows: A

two per cent. solution of cocain was dropped into each eye, producing conjunctival insensibility. By means of a long needle a painless path was anesthetized to the posterior inferior surface of the eyeball, the point of the needle resting as nearly as could be estimated on the optic nerve. About twenty minims of the solution were then injected and the other eye subjected to a similar treatment. The dog flinched several times during this process, and in the left eye there was some bleeding. The animal was then allowed to run at will in the laboratory. For a time he appeared to be normal, but soon acted strangely, becoming quite sedate, somewhat weaker, and was hesitating in his movements. After fifteen minutes he found difficulty in locating us when called, and looked about in a staring, troubled manner. When placed on a table, a position with which he was made acquainted previous to the experiment, he crouched down and seemed in great doubt and fear. He was finally induced to jump from the table, but so misjudged the distance that he landed upon his feet in an unprepared way. As nearly as could be estimated the sense of sight was almost wholly abolished. The following morning the animal had regained his normal condition.

28. May 29, 1897.—A small cur dog was placed under general anesthesia and under as good aseptic precautions as possible. The sciatic nerve on the right side was subjected to a cocain and a eucain block near each other. On the left side a "saline" block was made. On recovering consciousness the right side was paralyzed while the left was not affected ; that is, if there was any effect on the left side it could not be determined, for the general condition of the animal, though still feeling depressed from the anesthetic, was such that accurate observations of smaller degrees of difference between the experimental

and the normal could not be determined. The wounds were sealed with iodoform collodion, and both recovered with but superficial suppuration. The motions in the leg on the following day were free, excepting that the animal walked stiffly. Twenty-nine days later the field of experiment was examined, and no trace of injury or disease of the nerve could be determined either macroscopically or microscopically.

29. June 1, 1897.—A black cat was subjected to an experiment similar to the preceding, with practically the same results. The microscopic examination was made four weeks after the injection.

30. May 28, 1897.—A large cat, under ether anesthesia, by the administration of A. C. E., was subjected under aseptic precautions to a eucain block of the sciatic nerve. This required but a few minutes to perform, and when the animal first recovered from the effect of a general anesthesia the muscles supplied by the sciatic nerve were paralyzed. Later in the day the paralysis had entirely worn off, and while the cat seemed languid and not inclined to walk about, locomotion was easily accomplished. There was some superficial suppuration, but the wound, after a time, healed, and there seemed to be neither impairment of function nor interference with the general health of the cat. Four weeks later, on examining the point of injection microscopically, no change was noted.

31. May 28, 1897.—A large Maltese cat was subjected to an experiment similar to the preceding, with the exception that a two per cent. solution of cocain was used. The animal's leg was paralyzed almost an hour, but it was difficult to make accurate observations on account of the weakness and lethargy incident to the general anesthetic. The following day the limb could be used freely,

although the wound became greatly inflamed and sup-
purated.   The animal recovered after a rather tedious
convalescence and there was no impairment of function.
At the end of a month the animal was utilized for
another experiment, and on inspecting the former field of
operation it was found that there was a considerable
amount of dense scar-tissue filling in the skin wound.   No
trace of the point of application of the cocain block
could be determined either macroscopically or microscopi-
cally.

32. December 11, 1897.—Mongrel dog, eighteen pounds,
under ether anesthesia was subjected to the following ex-
periments.   On closing the innominate artery there was
an immediate fall in the central blood-pressure.   The
respiration was not affected.   This was repeated three
times.   In each instance there was a striking fall in the
blood-pressure, but practically no effect upon the respira-
tory action.   The pressure was finally maintained for three
minutes, but the respirations were but little, if at all,
altered.   Twenty minims of a two per cent. solution of
cocain were then injected into the jugular vein.   An im-
mediate increase in the blood-pressure followed, and at
intervals of six or seven beats there was an intermission.
The respirations were somewhat quickened and the ampli-
tude slightly diminished.   The abdomen was opened, the
intestines removed, and on manipulation for eighteen
minutes there were varying alterations in the pressure,
but on the whole the general blood-pressure was not
lowered.   The electrodes of a Dubois-Reymond coil were
then laid upon the exposed vagus and a slight inhibitory
action was induced.

33. December 7, 1897.—Shepherd dog ; weight, twenty-
five pounds, under ether anesthesia.   The left vagus was

exposed and the electrode applied as a control, causing complete inhibition of the heart. Fifteen minims of a two per cent. solution of cocain were then injected into the jugular vein. Upon reapplying the electrode, there was only a partial inhibition of the heart. Injecting thirty minims more of this solution, the strokes of the manometer were lessened in height. The respiratory excursions were likewise lessened. Removing the intestines, freely exposing them to the air, and subjecting them to manipulation produced a slight rise in blood-pressure. The respirations soon became very irregular. The arteries in the splanchnic area were diminished in calibre.

34. December 20, 1897.—Mongrel bitch; weight, eighteen pounds. As a control the intestines were exposed to the air and manipulated, producing a fall in the blood-pressure. The left vagus was exposed, the electrode applied, and the heart was immediately inhibited. Twenty minims of a two per cent. solution of cocain were then injected into the femoral vein. As before, the intestines were again exposed and manipulated, causing an actual rise in the blood-pressure. During the exposure and manipulation they became paler. Applying the electrode to the vagus, inhibition was produced.

35. January 3, 1898.—A mongrel dog; weight, twenty pounds, was subjected to the following experiment. As a control the mucous membrane of the larynx was subjected to mechanical stimulation, causing thereby an arrest of respiration and a marked fall in the blood-pressure, during which there developed very marked " vagal" heartbeats. Injected twenty minims of a two per cent. solution of cocain into the jugular vein. There was an immediate rise in the blood-pressure, followed by a slight fall. Ten minims more of the solution were then injected and a

marked fall in the blood-pressure occurred.   The second injection was made immediately after the first.   On repeating the manipulation of the laryngeal mucosa the respirations were arrested as in the previous observation, but the blood-pressure and the heart's action remained unaltered.   On exposing the intestines and manipulating them severely there was a great irregularity in the blood-pressure curve and on the whole a slight decline.   The respirations in the mean time were very irregular and there was difficulty in maintaining an even anesthesia. There was a marked tendency throughout this and the preceding experiment to clotting of blood in the cannula.

36. January 3, 1898.—Mongrel dog ; weight, twenty-four pounds, young and in good condition.   On exposing the vagus and applying the electrodes a marked inhibition of the heart occurred.   After injecting twenty minims of a two per cent. solution of cocain there was a rise in the blood-pressure, but no alteration in the respiration.   Upon repeating the application of the electrode to the vagus nerve no inhibition was produced.   The application of the current was made five times at intervals of about thirty seconds without producing any inhibition.   During these applications respirations ceased and the animal died.

37. January 12, 1898.—Pug dog ; weight, ten pounds, old and fat ; ether anesthesia.

First, electrodes applied to the vagus nerve produced marked inhibition of the heart, but no temporary change.

Second, injecting ten minims of a two per cent. solution of cocain produced a temporary rise in the blood-pressure.

Third, upon applying the faradic current to the vagus nerve there followed a marked inhibition of the heart with a fall in the blood-pressure.

Fourth, injected twenty minims more of the solution. No perceptible effect.

Fifth, reapplying the electrodes to the vagus caused marked inhibition with a fall in the blood-pressure.

Sixth, the injection of twenty minims more of the solution and reapplication of the electrodes was followed by complete inhibition of the heart. The contact of the electrodes with the nerve was allowed to continue, but the heart had ceased to beat.

38. January 15, 1898.—Spaniel ; weight, twenty-one pounds.

First, secured as a control a tracing of the normal blood-pressure and respiratory action.

Second, injected eighteen minims of a two per cent. solution of cocain into the jugular vein. This was followed by a rise in the blood-pressure with no alteration in the respiratory action.

Third, on exposing the intestines there was a slight fall in the blood-pressure.

Fourth, on pounding the intestines there was a slight rise. Respiratory action was extremely irregular. Upon stimulating the left vagus by applying the electrode, no inhibition was produced.

This was twice repeated with like results.

39. Double experiment. Two mongrel dogs ; one as a control, weighing sixteen pounds, the other as a cocain experiment, weighing nineteen pounds. Both of the animals were in good condition. Under ether anesthesia the following experiments were performed, after a tracing had been taken of the normal blood-pressure and the respiratory action.

First, fifteen minims of cocain were injected into the

jugular vein of the dog under experiment.   A rise in blood-pressure occurred in a few seconds.

Second, cutting the skin of the abdomen of each simultaneously produced about an equal fall in blood-pressure. The comparison could be very accurately made because the writing style of the monometers were recording directly in line upon the drum.

Third, on manipulating and removing intestines simultaneously, in the control there was a fall of the blood-pressure, but no change in the cocain dog.   The cocainized animal's intestines were paler than the control.

Fourth, manipulating intestines of both simultaneously produced a fall in the control, but no effect on the cocain animal.   The respirations in both were irregular.

Fifth, on making simultaneous manipulation of the parietal peritoneum,—in the control there was a fall; in the other, no change.   The respirations were altered in both alike.

Sixth, on burning the hind paws of both animals there was a greater rise in the control than in the cocain.

Seventh, fifteen minims more of cocain injected.   No effect upon blood-pressure.   Manipulation of intestines of each.   Rise in blood-pressure in the cocainized animal; slight fall in the control.   Respirations shallow and irregular in both.   The intestines of the cocainized animal were of quite a different color, a pale red, in contrast with a livid red in the control.

Eighth, on burning the hind paws there was a rise in both blood-pressures, but the latent period in the cocainized animal was longer than the control.   On stretching the sciatic nerves of both, the latent period was longer in the cocainized animal.   There was a rise in the blood-pressure in both, but more marked in the control.

Ninth, on applying the electrodes to the vagi both blood-pressures fell.

*Autopsy.*—Opened the heart of each immediately after death, within thirty seconds after cessation of the heart-beat. Slight clotting was found in the cocainized animal, while the blood in the control did not clot until two minutes had elapsed. During the experiment there was a tendency to clotting in the cocainized animal and the intestines were of a slate-like hue.

40. February 4, 1898.—Double experiment. The dog for injecting the cocain was a yellow cur, in poor condition, weighing five pounds; while the control was in good condition, weighing sixteen pounds.

First, sixteen minims of a two per cent. solution of cocain were injected into the jugular vein.

Second, on opening the abdomen, there was a fall in both blood-pressures.

Third, on removing the intestines and simultaneously exposing them to the air, neither blood-pressure was distinctly affected. The respirations in both animals became irregular.

Fourth, manipulating the intestines simultaneously produced a fall in the control, with no effect upon the cocainized animal.

Fifth, the same was repeated with like result.

Sixth, severe manipulation of the intestines of both produced a slight rise in the cocainized animal, but a distinct fall in the control.

Seventh, upon simultaneously burning the hind feet of both there was a rise, the latent period being longer in the cocainized animal. The veins in the control, especially in the splanchnic area, had become greatly dilated. Those of the cocainized animal were, if altered, more contracted than normal. There was a striking difference between the color of the abdominal viscera in the two animals. In the cocainized subject the viscera were a pale

red ; in the other, a dark, dull red. In the remainder of the experiments the animals were subjected to various kinds of operation and injury in which the control exhibited more marked change in the blood-pressure than the cocainized subject. With respect to respiratory changes there were practically no differences observed. Throughout the experiment there was a considerable amount of difficulty experienced in overcoming the tendency to clotting in the cocainized animal. In spite of the manifest disparity in both the size and the physical condition of the two animals, the cocainized subject endured the experiment much better and resisted a half-hour more experiment than the control. Before the cocainized animal's death the body was severed across the lumbar region.

41. February 15, 1898.—Double experiment. Control and cocain. The control dog, mongrel, young; weight, twenty-one and one-half pounds; ether anesthesia; blood-pressure one hundred and forty millimetres. Cocain dog, mongrel, young; twenty pounds; ether anesthesia; blood-pressure one hundred and thirty-eight millimetres.

First, injected ten minims of cocain into the jugular vein.

Second, cutting through the abdominal wall, fall of blood-pressure in both; more rapid in the cocain dog. Respirations irregular in both.

Third, manipulation and exposure of the intestines. Fall of blood-pressure very marked and immediate in the control. Fall very slight in the cocain. Irregular respirations in both. Intestines of the cocain dog very pale; of the control, very red.

Fourth, manipulation of the intestines, fall of blood-pressure in both about the same. The experiment was very much handicapped by an unusual tendency to clotting

in both animals.    It was afterwards learned that an assist-
ant in filling up the pressure-bottle employed a saturated
solution of sodium chloride instead of magnesium sulphate.
This experiment lacks accuracy.

42. February 24, 1898.—Double experiment.    Water
spaniels, the control weighing twenty-three pounds, the
cocain animal twenty-one pounds.    The initial blood-
pressure of the control was one hundred and forty-two
millimetres; of the cocain dog, one hundred and thirty-
six millimetres.    Twenty minims of the two per cent.
solution were injected into the jugular.

Second, in both animals the intestines were exposed,
turned out, and for twelve minutes a continuous manipu-
lation was made.    During this time the cocainized animal
exhibited comparatively slight fall in the blood-pressure,
the curve being quite irregular, while the control exhibited
a very decided fall with a comparatively regular curve.
The veins of the control were greatly dilated, while in
the cocainized animal the veins were of smaller calibre,
excepting those at the bases of the intestines, which were
dilated.    The intestines of the control were intensely red,
even livid, and those of the cocainized subject were com-
paratively pale.    At this point both animals were killed
by injecting chloroform.

43. *Cocain Series.*—*Protocols.*—November 2, 1900.—
Dog; weight, sixteen pounds; ether anesthesia.    Central
blood-pressure in carotid.    One per cent. solution of cocain
was injected, by means of a long needle, between the axis
and the third cervical vertebra.    Respirations were within
ten seconds completely arrested.    The spinal cord was then
laid bare from the lower thoracic region to the occipital
bone.    After injecting a solution of methylen blue in the
subarachnoid space at the lowest end of the exposed cord,

the solution travelled with remarkable rapidity the entire length of the cord, to the under surface of the brain.

44. November 3, 1900.—Dog; weight, twelve pounds; ether anesthesia.   Central blood-pressure in the carotid artery.   Respiratory tracings as usual.   The spinal cord
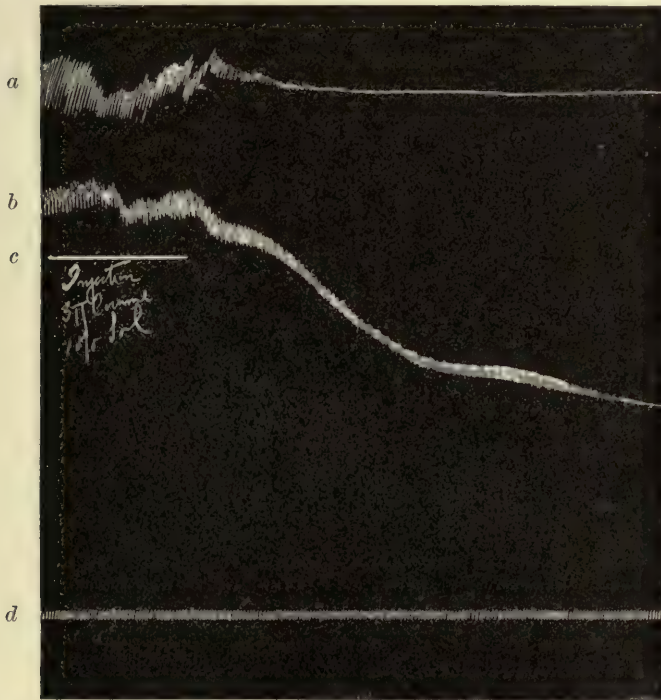


Fig. 9.—*a*, respiration; *b*, blood-pressure; *c*, signal; *d*, seconds.   Injection in lumbar region with considerable force, showing how quickly both the respiratory and the vaso-motor centres may be paralyzed.   The secondary rise in the blood-pressure was due to the first disturbance of the convulsive centre in the medulla.

was laid bare from the second to the fourth thoracic ver-tebra.   A considerable hemorrhage was encountered, producing a marked fall in the blood-pressure.   Injecting two drams of a two per cent. solution of cocain deeply colored with methylen blue into the subarachnoid space quickly and with force was attended by a rapid failure of

respiration and an immediate fall in the blood-pressure to the abscissa.

*Autopsy.*—The cord was found stained throughout; also the medulla and base of the brain.

45. November 5, 1900.—Dog; weight, eighteen pounds; ether anesthesia. In performing a laminectomy at the sixth dorsal vertebra an excessive amount of hemorrhage was encountered, and the dog died before the cord could be injected.

*Autopsy.*—The cord was injected at a level of the dorsal vertebra with a solution of methylen blue. On making dissection it was found that there was a complete coloration of the spinal cord, of the cisterna magna, and the basilar subarachnoid space as far forward as the optic chiasm. None of the ventricles were colored.

46. November 5, 1900.—Large bull-dog; weight, fifty-six pounds; difficultly anesthetized. On account of the great muscular rigidity and excessive loss of blood an attempted laminectomy at the fourth dorsal vertebra was but partially successful. An injection of one per cent. solution of cocain, colored with methylen blue, produced a marked fall in the blood-pressure with slowing of respiration. The animal died rather suddenly.

47. November 6, 1900.—Dog; weight, twelve pounds; ether anesthesia. Central blood-pressure in the carotid. Laminectomy was made at the sixth dorsal vertebra. At this point the animal was killed by an inadvertent injection of a solution of Epsom salts from the pressure-bottle.

48. November 6, 1900.—Small dog in poor condition. While making a laminectomy the cord was severed, which

produced a marked fall in the blood-pressure.    At this point the animal died.

49. November 6, 1900.—Small, anemic dog ; ether anesthesia.  The animal was not promising.  An interlaminar injection of one per cent. solution of cocain into the allanto-occipital space was given.  A steady decline of respiration immediately followed.  The animal died in two minutes.

*Autopsy.*—The spinal cord was laid bare throughout its entire length.  A solution of methylen blue was injected into the lower end of the subarachnoid space.  It passed with wonderful rapidity to the cisterna magna and the under surface of the base of the brain.  The fourth ventricle was slightly colored.

50. November 6, 1900.—Dog ; weight, thirteen pounds ; ether anesthesia.  Carotid blood-pressure.  Cord exposed at the fifth and sixth dorsal vertebræ.  It was observed that each time the cord was touched with the needle a short temporary stoppage of respiration followed.  On injecting a two per cent. solution of cocain, stained with methylen blue, a steady decline in respiration was noticed.  Respiration ceased at the end of forty-five seconds.

*Autopsy.*—The subarachnoid space of the cord, cisterna magna, and subarachnoid space at the base of the brain were colored.  There was slight coloration of the fourth ventricle.  The injection of additional colored solution, with point of needle directed towards the tail, was followed by a much greater flow upward than downward in the subarachnoid space.

51. November 7, 1900.  Small young dog ; ether anesthesia.  Carotid blood-pressure.  A two per cent. solution of cocain was injected into the fourth lumbar interspace.

This was followed by a temporary rise in the blood-pressure, which in turn was followed by a distinct fall. A solution of Prussian blue was injected at the same point before the needle was removed. In burning the hind foot there was a slight rise in the blood-pressure and no change in respiration.

*Autopsy.*—There was no evidence by coloration or puncture that the cord had been injected.

52. November 8, 1900.—Dog; weight, fourteen pounds; ether anesthesia. Carotid blood-pressure. On injecting two drams of one per cent. solution of cocain, stained with Prussian blue, into the subarachnoid space in the fifth lumbar vertebra there was a temporary fall in the blood-pressure with some excitation of respiration. On burning the hind paw there was no change in the blood-pressure. At the end of fifteen minutes respirations became more and more labored and finally ceased.

*Autopsy.*—Exposed the whole length of the spinal cord and brain. The cord was colored up to the middle of the cervical region.

53. November 8, 1900.—Dog; weight, sixteen pounds; ether anesthesia. Carotid blood-pressure. Cord was exposed at upper sacral region. A one per cent. solution of cocain was injected. Increased respiratory action immediately followed, together with a slight fall in the blood-pressure. After three minutes, burning the hind foot produced no change in the blood-pressure. Burning the forefoot produced a slight rise in the blood-pressure followed by a compensatory fall in a long sweeping curve, the excursions of the manometer increasing in length towards the middle of the curve, then gradually declining. The respirations at the end of ten minutes were considerably diminished.

54. November 9, 1900.—Cat ; ether anesthesia. Carotid blood-pressure. Spinal cord exposed in lumbar region. Three drams of twelve per cent. solution of cocain were injected into the subarachnoid space. Respirations failed entirely at the end of three minutes.

55. November 9, 1900.—Cat ; ether anesthesia. Carotid blood-pressure. The injection of two drams of one per cent. solution of cocain into the subarachnoid space was followed by a respiratory stoppage, after which there was a long excursion in the tracing, and at irregular intervals respiratory movements of varying degrees were executed. After a spasmodic contraction of the diaphragm there was total cessation of respiration.

56. November 10, 1900. — Dog ; weight, eighteen pounds ; ether anesthesia. Carotid blood-pressure. As control the hind foot was burned. This was followed by rise in blood-pressure and increased respiratory action. Subarachnoid injection of one-half dram of one per cent. solution of cocain then made. Repetition of burning produced no rise in the blood-pressure or alteration in the respiratory action. Burning the nose caused a very marked rise in the blood-pressure. The animal, after the injection of cocain, was not under full ether anesthesia, conjunctival reflex being present.

57. November 12, 1900.—Cat ; ether anesthesia. As the animal was not favorable for experiment a one per cent. solution of cocain was injected into the cervical subarachnoid space, producing almost instant death by respiratory and circulatory failure.

58. November 13, 1900.—Mongrel dog ; weight, thirty-six pounds ; ether anesthesia. Carotid blood-pressure.

The cord was exposed in the lumbar region. At 3.15, the right hind foot was burned, which was followed by a fall in the blood-pressure with a compensatory rise. The cord had been slightly injured in the laminectomy. At 3.16, the left forefoot was burned, which produced a rise in the blood-pressure. At 3.17, injected one-quarter dram of one per cent. solution of cocain into the subarachnoid space. A slight fall occurred in the blood-pressure. No change in the respiration. At 3.22, the left hind foot was burned. There was a slight rise in the blood-pressure. At 3.25, a one-half dram of one-half per cent. solution of cocain was injected into the spinal cord. At 3.30, an abdominal incision was made. The intestines were exposed. Manipulation and slapping the intestines caused a contraction of the same, which was followed by a slight fall in the blood-pressure. The intestines became paler.

59. November 13, 1900.—Mongrel dog; weight, twenty-six pounds; ether anesthesia. Carotid blood-pressure. At 4.18, injected two drams of two per cent. solution of cocain at the third lumbar vertebra. The respirations were temporarily arrested, after which each succeeding excursion became shorter. There was a slight rise in the blood-pressure followed by a decline, the strokes becoming gradually shorter until death.

60. November 15, 1900.—Mongrel dog; young; weight, sixteen pounds; ether anesthesia. Carotid blood-pressure. After control tracing was taken the right hind foot was burned, producing increased respiratory action and a rise in the blood-pressure. Three drams of a two per cent. solution of cocain was injected into the subarachnoid space. A rapid decline in blood-pressure occurred almost simultaneously with the injection of the

cocain, and although the experiment was continued twenty
minutes longer, the blood-pressure did not rise from the
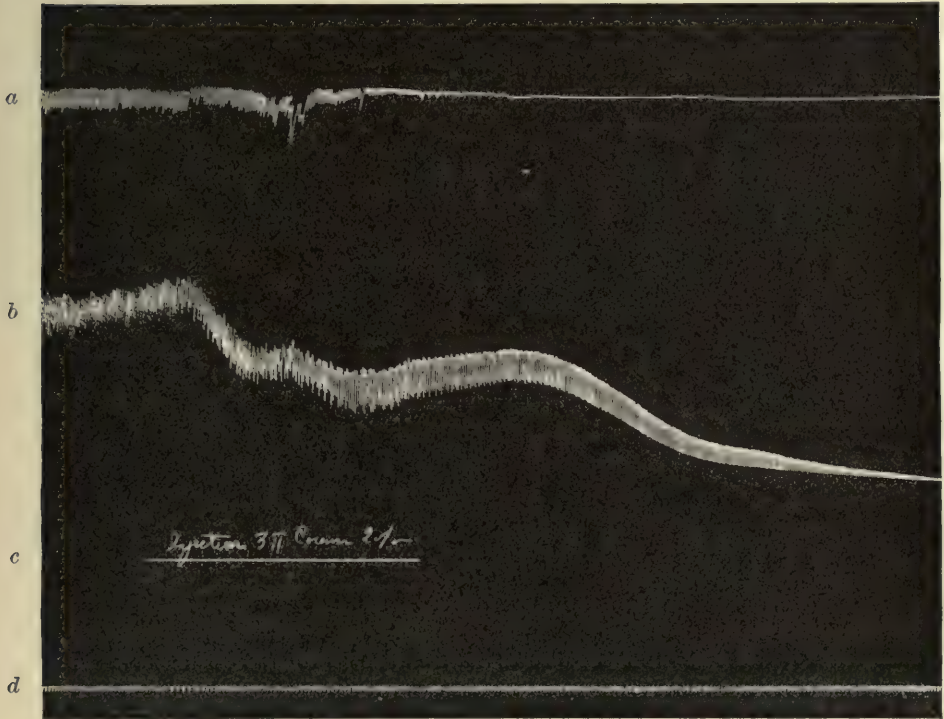


FIG. 10.—*a*, respiration; *b*, blood-pressure; *c*, signal; *d*, seconds.   Effect of injecting two drams of co-
cain into the lumbar subarachnoid space.   Note the gradual cessation of respiration, the irregular strokes
occurring during the convulsions, the abrupt fall in blood-pressure due to paralysis of the vasomotor
centre in the medulla.

low level to which it had fallen.   On burning the foot
and nose no change occurred in the blood-pressure or
respiration.

61. November 16, 1900.—Dog; ether anesthesia.   Cord
pierced in lumbar region.   Cord exposed.   Three drams
of one per cent. solution of cocain were forcibly injected
into the subarachnoid space, which produced a marked
fall in the blood-pressure and a rapid cessation of respi-
ration.   At first there was a slight convulsive action, after

which the animal was allowed to die. The asphyxia curve appeared in the blood-pressure tracing.

62. November 17, 1900.—Dog; fox terrier; weight, twenty pounds, in good condition. Carotid blood-pressure. A. C. E. As a control the right hind foot was burned before the conjunctival reflex was entirely abolished. There was a rise in the blood-pressure with an increase in the respiration. Injecting one dram of two per cent. solution of cocain in the subarachnoid space in the lumbar region produced a marked fall in the blood-pressure and diminished the respiratory action almost simultaneously. Both recovered their immediate depression. Burning the left hind foot, before the conjunctival reflex had been abolished, produced no rise in the blood-pressure. Respirations became more shallow and slower. On burning the nose there was considerable rise in the blood-pressure. One and one-half drams of two per cent. solution were then injected, after which manipulation of the intestines produced no effect. Intestines became paler and markedly contracted. Manipulation of the liver, of the kidney and bladder, produced no effect. Crushing of the testicle produced no effect.

63. November 17, 1900.—Puppy; weight, six pounds. A forcible injection of cocain solution into the subarachnoid space in the lumbar region produced death by respiratory failure. There was a convulsion at the time of injection.

64. November 20, 1900.—Mongrel dog; weight, twenty pounds. The injection of one and one-half drams of a two per cent. solution of cocain produced an immediate fall in the blood-pressure with marked alteration in the respiration. Respirations ceased in five minutes. The blood-pressure curve exhibited the asphyxia characteristics. There was a convulsion at the time of injection.
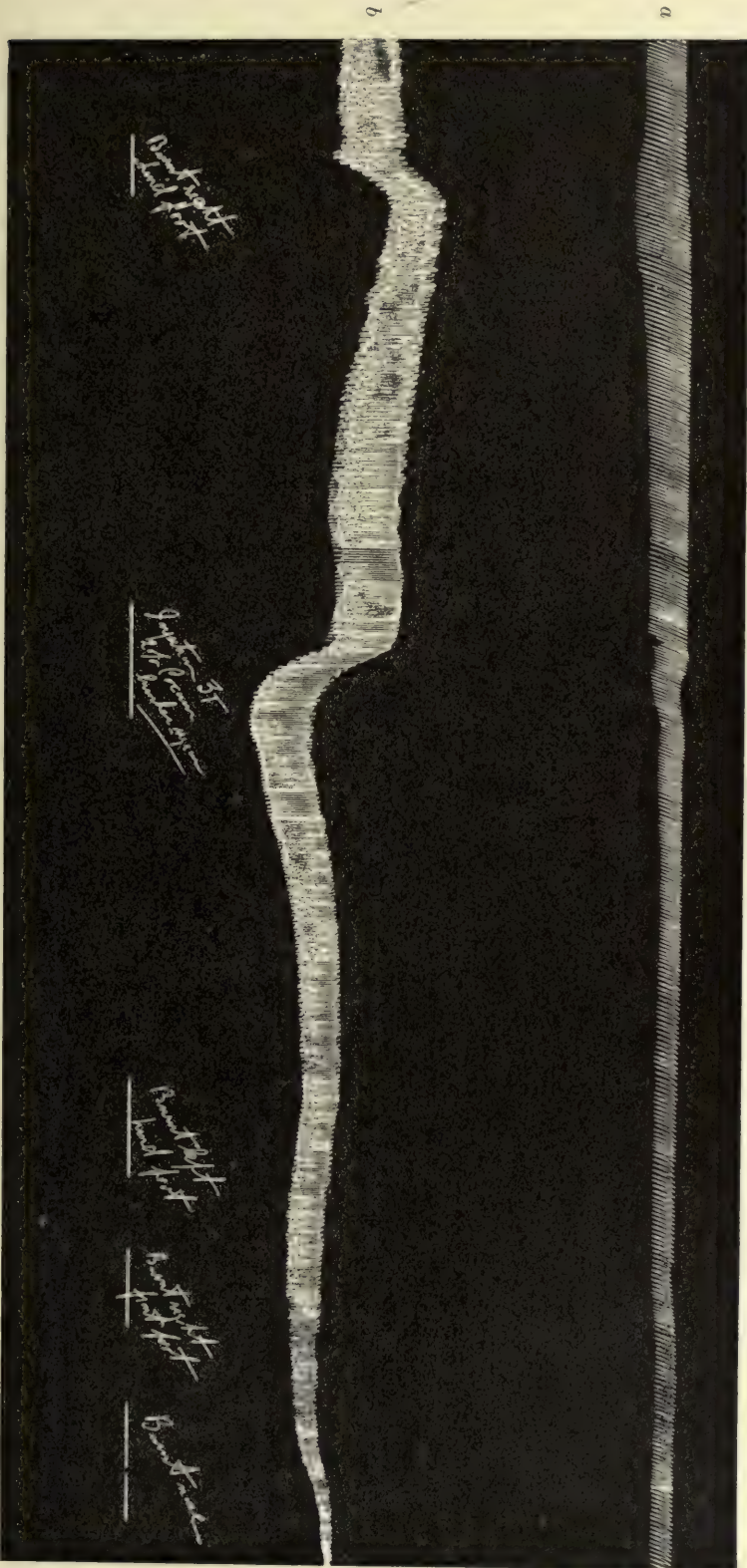
Fig. 11.—*a*, respiration; *b*, blood-pressure. As a control the hind foot was burned, causing a rise. Then cocain solution was injected into lumbar region, after which burning of the foot caused no effect upon either the blood-pressure or the respiration.

65. November 20, 1900.—Dog; weight, nine pounds; good condition. The animal was killed by an inadvertent injection of magnesium sulphate.

66. November 20, 1900.—Mongrel dog; A. C. E. Carotid blood-pressure. Cord exposed in lower thoracic region. Two drams of two per cent. solution of cocain injected into the subarachnoid space in lower thoracic region. For twenty-five seconds the respirations were not altered, after which they became more rapid. The amplitude of their excursions diminished and in two minutes ceased. The blood-pressure fell simultaneously with the injection of the cocain. On cessation of respiration there was a slight temporary rise and the animal died. There was a convulsion at the time of injection.

67. November 21, 1900.—Mongrel dog; weight, twelve pounds; A. C. E. Spinal cord in lumbar region. Right hind foot burned. Respirations became deepened. The blood-pressure rose, followed by a compensatory fall. Injected one dram of two per cent. solution of cocain into the subarachnoid space in thoracic region. There was a considerable fall in the blood-pressure with irregularity of strokes; a slight convulsive action extended over the entire animal. On manipulating the intestines no change occurred in the blood-pressure. Manipulating the liver, kidneys, and bladder produced no effect. Intestines became paler and markedly contracted.

68. November 22, 1900. — Dog; weight, fourteen pounds; ether anesthesia. Carotid blood-pressure. Spinal cord exposed in lumbar region. Cord was injured in exposing it. On burning the right hind foot there was a fall in the blood-pressure. On burning the forefoot there was a rise. Conjunctival reflex was present. Injected two

drams of a two per cent. solution of cocain.   Animal died of respiratory failure after a slight convulsion.   The heart continued to beat two minutes and ten seconds after the respiratory failure.
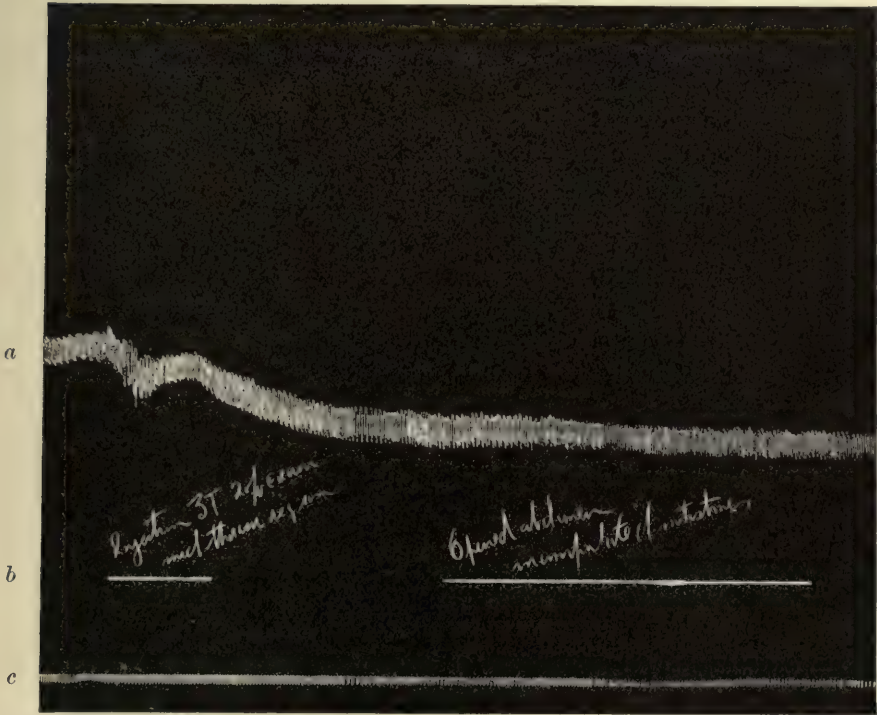


Fig. 12.—a, blood-pressure; b, signal; c, seconds.  This experiment shows that after an injection in the thoracic region manipulation of the abdominal viscera does not affect the blood-pressure.

69. November 22, 1900.—Dog; weight, sixteen pounds; ether anesthesia.   At 3.50, the spinal cord was exposed in lower thoracic region.   At 4.08, the left testicle was crushed.   A marked fall in the blood-pressure occurred, followed by a compensatory rise.   Respirations irregular. At 4.11, injected one dram of two per cent. solution of cocain into the subarachnoid space.   Marked fall in the blood-pressure.   Respirations not affected.   At 4.14,

crushing the right testicle produced no effect.    No change in blood-pressure or respiration.

70. November 22, 1900.—Mongrel dog; weight, eleven pounds; ether anesthesia.  Carotid blood-pressure.  Owing to difficulty in the way of clotting the experiment was not promising, and the animal was killed by the injection of two drams of a two per cent. solution of cocain into the cervical cord.    Death was produced in two minutes by respiratory failure.

71.  November  23,  1900. — Dog;  weight,  fourteen pounds;  ether anesthesia.  Laminectomy performed in lower thoracic region.    Animal died from effects of anesthetic.

72. November 23, 1900.—Mongrel dog; weight, twelve pounds; ether anesthesia.    At 4.47, cord was exposed in lumbar region.    At 5.05, burning the right hind foot was followed by a spasmodic respiratory act together with a rise in the blood-pressure.    The right hind foot was burned at 5.10.    A rise in the blood-pressure followed. Injected two drams of a two per cent. solution of cocain in subarachnoid space, producing rapid cessation of respiration.    Blood-pressure rapidly fell.    Burning of paws produced no effect.    Animal promptly died.

73. November 26, 1900.—Cord exposed in lower thoracic region.    At 3.25, the right testicle was crushed, which was followed by a slight fall in the blood-pressure. Respirations more frequent.    At 3.26, clot in cannula. At 3.27, burned right hind foot.  Respirations spasmodic. At 3.29, burned right hind foot.  Respirations unaltered. At 3.32, injected two drams of two per cent. solution of cocain, producing a gradual fall in the blood-pressure. At 3.34, burning of right hind foot produced no change,

and burning of right fore foot and nose produced no change. Animal died suddenly.
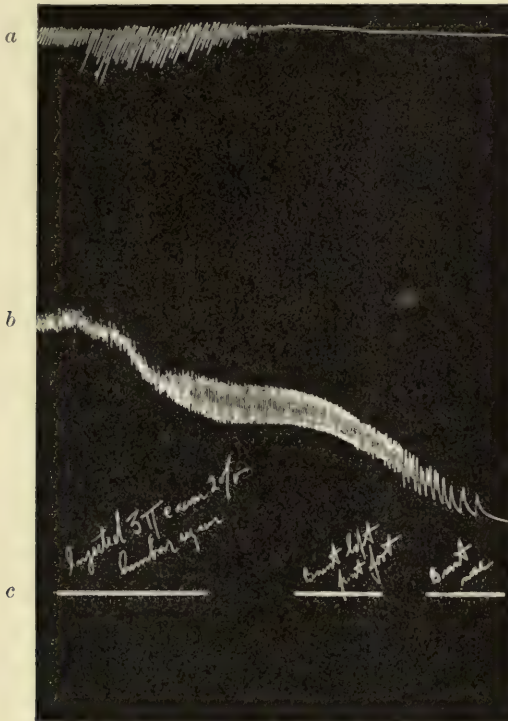


FIG. 13.—*a*, respiration; *b*, blood-pressure; *c*, signal. This experiment shows how quickly an injection in the lumbar region may kill, and that after the effect is obtained burning of the feet does not produce any change in blood-pressure.

74. November 26, 1900.—Mongrel dog; weight, nine pounds; ether anesthesia. Heart suddenly stopped while separating the vagus nerve from the carotid artery.

75. November 27, 1900.—Mongrel dog; weight, twelve pounds; ether anesthesia. At 11.28, right hind foot burned, with rise in blood-pressure following. At 11.31, injected one dram of two per cent. solution of cocain, producing a marked fall in the blood-pressure. Burned left hind foot; no change in the blood-pressure. Burned

right fore foot; no change. At 11.40, burned the nose; no change. Animal died of respiratory failure.

76. November 27, 1900.—Mongrel dog; weight, twenty-two pounds; ether anesthesia. Cord exposed in lumbar region. At 11.42, crushed the right testicle. A fall in the blood-pressure followed. At 11.45, injected one dram of one per cent. solution of cocain. A marked fall in the blood-pressure occurred. Respirations not affected. At 11.50, crushing the left testicle produced no change in circulation or respiration. Injected one dram of a two per cent. solution of cocain. This was followed by marked convulsions of the anterior limbs, while the posterior ones were not affected.

77. November 30, 1900.—Spaniel dog; weight, twelve pounds; A. C. E. anesthesia. On opening the abdomen there was a slight fall in the blood-pressure, a compensatory rise immediately occurring. On manipulating both the small and large intestines there was a gradual fall in the blood-pressure. Injected one dram of one per cent. solution of cocain into the subarachnoid space. On repeating the manipulation of the intestines no fall occurred.

78. November 30, 1900.—Cord exposed in thoracic region. One dram of two per cent. solution of cocain was injected at this point. Marked fall in blood-pressure. On opening the abdomen and manipulating the intestines no fall in blood-pressure was noted.

79. December 1, 1900.—Mongrel dog; weight, twenty-six pounds; A. C. E. anesthesia. The cord was exposed in the lower lumbar region over several vertebræ. The cord was incised in the lower end of the exposed portion. No change in either the circulation or the respiration. One

dram of a two per cent. solution of cocain was injected above the incised cord. There was no fall in the blood-pressure. Excursions were slightly increased in length. The respirations were slowed. Burning the right fore foot produced no change; burning the nose, no change.

80. December 1, 1900.—Mongrel dog; weight, thirty-two pounds; A. C. E. anesthesia. Crushing the right testicle was followed by fall in blood-pressure. Injecting one dram of a two per cent. solution of cocain into the lower thoracic region produced a fall in the blood-pressure, with irregularity of respiratory action. Crushing the left testicle produced no change in the blood-pressure or the respiration. After the lapse of three or four minutes, oil of absinthe was injected into the external jugular vein. Respiration was diminished; blood-pressure slightly lowered. On burning the right fore foot and nose slight twitchings were noticed in the anterior extremities, also in the lower jaw. The hind limbs were not affected. At death the fore limbs and the muscles of the body were entirely relaxed.

81. December, 1900.—Mongrel dog; weight, sixteen pounds; ether anesthesia. Lumbar cord was exposed and one-half dram of one per cent. solution of cocain injected. After ten minutes the abdomen was opened, intestines exposed and severely manipulated during fifteen minutes. There was irregular respiratory action and some irregularities in the blood-pressure tracings, but the pressure did not materially fall. Rudely manipulating the kidneys, liver, and spleen produced but slight effect. The animal was then killed by injecting two drams of one per cent. solution of cocain into the subarachnoid space, which after a slight convulsion suddenly produced respiratory failure.

82. December, 1900.—Mongrel dog; weight, fifteen pounds; ether anesthesia. Cord was exposed in lumbar region. One-half dram of one per cent. solution of cocain was injected into the subarachnoid space. On crushing the testicle no fall in the blood-pressure occurred. Manipulating the intestines produced a marked fall in the blood-pressure, the intestines becoming paler and harder. Two drams of one per cent. solution of cocain were then forcibly injected into the subarachnoid space. This was attended by marked convulsions, following which respirations grew gradually slower and shallower until they ceased, the diaphragm being the last to stop. There was a very marked decline in the blood-pressure, the heart beating slower and with less force until the end, which occurred about a minute after the cessation of the respirations.

83. December, 1900.—Mongrel dog; weight, eighteen pounds; ether anesthesia. The injection of normal saline solution into the subarachnoid space produced but a slight change in the blood-pressure and respiration. The injection of one per cent. solution of cocain produced a marked fall in the blood-pressure and a slowing of respiration.

84. *Cord Series.*—Shepherd dog; weight, thirty pounds; good condition. Twenty-five minims of a one per cent. solution of cocain were injected into the second lumbar interspace. Result negative. Twenty-five minims of a one per cent. solution in fourth lumbar interspace were without effect. Dog watched for thirty minutes. Twenty-five minims of a one per cent. solution in first lumbar interspace were then injected. In one minute legs began to sag, tail drooped, and in three minutes sensation and motion in hind legs were abolished. That sensation was abolished was shown by applying Bunsen flame, deep

pricking with needle, etc., without eliciting response.    In twenty-seven minutes both sensation and motion had returned completely, though there was a slight return of both at the end of twelve and one-half minutes.    The next day the dog was apparently normal.    He was playful and had good control of his legs.    An injection of twenty-five minims of a one per cent. solution of cocain between last dorsal and first lumbar was negative.    The third day the dog was apparently as well as before.    Three attempts to inject twenty-five minims of a one per cent. solution of cocain in first lumbar and last dorsal interspace were all failures.    No effect on sensation and motion was noted.    There was a constitutional effect.    The dog became wild and restless, with dilated pupils.    The following day the dog was killed, and at autopsy it was noted that the failure in securing anesthesia was due to the fact that the needle had not penetrated the canal, but had been inserted beside the spinal processes.

85. Small yellow dog; weight, twelve pounds; playful, active, and apparently in good condition.    Without aseptic precautions an attempt was made to inject cocain into the spinal canal.    After several failures in getting the needle into canal an injection of twenty-five minims of a one-half per cent. solution in lumbar region produced an immediate paralysis of the hind legs.    Sensation as well as motion was abolished.    The dog sat squatting on his haunches with both hind legs spread out flush with the floor.    He made no response to pinches, burns, etc., which were applied to hind legs.    In fifteen minutes he began to regain some motion, but sensation was still blocked.    In twenty-five minutes he had regained full control of his legs and sensation had returned.    By this time he was running around as playful as before.    The following day the experiment was repeated under aseptic precautions.    Injec-

tions made one interspace caudad. The effect again was immediate, and his recovery from all disturbance of motion and sensation was complete in thirty minutes. Six days later the dog was killed by an overdose of chloroform. Meanwhile, he was in excellent health and showed no signs of disturbance in hind legs. The cord was very carefully dissected out, and when exposed only the site of the first (non-aseptic) puncture could be determined. This was seen as a small red spot on the cord, the track of the needle having been followed through the muscles and coverings of the cord. There was a slight injection and redness along the entire course. A transverse incision, made through the cord at sight of puncture, showed the needle to have reached to within one millimetre of anterior part of right segment. Its course was marked by a slight congested streak. Cord was hardened in formalin, and sections made through this area showed considerable round-celled infiltration in the course of the needle. There was some disturbance in the gray matter in this half of the cord, and in some areas evidence of degeneration. The right posterior horn showed a hemorrhage. Careful search failed to reveal the site of puncture of the second or aseptic injection.

86. Yellow cur; weight, sixteen pounds; good condition. Under aseptic precautions an injection of twenty-five minims of a one-half per cent. solution of cocain in third lumbar interspace produced complete paralysis within three and one-half minutes. Recovery began in fifteen minutes and was complete in thirty. The anesthesia was tested by Bunsen's flame, pinching, etc., and found to be complete. The experiment was repeated the following day, but met with failure. Three injections of twenty-five minims of a one per cent. solution of cocain injected in lumbar region. For some reason the needle failed to

enter the cord. The following day another injection of twenty-five minims of a one-half per cent. solution in lumbar region was followed at once by complete loss of motion and sensation. In sixteen minutes there was a slight return of motion, and in thirty-one minutes recovery was complete. The next three days the dog was carefully watched, but no disturbance of the hind legs was observed. The dog was killed by an overdose of chloroform. The cord was carefully dissected out. Careful and prolonged search failed to demonstrate the site of injection. Microscopically nothing abnormal could be seen. The cord was hardened and sectioned, but the site of the injection could not be found.

87. Large Dane; weight, twenty-five pounds; good condition. Under aseptic precautions many attempts to insert needle into the canal were failures. There was some slight constitutional effect. No effect on sensation or motion of hind legs. The attempts were repeated three days later, but likewise met with failure. Dog killed, and at an autopsy it was discovered that the spinous processes of lumbar region ran obliquely cephalad and that the needle had passed along and by them.

88. Large, healthy Newfoundland; weight, fifty-three pounds. Under aseptic precautions, after several failures to enter the cord with the needle, twenty-five minims of a one-half per cent. solution of cocain was injected into the canal in the lower lumbar region. There was immediate loss of sensation and motion, which lasted twenty-two minutes. The motion slowly returned and later sensation. Recovery was complete in forty-two minutes. The dog was kept in the kennel and very closely watched for ten days. At no time was there any evidence of im-

pairment of function in hind legs. The dog was apparently normal.

*Autopsy.*—Ecchymosis over lower areas in muscles and fascia at small lumbar region. Cut out spinal column just beneath this region. Cord apparently in good condition. Nothing could be discovered in the covering or the cord itself to indicate point of puncture.

89. Small, twelve-pound yellow bitch, in good condition. Under careful aseptic precautions twenty-five minims of a one-half per cent. solution of cocain were injected into lumbar cord. There was an immediate loss of sensation and motion, not so complete as in other dogs. Tested as before. Recovery was complete in twenty-two minutes. Paralysis lasted thirteen minutes. This one successful injection was preceded by two failures. Dog developed constitutional symptoms.

*Autopsy.*—Ecchymosis in fascia and muscles was found very low in sacral region. Cut out column from last lumbar to middle of sacrum. Only a few small nerve-fibres were found. At no point could injury be detected in cord. Evidently the needle had failed to strike the cord in this case, and only some filaments of cauda equina were caught.

### SUMMARY OF EXPERIMENTAL EVIDENCE.

*Histologic Examination of Cords.*—In the recovery experiments in the cases in which the solution was injected into the cord very great difficulty was experienced in locating the point of injection. Only in those cords in which no aseptic or antiseptic precautions had been taken at the time of injection could the track of the needle be traced with the unaided eye. Careful inspection of the cords in which aseptic precautions had been taken failed to reveal the point of injection. The cords were hard-

ened and sectioned throughout the approximate area of injection.   In but few instances was there any degeneration, infiltration, or hemorrhage found.   In the non-aseptic cords the track of the needle was readily traced by the slight congestion present.   Sections through this area after the cords were hardened showed some small-celled infiltration with some degeneration, and in one instance a hemorrhage into the right anterior cornu.   The needle had traversed the right half of the cord to within one millimetre of the anterior surface in this case.

*Effect upon Peripheral Nerve-Trunks.*—The injection of eucain or cocain into a nerve-trunk so as to place all of its structure in contact with the drug produces an effectual physiologic " block."   By the word " block" is meant such a condition of the nerve that neither afferent nor efferent impulses can pass, the conductivity being as completely interrupted as if the nerve were divided.   While general anesthesia prevents the appreciation of pain and the production of voluntary motion, it does not prevent such other afferent impulses as those caused by mechanical, thermal, or electrical stimulation of the nerve-endings or trunks, which produce changes in the frequency and the amplitude of respirations, in the frequency and the force of the heart-beats, and in vasomotor action.   Either eucain or cocain when injected into a nerve-trunk as above described prevents the passing of such afferent impulses, thereby preventing effects upon the respiration, the heart, or the vasomotor mechanism,—*i.e.*, *shock*. Under general anesthesia, if the paw of an animal is subjected to the flame of a Bunsen burner, after the lapse of a short time the leg is drawn up by the contraction of groups of muscles in a deliberate but rather forcible manner, removing the foot from the flame. General anesthesia, no matter how deep nor what anesthetic employed, does not prevent such action of the

muscles. It seems, if the expression may be allowed, to be an "unconscious purposive" action. Either eucain or cocain injected into the path of these afferent impulses prevents this phenomenon. If it is intended to produce an immediate effect it is necessary to make a thorough injection. If a little time is allowed to elapse, the solution need not be so directly injected into all the parts of the nerve-trunk. Even if injected underneath the sheath, without penetrating the substance of the nerve-trunk, a physiologic "block" may be produced. No unfavorable later effects were noted. In a number of cases in which the nerves were thus blocked, and the animal allowed to recover, there was but temporary functional impairment, and in no instance was there evidence of a neuritis or of degeneration following. The effect of the eucain and cocain upon nerve-structures is apparently the same as their well-known general effects upon protoplasm; that is, they temporarily suspend its functional activity. They form no chemical combination and cause no destruction either of its physiologic properties or of its substance. As to afferent impulses, it was found that the cortical discharges of the brain were blocked either when they originated as a voluntary action, or when they originated as an artificial convulsion produced by the administration of the essential oil of absinthe. Even powerful electrical currents applied to the nerve-trunk, near the block, were found to be incapable of forcing their impulses through the "block." That which has been said of the effect of cocain thus applied to the nerve-trunks may be said of like injections into the spinal cord. The effect upon the optic nerve is that of blocking the impulses of the light waves through this nerve, at least partially, and were the injections given directly into this nerve the "block" would probably be complete. Either eucain or cocain when applied upon the medulla

or fourth ventricle within a few seconds suspends the action of the respiratory centre. This suspension is characterized by a gradually increasing slowness of respiration, together with gradually decreasing amplitude, so that within thirty seconds respirations cease. The blood-pressure in nearly every instance suffers a profound depression, the nature of which is a gradual decline such as is observed on making a cross-section of the cervical spinal cord ; that is to say, the vasomotor centre or paths are anesthetized. Another effect of the application of eucain or cocain upon the medulla or the floor of the fourth ventricle is immediate complete general anesthesia and immediate total loss of all voluntary action. The corneal reflexes are at once abolished and the pupils are dilated. When the paws of the dog are exposed to the flame of a Bunsen burner the legs are not drawn up, the blood-pressure is not altered, and the heart's action is not affected. It is needless to say that there are no respiratory changes. In other words, application of these anesthetics upon the medulla or the floor of the fourth ventricle suspends temporarily all the manifest functions of that organ excepting the heart's action, and that is modified. General anesthesia may be indefinitely prolonged by repeated applications. Upon the vagi the effect of an injection of these drugs is to suspend their inhibitory action. The action of cocain is probably a little more prompt than that of eucain ; the latter, however, seemed to be quite as effective as the former. Cocain and eucain block the impulses set up by electrical stimulation in nerve-trunks even after death ; that is, if after the death of an animal a nerve-trunk is stimulated, within a certain time the muscles supplied will be thrown into contraction ; but if cocain or eucain is injected into the nerve-trunk and a stimulus applied above it, no contraction will occur.

The physiologic action of cocain and eucain, both local and general, are so nearly alike that one description may serve for both. The first effect observed after an intravenous injection is a temporary increase in the blood-pressure. This increase appears almost immediately, and continues for a brief period of from five to twenty seconds, when the blood-pressure returns to or near its former level. The heart-strokes forming the curve are usually a little shorter, and the rapidity of the heart's action is somewhat increased. No definite vasomotor change was indicated by the peripheral venous or peripheral arterial manometers. A water manometer recording the splanchnic blood-pressure indicated a rise out of proportion to the rise in the general blood-pressure. In rare instances there was a fall in the blood-pressure, but compensation was immediately inaugurated and the lost pressure was quickly regained. In overwhelming doses with lethal effect the general blood-pressure, in fact all the pressures, rapidly sank to the abscissa line. It was noted that when an animal was under the systemic effect of these drugs the blood-pressure curve was, as a rule, not so regular as under normal conditions. It was also noted that in a number of experiments the length of the stroke of the writing style, expressing the heart's action, was shortened under the systemic effects of these drugs. This irregularity of the blood-pressure curve was similar to the irregular curve when the animal was under physiologic dosage of atropin or when both vagi had previously been severed. It was also found that when animals were under the effect of these drugs, stimulation, by applying the electrodes upon the vagi, did not produce normal characteristic effect; that is to say, that while in normal conditions the application of a Dubois-Reymond electrode upon the vagi causes slowing or arrest of the heart, in animals under the systemic in-

fluence of cocain or eucain the application of such stimulation to the vagi in most instances produced little or no effect. In a number of experiments it was observed that if after having secured a control tracing of the inhibitory effect of intralaryngeal manipulation the animal was subjected to a physiologic dosage of cocain or eucain, a like manipulation of the larynx usually produced no inhibition. In the experiments in which inhibition was noted it was in most instances less than normal. The same may be said of other experiments upon the superior laryngeal nerve. The physiologic effect of cocain and eucain in this respect is quite analogous to that of atropin, though the effect is not so marked. The increase in the blood-pressure after the administration of cocain is in a measure similar to that which follows section of both vagi. Taking into consideration all of the evidence, it would seem that cocain and eucain partially or wholly suspend the inhibitory function of the vagi, whether produced by direct or indirect stimulation. While not prepared to make a positive statement on the subject, it appears that the increased rapidity of the heart's action under the influence of these drugs was due to the removal of the vagal influence and not to stimulation of the accelerators. The splanchnic area, especially the veins, when the abdominal viscera were subjected to exposure or irritation, or both, was dilated, the intestines became red, extremely congested, and often livid. When the animal had been given a physiologic dose of cocain or eucain and exposed to like experiment the splanchnic vessels did not dilate, excepting those at the bases of the intestines. The arteries became decidedly smaller and the intestines a peculiar palish red. In a large series of control experiments it was found that with but rare exceptions such irritation or exposure of the splanchnic area caused a fall in the general blood-

pressure proportional to the exposure or irritation and the condition of the animal. In some instances the fall was extremely rapid and the animal soon died, but in a series of experiments in which cocain was systemically administered there was but slight, if any, fall in the general blood-pressure. There was a striking difference between the results in the control experiments and the " cocain" ones. In order to make the comparisons more reliable double experiments were performed. Two animals of as nearly the same size and under as nearly the same conditions as possible were placed side by side on similar dog-boards, and precisely the same experiments were simultaneously performed upon each. In every instance the benefit of any doubt was allowed the control dog. The writing style recording the blood-pressure and the respiratory action of each was placed in a vertical line, so that direct comparison could be accurately made. The result of these double experiments may be summarized as follows. In the control dogs exposure and manipulation of the intestines produced a fall in the blood-pressure; in the cocain and eucain dogs, as a rule, no fall occurred. The cocain and eucain dogs endured more mechanical injury than the control dog. The latter in every experiment died first. In burning the hind feet of the animals the blood-pressure in the control rose higher and more promptly than in the cocain or eucain animals. In crushing the testicle the blood-pressure fell more promptly and a greater distance than in the cocain or eucain dog. The same may be said of manipulation of the larynx, stimulation of the vagi, operations in the pharynx,—in short, of every portion of the body. The comparison between the appearance of the abdominal viscera in the control dog and that in the cocain or eucain dog is that in the latter the intestines were of a peculiar shade of pale red, and the vessels were, if any change was noted,

of less calibre than before the experiment; while in the control dog the vessels were all engorged, the viscera exceedingly red, and in many instances livid. It was at once apparent that the difference between the amount of blood in the splanchnic area in these two animals was very great. Even the inferior vena cava was smaller in the cocain animals. The effect upon the circulatory apparatus is, first, an immediate rise in the blood-pressure lasting a few minutes, followed by a compensatory fall. Later, a gradual rise occurs. The inhibitory influence of the vagus is partially or wholly suspended. The vasomotor reflexes are very considerably lessened. The circulatory apparatus is less responsive to stimulation. The latent period of vasomotor reflex action is markedly increased. The vessels of the splanchnic area are contracted.

There is but little doubt that there is an increased tendency to clotting. Upon the respirations a small dose seemed to act as a stimulant. A medium dose seemed to lessen the length of the respiratory stroke, while a large dose caused respiration to gradually diminish. It was frequently observed that if a series of injections of these drugs were administered at given intervals a very marked tolerance was acquired, so that finally but little effect could be produced. It was also observed that animals under the influence of these drugs were more difficult to maintain in the condition of even surgical anesthesia. More general anesthesia seemed to be required, and the animals had a tendency to come unexpectedly out from its influence.

### SPINAL CORD ANESTHESIA.

INJECTION INTO THE CORD.—In 1897, after performing the experiments upon nerve-trunks showing that cocain was capable of producing physiologic section,—that.is to

say, the afferent or efferent impulses could not pass the point cocainized,—and after having performed amputations on the human subject without pain and without shock by this method, similar procedures upon the spinal cord were suggested. The experiments along this line consisted in injecting the solution directly into the substance of the cord. This produced immediate anesthesia at all the points with which the cocain came in contact. Although the anesthesia was immediate and complete, and for operative purposes was entirely satisfactory, it was obvious that this procedure necessitated a physical damage to the cord.

Recovery experiments were made as follows : The cord was anesthetized by injecting cocain directly into its substance by means of a fine needle. The completeness of the anesthesia was proved, the animal allowed to recover, and after the lapse of varying periods of time was killed. The cord was subjected to microscopic examination. While in some of the cases it was impossible to detect any microscopic damage to the cord, there was found some round-celled infiltration and disturbance of the normal histologic arrangement. It was at that time concluded that this was not a justifiable procedure in any but most exceptional cases. Later experiments were made by injecting cocain into the subarachnoid space. In dogs this space is so small that it is necessary to expose the cord in order to make an injection without traversing the cord. The injection of a one per cent. solution of cocain into this space produced almost immediate anesthesia.

SUBARACHNOID INJECTION.—*Effects on the Circulation.*—The effect of injecting a solution of cocain into the subarachnoid space in the lumbar region was an immediate fall in the blood-pressure, the beginning of the fall being almost coincident with the contact of the solution of cocain with the cord. The depth of the fall was pro-

portional to the completeness and the anatomical parts involved.  The curve in the descent of the blood-pressure was gradual and even, after which a regular line was maintained for some distance, which indicated the loss of vasomotor control.  The effect upon the blood-pressure when the medulla or the fourth ventricle was cocainized was the greatest of all, the pressure falling almost to the abscissa line.  When the cord had been subjected to the influence of cocain and the pressure had fallen as above described, if any part of the body below the level of the cord cocainized was subjected to burning, crushing, or any other mechanical, thermal, or electrical stimulation, no rise in the blood-pressure occurred.  There was usually but a trifling amount, if any, of compensation after the fall of the blood-pressure until the cocain effects passed off.

*Effects on Respiration.*—The immediate effect upon respiration, of a subarachnoid injection of a comparatively small amount of cocain in any part of the spinal cord, not involving the medulla, is acceleration.  The application of a one per cent. solution of cocain upon the medulla or the floor of the fourth ventricle produced within a period of time, ranging from a few seconds to a few minutes, complete respiratory paralysis.  There is first loss of the intercostal and the extraordinary muscles, then the abdominal muscles, and lastly the diaphragm.  The action of the diaphragm becomes shallower at each contraction until it is entirely paralyzed.

The membranes of the cord are so nearly inelastic that for the present purpose they may be regarded as being so, while the cord itself is so nearly incompressible that it may be so considered.  The subarachnoid space is always filled with its own fluid.  If additional fluid is added, it must cause a displacement similar to that of fluid in a capillary glass tube.  The rapid and uncon-

trollable ascent of the anesthesia of the cord was most
striking.   In order to better study this a series of injec-
tions was made with cocain solution colored with methy-
len blue.   It was found that an ordinary injection in the
lumbar region of one-half dram of this solution stained
the entire cord and the under surface of the brain within
thirty seconds.   All the various localized functions of the
cord and medulla were with rapidity anesthetized.   The
respiratory centre in the medulla, for example, could be
anesthetized by lumbar subarachnoid injection within a
few seconds, so rapidly did the fluid pass up the cord.
Marked fall in the blood-pressure and cessation of res-
piration occurred within a few seconds, after a rather
forcible injection in the lumbar subarachnoid space.   The
fluid ascended about as readily in a vertical posture as
in a horizontal.   There can be but little doubt that the
effect is due to the local contact of the nerve-structure
and not to absorption.   This view is in full accord with
the general action of cocain on other nerve-tissue.   A
solution injected with considerable force into the lumbar
subarachnoid space was attended immediately by convul-
sions.   The convulsions were due to the stimulation of
the convulsive centre in the medulla.   The dosage used
in these experiments was purposely made large to deter-
mine the control, or rather the want of control, the oper-
ator could have upon the extent of the anesthesia.   In
control experiments in which normal saline solution was
injected into the spinal cord an immediate fall in the
blood-pressure occurred, but compensation quickly fol-
lowed.   The respirations were but slightly affected.   There
was the most striking difference between the overwhelm-
ing paralysis in the one case and the want of it in the
other.   The experiments showed that the operator has
but little control over the extent of the anesthesia pro-
duced under a subarachnoid injection.   While direct

injection into the cord gave a complete control of the extent, it produced a distinct mechanical lesion.    In the clinical reports of the subarachnoid anesthesia the experimental data have been corroborated.    This was most strikingly exhibited in a case described by Fowler, in which the anesthesia during three minutes extended up to the level of the clavicle, at which time the patient became cyanotic and artificial respiration was necessary.  Other observers have noted the marked effect upon respiration, the lowered blood-pressure, and the rapid pulse, the latter indicating that the cocain solution was affecting the centres in the medulla.    In six hundred and ninety-two cases there were six deaths that were attributable to the anesthesia, a mortality rate at least fifty times greater than that of chloroform.



FIG. 14.—Showing the most accessible portion of the anterior crural nerve.

ON THE CLINICAL APPLICATION OF THE EXPERIMENTAL EVIDENCE.—*Operations on the Extremities.—Leg.*—The " blocking" method was employed independently by Dr. Rudolph Matas, of New Orleans, of which his brilliant monograph on anesthesia gives a full account.  Applying the so-called physiologic " blocking" properties of cocain or eucain to surgical practice, we have been enabled to perform certain operations upon the extremities without causing pain and without shock by injecting a one per cent. solution of

cocain into the supplying nerve-trunks. The external
cutaneous nerve is so superficial that it is readily acces-
sible. The anterior crural is easily exposed in its rela-
tions with the artery and the sciatic at the margin of the
gluteal fold, along the inner border of the biceps muscle.
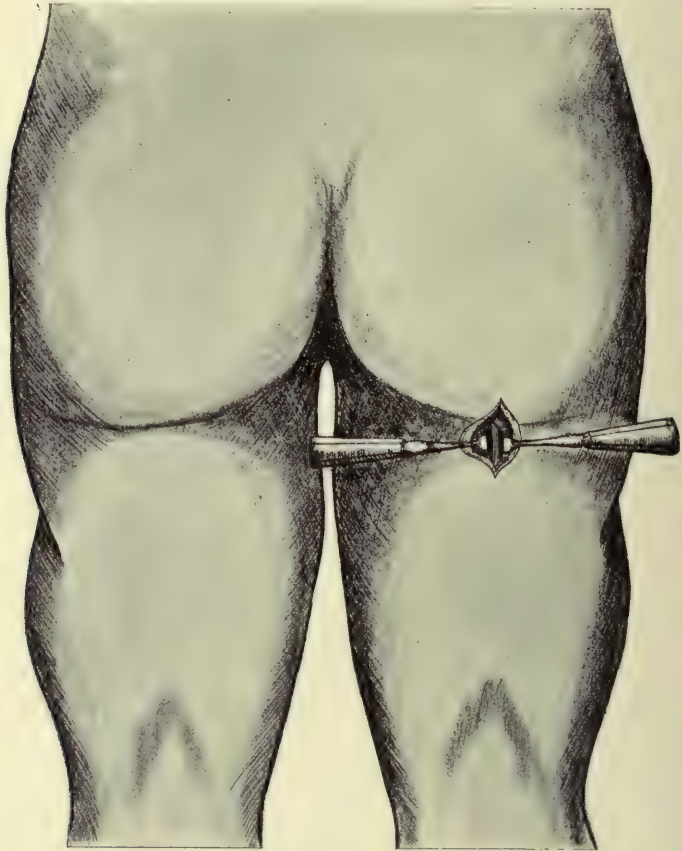


Fig. 15.—Showing the most accessible portion of the sciatic nerve.

In operations performed upon the area supplied by the
"blocked" nerve-trunks the afferent impulses cannot
reach the central nervous system. There is, therefore,
neither pain nor shock. This method is of the greatest
possible importance in operations in which general anes-

thesia is for any reason contraindicated. The operation under these circumstances cannot cause any more shock than if the member had no connection with the body, as the " block" for all such purposes is equal to a physiologic amputation.

In this manner I have five times performed amputation of the leg below the knee, and in all but one the person was not aware that the operation was performed until told of it afterwards. It is necessary to control the patient well. After preliminary preparations have been made, the patient's attention should be diverted. I have usually said that an examination and a dressing would be made requiring considerable time and that the operation would be performed the next day. In the mean time the eyes were covered. In the one case the patient became aware of the progress of the operation by hearing the noise of the saw while dividing the bone. The " block" continues from twenty-five to thirty minutes. The clinical observations are in entire accord with the experimental evidence.

*Operation in the Area of the Distribution of the Ulnar Nerve.—Remarks.*—The superficial position of this nerve at the elbow-joint enables the surgeon to apply a cocain or eucain " block" almost painlessly by inserting a hypodermic needle, first into its close vicinity, then into the trunk itself, injecting the solution on its way. After the lapse of ten minutes the entire area supplied will be rendered anesthetized, and if the patient's attention is diverted, operative procedures, such as amputations and resections, may be performed painlessly and without the patient's knowledge.

*Report of Cases.—Case* 1.—A railway employee whose hand and little finger were severely crushed within the area of the distribution of the ulnar nerve required amputation and revision. Bending the elbow, a wheal was produced by injecting a one-twelfth per cent. solution

of beta-eucain, thereby creating a painless path to the nerve-trunk, which was then anesthetized. In a few minutes there was complete anesthesia, and the finger and the corresponding metacarpal bones were removed while the patient was an interested spectator. The night following this operation the patient complained of a burning sensation over the distribution of this nerve. There was some local tenderness at the point of injection, but this disappeared after several days.

*Case* 2.—A small boy discharged a pistol, which took effect in the ulnar side of the hand, tearing away the soft parts and a portion of the fifth metacarpal bone. By "blocking" the ulnar nerve at the elbow the wound was revised, and fragments of the bone removed without pain. In this case there was no complaint of the burning sensation described in the preceding. The wound healed readily.

*Case* 3.—In a tubercular subject a local focus appeared on the metacarpo-phalangeal joint. In performing an operation for the removal of this focus, the ulnar nerve was "blocked." At first an attempt was made to secure anesthesia by injecting the solution around the nerve, but after waiting five minutes it was found that the anesthesia was only partial, and that it was necessary to inject the nerve itself. In performing this operation it is best to fix the nerve well against the bone and insert the needle gradually as anesthesia occurs in advance of the needle. After such an injection the anesthesia was complete, and the operation was performed painlessly. This patient complained of some burning the first night, but the second day it decreased and was not again experienced.

*Observations.*—In two other cases this nerve was in a similar manner "blocked." In each the anesthesia was complete in from five to ten minutes and no after-effects were noted. In no case was there any interference with

the function of this nerve in consequence of the injection. Neither did the points at which the injections were made remain tender.    No neuritis followed.

*Amputation at the Shoulder-Joint.*—Amputations at the shoulder-joint are usually indicated on account of a serious accident or disease, and in consequence such operations are frequently performed under unfavorable circumstances.    There has been a considerable mortality following this operation even under the more favored conditions. In operations for malignant disease in the aged, and operations in the presence of profound depression or shock, general anesthesia adds seriously to the danger.    There are many instances of contraindication to the use of general anesthesia.    A method by which this operation may be performed without general anesthesia, without shock, and without hemorrhage, was devised in accordance with the experimental evidence set forth in the preceding pages, and put into practice in June, 1898.

*Technique.*—The technique is based upon the fact that nerve-trunks may be safely and effectually subjected to a physiologic "block" by injecting cocain or eucain in comparative weak solution, and that arteries may be, with entire safety, temporarily closed without injuring their walls.    Fortunately in the application of these principles, in amputation of the shoulder-joint the subclavian artery is in close surgical relation with the brachial plexus, so that the same incision may be utilized for exposing the nerve and the blood-supply.

*Report of Cases.*—*Case* 1.—Female, aged seventy-four, was suffering from a sarcoma of the arm, situated in the lower third and extending well down to the elbow. There was a metastatic growth in the axilla.    She was suffering great pain and the tumor was growing rapidly. Owing to her extreme age, an amputation at the shoulder-joint by the methods hitherto in vogue, giving a general

anesthesia without "blocking" the nerve-trunks to protect her against the afferent impulses caused by the mechanical irritation of the amputation, thereby producing shock, would have been a risk too great to assume. It was decided to perform the operation by employing the technique above described. An incision was made along



Fig. 16.—Point of election in making the incision for exposure of the subclavian artery and the brachial plexus.

the outer border of the sternomastoid muscle under one-tenth per cent. infiltration cocain anesthesia. The dissection was carried through the superficial and the deep fascia, exposing in the first part of the incision the external jugular vein. The lower end of the incision was carried well down on the clavicle. The omohyoid muscle was retracted downward, the anterior margin of the tra-

pezius backward, and the posterior margin of the scalenus anticus forward, thereby exposing the trunks of the brachial plexus, and by extending the dissection a trifle farther downward and inward the arching subclavian artery was brought into the field.   In making this dissection it is important to keep the field of operation en-



Fig. 17.—Showing the point of election for exposing the subclavian artery and the brachial plexus.

tirely free from blood, so that the translucency of the tissue will permit the ready recognition of the anatomical structures in their minutest detail.   It will then be possible to detect small nerve-twigs before they are encountered and enable the operator to subject them to local anesthesia in advance.   In this way the area supplied by

these branches may be rendered anesthetized. The small vessels may be caught with narrow-bladed forceps, between which the incision may be carried. The smaller nerve-twigs are usually found running along the blood-vessels or in the connective-tissue planes. It was observed in this dissection that in the deeper structures the sensory nerve-supply is not so abundant as in the more superficial. After exposing the trunks of the brachial plexus, there being but a slight amount of pain in the dissection, they were subjected to a physiologic " blocking," by injecting first on their outer covering, then into their substance, a one-half per cent. solution of cocain, just sufficient to cause a localized swelling. It required but a small amount of solution to accomplish this. After injecting each trunk there was a total loss of sensation and of motion in all the parts supplied by the brachial plexus. The subclavian artery was then closed by means of a special clamp, over the blades of which rubber tubing was drawn. The blades were then approximated by adjusting the screw sufficiently to close the lumen of the vessel. The patient was then told that the operation would not be performed at that time, but would be deferred until the next day. A towel was thrown over her eyes, and under the pretext of making a careful examination of her arm the amputation was made without her knowledge. The flap on the outer and posterior aspects over the deltoid was made rather low, because of the cutaneous distribution of branches of nerves from the cervical plexus, which of course had not been included in the physiologic " block." She experienced no pain except a slight one as the incision was carried around the posterior surface of the upper portion of the arm supplied by the supra-acromial nerve. The pain was, however, comparatively slight, and was felt only during the incision of the skin. During the disarticulation the patient was not at all aware that she was being touched.

After the operation had been completed it was found there was absolutely no shock and that the operation had made no appreciable impression upon her. The vessels were all picked up and tied before releasing the clamp from the subclavian. The total amount of cocain used in the operation was about one-eighth of a grain. A portion of this amount was recovered by sponging away the free solution in the wound. When the patient was returned to her bed she was not aware that her arm had been removed. She soon missed it, and manifesting some excitement was informed by the nurse. She experienced some pain several hours after the operation and vomited several times the first night. She made a good recovery from the operation, and there was nothing in the after-progress of the case different from operations performed in the usual way.

*Case* 2.—Amputation of the arm at the middle was performed by the same technique as the preceding without producing any pain and without the slightest shock. Patient made a good recovery. The operation was performed on account of moist gangrene of the forearm in a patient having advanced pulmonary tuberculosis.

*Amputation of Half of the Shoulder-Girdle.*—*Remarks.* —This operation has been performed a number of times by various methods. The purpose of discussing it is to point out a technique by means of which hemorrhage and shock may be almost wholly avoided. Under general anesthesia an incision is made over the clavicle and the inner half of this bone is resected, after which the subclavian vein and the trunks of the brachial plexus are exposed. The trunks are then subjected to a physiologic "block" of cocain or eucain in comparatively weak solution,—say one-half per cent. The brachial plexus is next severed, the artery and vein closed by ligature. The incision for the further technique in removing the scapula will vary

with the object for which the operation is done. The amount of shock will be limited to what would be produced by making the incision through the structures sup-
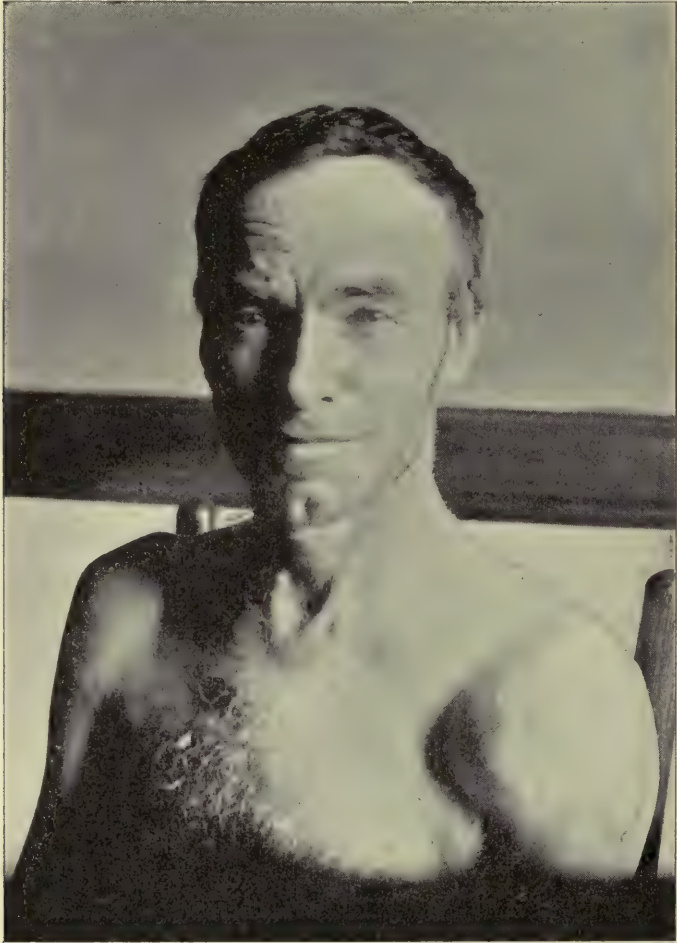


FIG. 18.—Showing sarcoma of the head of the humerus involving the scapula.

plied by the nerves from the cervical plexus, which is almost *nil*.

*Observations on the Pharnyx.*—Clinical experience, as well as physiologic experiments, have demonstrated that

when the pharynx is subjected to a considerable manipulation, especially that portion nearest the glottis, reflex inhibition both of the respiration and of the heart may
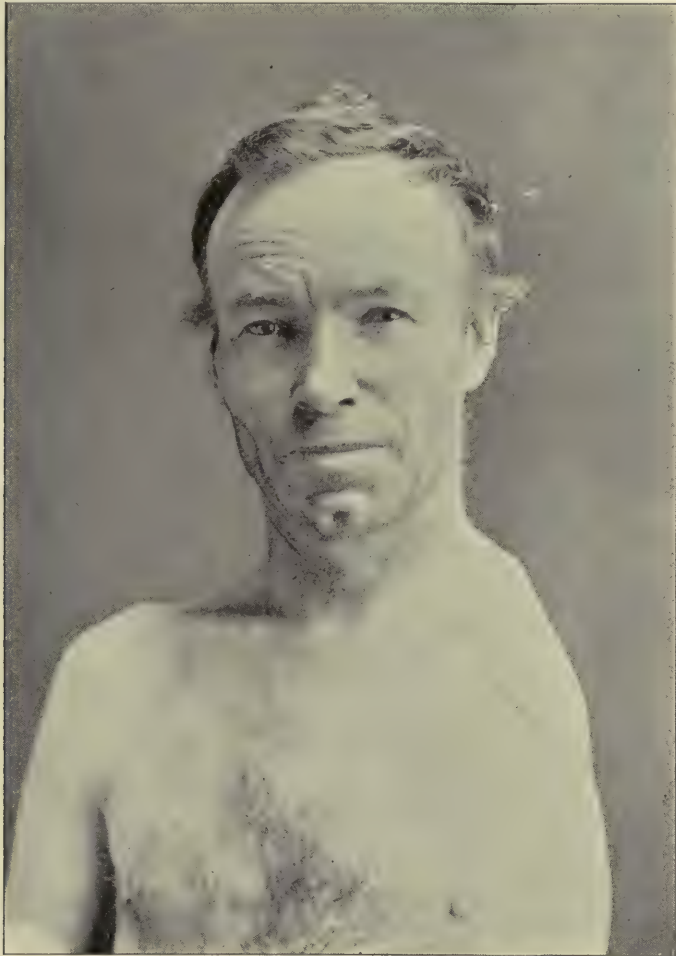


FIG. 19.—Patient upon whom excision of the left half of the shoulder-girdle was made.

occur.   The respiratory inhibition is the more frequently produced.   In the cases in which manipulation required considerable force the heart may be inhibited, causing collapse.   I have observed this reflex inhibition of both

the heart and the respiration in removing a tumor of considerable size from the nasopharynx. In operations for removing adenoid growths from the nasopharynx these phenomena have also been observed. In extracting large foreign bodies collapse may be produced. Not infrequently, in performing difficult operations in this portion of the pharynx, reflex inhibition confuses the operator. The respiratory inhibition is likely to give the impression that the patient is suffering from mechanical obstruction. The inclination might be to clear out the upper respiratory passage, but this additional irritation would increase the symptoms. In the experiments it was found that reflex inhibition in this area may be prevented by the local application of a two per cent. solution of cocain. The solution may be as weak as a one per cent., or even a onehalf per cent., and be effectual. A hypodermic injection of atropin prevents reflex inhibition of the heart. In cases necessitating the removal of adenoid growths and tumors of the pharynx the efficiency of these drugs was proved. It is advisable, before beginning the technique of an operation involving this area, to make a local application of a solution of eucain or cocain, and a hypodermic injection of atropin, to prevent reflex inhibition. If during an operation inhibition does occur, the distinction between inhibition and obstruction must be borne in mind,—for if the case is one of obstruction there will be increased respiratory efforts, but if it is a reflex inhibition respirations instantly cease. In obstruction the pulse continues unaltered for some time before it becomes markedly slower. In reflex inhibition the pulse is instantly and markedly slowed or arrested.

*Laryngotomy.—Remarks.*—Not infrequently in this operation at the moment the larynx is opened the patient goes into a state of collapse from which he may never recover. This operation is more frequently performed on

children, oftentimes in great haste, under the stress of circumstances.   If the operation is performed through the cricoid, collapse at the moment of entering does not occur.   If made higher, it is very likely to occur, the reason being, that in the higher operations the inhibition area of the larynx is mechanically stimulated.   This causes a reflex inhibition, as in operations upon the pharynx.   The superior laryngeal nerves . are endowed with very strong inhibitory functions, which are more active in the upper part of the larynx.   The clinical observations are in entire accord with the experimental evidence.

*Report of Cases.*—*Case* 1.—Dr. M—— called in a colleague to aid in performing a laryngotomy upon a child who had a grain of corn in the larynx.   The operation was successful until the larynx was opened, when suddenly collapse occurred, resuscitation seeming impossible. During the first stages of the collapse the grain of corn was removed.   Artificial respiration was maintained for a time, though life seemed extinct, when suddenly respirations began and there was an uneventful recovery.

*Case* 2.—I was called to see a child three years old having a large bean lodged in the larynx.   The history of the case was that the child while playing with the bean, in a fit of laughter, inspired it into the larynx. Paroxysms of coughing followed.   These occurred at intervals.   Each time the child stopped breathing, became cyanotic and apparently dead.   After a brief interval respiration returned, but another paroxysm soon followed with a repetition of the collapse.   From these symptoms alone the location of the bean was diagnosed as being in the upper part of the larynx.   An operation under local anesthesia was performed.   The incision was made through the cricoid cartilage, below the so-called inhibition area, and the laryngeal mucosa was treated with

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a two per cent. solution of cocain, after which the larynx
could be readily explored, the bean located, and removed
without inducing reflex inhibition.

*Observations.*—Cases might be multiplied, but the fore-
going are typical. The difference between reflex inhibition
and obstruction is very marked. Reflex inhibition cannot
be produced by a foreign body at any point below the
so-called inhibition area of the larynx. The importance
of the use of local anesthesia, to prevent reflex inhibi-
tion in laryngeal operations, cannot be overstated.

In all the operations upon the larynx, especially in
laryngectomy and intralaryngeal procedures, the use of
cocain or eucain is of the greatest importance. In laryn-
gectomy especial attention has been called to the collapse
that not infrequently appears while removing the larynx
from its attachments.

Bardenhauer encountered this three times in one case
while inflating the Trendelenburg apparatus. In intuba-
tion sudden death frequently occurs, the collapse being
due to reflex inhibition of either the respiration or the
heart, or both. Cocain or eucain applied upon the mu-
cous membrane wholly prevents such reflex inhibition.
If such local application cannot be applied, all the
necessary arrangements for the maintenance of artificial
respiration may be made in advance. A hypodermic in-
jection of atropin will prevent the cardiac inhibition,
so that, without the use of local anesthesia, atropin, with
artificial respiration, may be depended upon to carry
the patient over an inhibition crisis. In one hundred
and fifty-six intubations, I have encountered reflex in-
hibition six times, twice fatal, and they occurred before
the nature of the inhibition was comprehended. Since
making use of the experimental data, no case has been
lost from reflex inhibition or " laryngeal collapse."

Death cannot occur as a result of reflex inhibition if

a preliminary hypodermic of a physiologic dose of atropin is given. The use of cocain is not practical in intubations for diphtheritic stenosis.

*Clinical Summary.*—In the clinical use of cocain and eucain particular attention is called to a most important feature,—viz., that shock is almost wholly avoided as all afferent impulses are blocked. It is now known that the afferent impulses set up by injury or operation are the causes of shock. These impulses are but slightly modified by general anesthesia. The afferent impulse, constituting pain, is abolished by general anesthesia, but those affecting the vasomotor, the respiratory, and the cardiac mechanisms are not controlled; but cocain or eucain absolutely blocks their passage, making a physiologic amputation of the part. These anesthetics also wholly prevent reflex inhibition, the principal causes of collapse in operations and injuries,—*e.g.*, operations on the larynx and pharynx. Given hypodermically, the experimental evidence shows that they diminish shock in operations on the splanchnic area and absolutely alter this area in the processes of operation or exposure, as abundantly proved by the series of double experiments.

I have had but two opportunities of testing this clinically, both in operations for gunshot wounds of the intestines, and in each the experimental evidence seemed to be corroborated. Comparative results require such a large number of observations that I prefer for the present to offer no more than the clinical suggestion.

## ON THE EFFECT OF TEMPORARY CLOSURE OF THE CAROTID ARTERIES.

*Remarks.*—The question of effectually controlling hemorrhage in certain operations upon the head and neck has always claimed the attention of practical surgeons. An experimental research was undertaken for the purpose

of determining, first, the direct and the indirect effect upon the circulation and respiration from the closure of both the common carotid arteries; second, the effect upon the arteries themselves by such closure; third, the after-effect; and fourth, the best means of accomplishing the same.

From the account of Rufus of Ephesus it appears that the result of compressing the arteries was known to the ancients previous to the time of Galen. In his age it was discovered that the effects were produced by the compression of the sensitive nerves which lie near the arteries, and not from interference with the arteries themselves.

Galen says that in experiments upon the carotid arteries the greater number included the nerves in their ligatures with arteries; and that the effects, such as loss of voice, etc., which they incorrectly called sleep, were ascribed by them to the arteries; but Galen, denying that sleep is thus produced, denies also that any other function suffers injury from tying the arteries.

Avicenna remarked that when these vessels are ligated sense and motion are immediately lost. Morgagni adds that Carolus Stephanus and Bagliri agreed with Avicenna in this opinion.

Valverdus observes that, the carotid arteries being obstructed, or from any cause closed, we immediately grow stupid and fall asleep, and states that he saw this experiment made at Pisa in the year 1554, on a young man, in a large circle of gentlemen, equally to the terror and to the amusement of the operators, who persuaded them that it was done by the force of incantation.

Enettus tied the carotids and jugulars in a dog, which afterwards enjoyed the most perfect health and vivacity for some weeks; but upon frequently repeating the experiment, though none of the dogs were seized with apoplexy or died, it happened that for a space of two hours the animals seemed sleepy.

Valsalva tied both carotids in dogs three times, with variable results. In the first case the vivacity and vigor of the animal were impaired, but it retained full power of motion in all parts of the body. Afterwards, however, swelling of the lips, head, and anterior part of the body, with profuse discharge from the mouth, and great weakness supervened. The animal died on the sixth day. In the second dog there was the same drooping of the head and weakness of the muscles. The animal remained in this stage, refusing food for six days, when secondary hemorrhage occurred. The dog recovered. The third animal was averse to food and appeared almost rabid, barking at every one. It died in three days.

Drelincourt found that the incomplete obstruction of the carotid of a mastiff produced lethargy, which disappeared when the head was raised and one of the carotids opened.

Dionis found that the operation rendered the dog sleepy for a time, but that it recovered after some days.

Lamur, on the contrary, found that tying both carotids in a dog produced no stupor.

Von Swerten tied both the carotids of a dog, but could not perceive that the animal suffered any injury from the operation.

Bichat's experiments upon this subject led to no uniform results. Sometimes the animal appeared stupefied, at others no change occurred. In general, he says, "the obliteration of the carotids is not suddenly fatal." Two of the animals, however, upon which he operated survived only two hours.

Dr. Keller tried this experiment repeatedly, and found that, although the animals were kept alive for several days afterwards, they appeared to suffer no inconvenience.

Dr. James Spence made some experiments upon the lower animals which led him to decide that the two principal arteries of the neck may be tied with impunity.

In 1831 Professor Mayer, of Bonn, published the results of a series of experiments upon animals, which he had undertaken with the hope of setting this question at rest. "To determine the effects of ligature of the arterial trunks proceeding to the brain," he applied a ligature to one or both of the carotid arteries in eighteen different cases in rabbits, dogs, and pigeons, in a horse, a goat, and a marmot, but with different effects, according as the circulation of one or both vessels was interrupted. Where one carotid was tied, there appeared slight insensibility and even loss of power. These symptoms were temporary, and after two or three hours the animal presented no remarkable change. When both carotids were ligated, most of the animals died. Both common carotids were tied in nine rabbits and two dogs; in one of these no remarkable effect was produced; in three very severe symptoms ensued, but the animal ultimately recovered; in three the operation was fatal. Among the symptoms stated to have been produced are the following: diminished cardiac and pulmonary action, falling of temperature, lethargy, stertor, wavering of head, lolling of head to one side, tremor, decussating palsy and insensibility of the eye and ear, giddiness, inability to stand, convulsions, trismus, tetanus, chorea, and strabismus.

In 1836 Sir A. Cooper experimented in two instances (in rabbits): in one of the animals respiration was merely quickened for a few moments, and in the other the heart's action was increased.

Mr. Jobert de Saurtalle in his experiments found that this operation could be performed with impunity upon the dog, sheep, rabbit, and a calf, but was fatal in a horse.

*Effects of obliteration of both primitive carotid arteries in the human subject.*

Under this heading Chevers states that in five cases

upon record in which, either by surgical operation or in consequence of disease, both of the primitive carotid trunks became obliterated at different periods, the individuals survived without suffering in any remarkable degree from cerebral disorder.

The author further states: "I find fourteen instances in which obliteration of one of the carotids was distinctly followed by great interference with the circulation through the brain, which in eleven cases produced fatal results."

In conclusion he gives the following deductions: That by far the larger portion of those in whom the primitive carotid artery, on one side, is obliterated recover.

Mr. Thomas Inman, London, October 5, 1843, found that in forty cases in which the carotid was tied eleven died.

A considerable number become hemiplegic and perish from disease of that hemisphere of the brain which corresponds to the obstructed artery. The conclusion that obliteration of one carotid artery is never liable to be followed by impairment of the cerebral functions must therefore be discarded.

The larger portion of deaths after ligature of the carotid occur from affections of the respiratory organs.

Kussmaul and Tenner, on "Convulsions," etc., under the heading "Compression of the Carotid in Man," write:

"During the present century compression of the carotids was introduced as a remedy by Caleb Parry, and brought into very general use. For ample details on this subject we are indebted to the distinguished Jacobi, of Siegburg. It occurred to us, however, that neither Jacobi, who assures us that he performed some hundred experiments, nor any of the numerous authors who have investigated the subject of compression, such as Trousseau, Bland, Dezeimeris, Lallier, Strechlin, Romberg, Fleming, and some others, made any mention of the convulsive attacks

following these experiments. Jacobi relates the following symptoms as generally observed : dimness of sight, dizziness, stupor, weakness in the legs, staggering, swooning, loss of consciousness, and sudden apoplectic falling down, and in these agrees with what is described by the above authors. It seemed, however, improbable that the results in every case should be limited to these precursory symptoms of epilepsy, and that no convulsions should ensue. Fresh experiments were therefore deemed necessary. In six male adults complete compression of both arteries was made. In all the face turned pale. First they made convulsive efforts to close the eyelids; in four of them the pupils at first contracted ; in all they became eventually much dilated. The contraction at the commencement was very considerable. Although the experiments were performed in a moderately darkened room, still the pupils became remarkably contracted, even more so than afterwards, when strong daylight was readmitted. As soon as the dilatation of the pupils began to take place the respiration became slow, deep, and, as it were, sighing. Afterwards dizziness, staggering, and unconsciousness ensued, and the patient would have fallen but for support. In two subjects of weak intellect, and moderately anemic, in whom, notwithstanding the above symptoms, the compression was continued, a choking sensation, attended by vomiting and general convulsions, occurred, which, however, did not attain an aggravated form, for on withholding the compression it disappeared in a few seconds. In one instance a twitching in the muscles of the cheek was observed previous to the attack of general convulsions. The face became suffused, the eyes moist, and the pupils more and more dilated as the thumbs were removed from the neck. Consciousness and volition did not return immediately, but after the lapse of a few seconds, while the red appearance of the face gradually subsided. The

first inspirations upon the restoration of the circulation were deep.    No further prejudicial consequences ensued.

"We consider it, then, established that compression of both the carotids in men may occasion loss of consciousness, dilatation of the pupils, prolonged breathing, and general convulsions,—in short, all the symptoms of a slight epileptic attack.    As these experiments were not always successful, it is well to consider that in closing the carotid no complete stoppage in the flow of arterial blood from the brain is occasioned, and that the arrest itself is mainly compensated by the collateral circulation kept up by the vertebral arteries.    Still, the probability becomes stronger that the sudden retention of all the blood conveyed to the head will have the same result in the human being, when experiencing the loss of much blood, as in other warm-blooded animals; that is to say, that sudden occlusion of all the arteries of the head will as certainly produce epileptic convulsions in man, as has been proved to be the case in rabbits, provided the strength of the former be not too much exhausted and the nutrition of the nervous system not too much impaired."

B. Naunyn experimented on a number of pupils.    In six, about thirty years old, pressure on the carotids produced no effect or only a slight dizziness.    In two men over fifty, with marked arteriosclerosis, after a few seconds' pressure there was loss of consciousness, with slowing of the pulse and a slight convulsion.    On pressure being removed there was immediate return to consciousness, and there were no disturbances.    Where he was able to produce epileptiform attacks there was always arteriosclerosis, and he believed the effects of the pressure in these cases to be due to the fact that the brain did not get enough blood from the vertebral arteries, and that the circle of Willis was damaged.

Concato had the same results as B. Naunyn.    In young

people there was no effect from compression; in people with arteriosclerosis he produced epileptiform attacks. These attacks may not always be due to arteriosclerosis, but the brain anemia may result from diseases of heart-valves or weakness of heart pulsations.

De la Harpe reports a case where pressure on the carotid caused intermittency of the pulse. Pressure on right carotid produced more marked effect than on the left, and slight pressure was equally effective as deep pressure. Ordinarily the pulse would not drop more than ten to fifteen beats per minute, though sometimes more. Once it dropped from 96 to 48. He believes that this was due to a slight excitation of the vagus nerve, the immediate cause of the intermittency of the pulse after pressure on the carotids for a few seconds being due to an exaggerated impressionability of the heart-muscle; but he cannot explain the difference of effect following pressure on the right and the left carotid. The patient who showed this condition had just had an attack of apoplexy and was sixty-five years old.

A. Kussmaul in experimenting with rabbits found that when the carotids were compressed there was,—

1. Retraction of the eyeball.
2. Narrowing of space between the eyelids.
3. Narrowing of the pupil.
4. The eyeball was twisted so that the pupil was turned inward.
5. The nictitating membrane showed forth.

The mucous membranes of the eye and nose became paler, likewise the iris. The fundus of the eye never became pale. General convulsions were never seen, though sometimes the animals appeared a little dull.

When pressure was taken off there resulted,—

1. Prominence of the eyeball.
2. Widening of the space between the eyelids.

3. Dilatation of the pupil.

4. Turning of the eye so that the pupil assumed a more normal position. The mucous membranes and the iris again became red.

All of these symptoms were seen in only five rabbits. In seven others, some only appeared. Dilatation of the pupil was more frequent and more marked than narrowing. Retraction of the eyeball was more marked than projection.

### EXPERIMENTAL RESEARCH.

*Protocols.*—*Carotid Series.*—1. Small yellow cur ; good physical condition. Under aseptic precautions the carotids were exposed and clamped. The clamps were so adjusted as to close the artery and prevent all pulsation above the point of clamping. Sterile dressing was applied. For the first six hours the dog was inactive and "groggy." Later he was more active, and ate quite greedily. At the end of forty-eight hours, under the same aseptic precautions, the clamps were carefully removed. At this time there was no pulsation above the clamped point. The wound was dressed antiseptically and the animal kept under observation for two weeks. During this time he gained in weight and apparently was in perfect health. The dog was then killed by chloroform, and before death the neck was opened and the carotids exposed to view. Both arteries were filled and pulsating. The arteries were excised and carefully inspected. The point of clamping could be readily determined. The artery at this point presented an oval contour. Both specimens were hardened and sectioned.

*Histologic Examination.*—Sections through the clamped area showed the lumen to be oval and somewhat flattened in shape. Compared with the lumen above the clamped area the oval portion appeared slightly smaller. The

connective tissue or outer coat was not much disturbed. The media was partially degenerated, its original structures being made out without difficulty. The internal
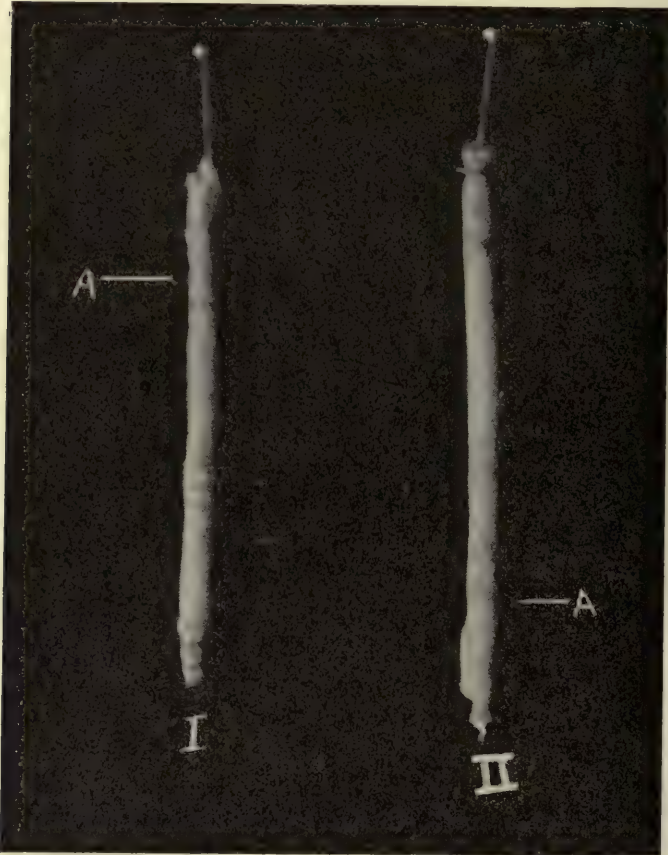


FIG. 20.—A, A, showing the point at which the vessels were for forty-eight hours closed. After which the lumen was restored.

elastic membrane was intact. The intima was intact but somewhat thickened.

2. Pug dog; weight, twelve and one-half pounds, in good physical condition. Under aseptic precautions the carotids were exposed and clamped. Wound closed; sterile dressings applied. The neck began to swell in eight

hours, and at the end of twenty-four hours there was considerable edema and the dog was quite sick. Temperature, 102° F.; pulse, 120. The wound was opened and a profuse discharge of pus followed. There was foul
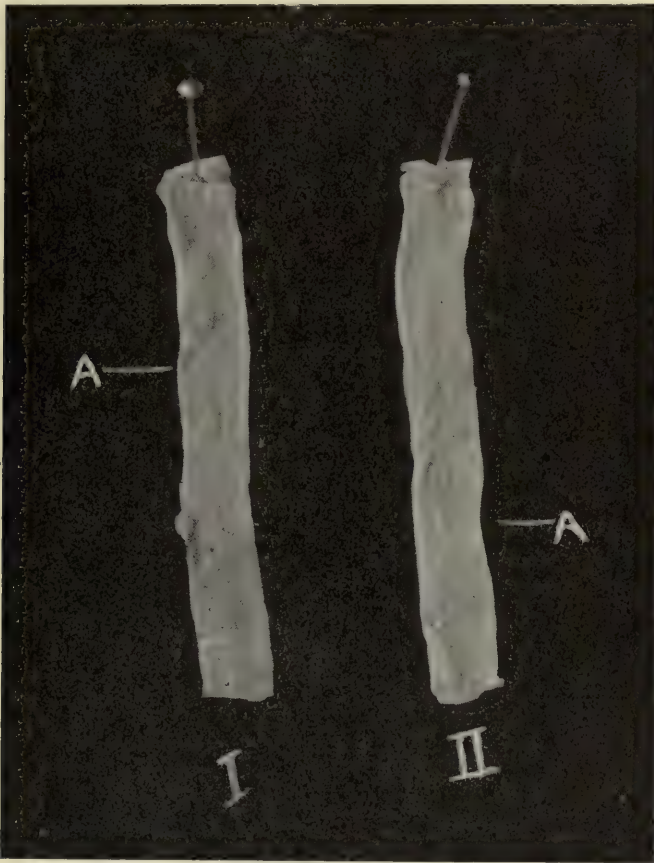


Fig. 21.—Showing the specimen in Fig. 20 opened. Note the smooth contour of the exposed inner coats of the vessels.

odor. The dog was watched for twelve hours. He grew worse and finally was chloroformed. Carotids were exposed and the right one was found to be severed. Both ends looked gangrenous and contained thrombi. The left

carotid was edematous and entirely closed. At the point of clamping there was a thrombus.



FIG. 22.—Micro-photograph of a cross-section at point of closing the carotid artery in a case in which the artery had been closed twenty-four hours.

*Histologic Examination.*—Both specimens were hardened and sectioned. Sections through the clamped area of right carotid showed little or no organized tissue. Everything was necrotic and granular and stained poorly. Sections of left carotid at margins of the clamped portion

showed entire disorganization of intima and elastic membrane, with a marked edema. Lumen contained a red thrombus with hemoglobin crystals. Media was partially degenerated and of a hyaline appearance. Adventitia in some sections showed presence of small round-celled infiltration.

3. Large mongrel; good condition. Under aseptic precautions the right carotid was clamped so that no pulsations could be seen or felt in the artery above the clamp. Sterile dressings were applied. The clamp was left in position for four hours, when it was removed under aseptic precautions and the wound again closed aseptically. The blood-stream was re-established in the carotid, as evidenced by filling up of artery and renewed pulsations. In ten days the dog was killed by chloroform and the artery inspected. The circulation had been wholly re-established. The artery was removed. At the point of clamping the vessel was slightly flattened.

*Histologic Examination.*—The lumen was found more oval than normal in the constricted area. The adventitia was not disturbed. The media showed evidence of some distortion of its fibres. The inner elastic membrane was intact. The intima, though sharing in edema with the media, was intact.

4. Young mongrel puppy; good physical condition. Carotids exposed under aseptic precautions, and both clamped so that no pulsations were visible or palpable in the artery distal to the clamp. Wound was closed and sterile dressings were applied. The dog was drowsy and inactive. He revived somewhat during the second twelve hours. At the end of twenty-four hours the clamps were removed aseptically and sterile dressing was applied. At this time, however, there was some edema and swell-

ing and a serous exudate. The following day there was profuse discharge of pus. The temperature rose three degrees and the pulse was extremely rapid. The animal remained in this condition two days, when he was killed by chloroform. Inspection of carotids previous to death showed the right one to be thickened, though pulsating throughout its entire length. The left carotid was also enlarged and swollen, but no pulsations could be seen above the clamped area. The right carotid when removed showed very marked edema an inch above and below the clamped portion. The left carotid contained a thrombus which was quite firm.

*Histologic Examination.*—The left carotid contained a thrombus which filled the entire lumen. Adventitia showed some small round-celled infiltration and granulation-tissue at clamped area. Media was degenerated and markedly edematous. Inner elastic membrane was distorted, and the intima was disorganized and so disarranged as to be no longer recognized. Right carotid shared in the edema and infiltration of adventitia. The inner elastic membrane was more intact than the intima, though thickened. The loosened endothelial cells were crowded together, presenting a ragged lumen. There was no thrombus present, though the edema had decreased the lumen to one-quarter the former size.

5. Large bull-dog; good condition. Carotids exposed and clamped with aseptic precautions. Clamps left in position twelve hours, when wound was reopened and they were removed. At this time right carotid was found severed. There were thrombi in both ends. Left carotid clamp had slipped off, and the artery appeared normal. Right carotid clamp had been screwed too tightly, and replaced in such a way as to cause considerable lateral pressure on the artery.

6. June 10, 1897.—Scrawny dog, weight, twenty-seven pounds, under ether anesthesia, was subjected to the following experiment.    Both carotid arteries were carefully separated from the vagi.    They were closed by means of a screw-clamp.    The blades were so arranged as to be parallel to each other when closed upon the artery. Over the free ends of these blades a small rubber tubing was stretched to minimize the effect of their contact with the vessel-walls.    By means of this adjustable screw the artery may be closed partially or entirely in a most precise manner.    The general blood-pressure and respiratory actions were being recorded on a drum.    As each vessel was closed the blood-pressure rose, and as the screws were turned on or off the blood-pressure would vary correspondingly.    The respirations were not at all altered by closing both carotids simultaneously. At the end of an hour the clamps were removed and the blood circulated freely through the vessels.    The animal was allowed to live until the fifteenth day, when he was killed.

*Autopsy.*—The lumen of the vessels was entirely free. The blood circulated without any interruption or impediment.    There were no clots found in the vessels, and a microscopic examination revealed a slight thickening at the point of closing.    There was a trifling amount of inflammation in the fibrous structure of the vessel.    The histologic structure of the intima was not all disturbed. The blood-vessels of the brain were normal.

7. July 20, 1897.—A female puppy, about eight months old, was placed under ether anesthesia, and the left carotid was closed by means of a clamp and allowed to remain two hours.    The clamp was then removed and the wound carefully dressed.    Intense suppuration occurred.    The neck was very largely swollen and death was feared.

The animal soon improved, and on the eighteenth day was killed. Making an observation before death, the blood was found to circulate freely through the vessel.

*Autopsy.*—There was a great deal of thickening in all the structures of the neck, showing severe infective inflammation. The artery itself was thickened, its outer walls somewhat edematous, but the intima was wholly intact. There was no clotting, but the lumen of the vessel at this point was slightly decreased on account of the thickening of the vessel-wall. The vessels of the brain were normal. No clotting was found.

8. August 1, 1897.—Old toothless dog; ether anesthesia. On closing the carotids there was a distinct rise in the blood-pressure. The respirations remained unchanged, but it was noted that there was a slight increase in their frequency on releasing the clamps. Both were allowed to remain for three hours, when they were removed. The vessels above them did not impart a pulsation on palpation. The point at which the clamps had been applied was flattened. The blood-stream immediately passed through the vessel and the flattened portion assumed a more rounded contour. The animal was killed, as it seemed that such imperfect aseptic precautions had been taken in the operation as to make it almost uncertain to be a satisfactory recovery experiment. A histologic examination of the vessels at the point of clamping showed that the connective tissue was somewhat disturbed in its histologic relation. There was no lesion of consequence. The intima was both histologically and anatomically intact.

9. August 28, 1897.—A mongrel dog, weighing twenty-four pounds, in good condition, was subjected to ether anesthesia. The clamp was allowed to remain for two

days.   The dog was quite lively, and at the end of forty-eight hours the clamp was removed.   During the time the clamp was carried the dog's temperature ranged from 99° to 101° F.   The artery was considerably swelled above and below the point of application.   A histologic examination showed that the intima was intact, but there was a very great disarrangement of the structures of the other coats of the vessel.

10.   August 31, 1897.—Closing the carotids.   Water spaniel; weight, twenty-three and one-half pounds; not well nourished.   The animal was reduced to chloroform anesthesia, and both carotids were closed by means of the clamps.   This occupied but a few minutes' time.   Nothing unusual was observed either during the application or afterwards.   During the first twenty-four hours the dog was quiet, at the end of which time a swelling was observed beneath the lower jaw, when the clamps were immediately removed.   The following day the swelling increased; the pulse was 184, respiration 18.   In the third twenty-four hours it increased very markedly.   In the fourth twenty-four hours the animal became very weak, did not eat, and the swelling included the entire neck.   After this the animal began to improve, though a considerable discharge of pus was observed.   After the wound healed the animal was killed by an overdose of chloroform.   Before administering the fatal dose the circulation through the carotids was observed to have been entirely re-established on one side, but on the other the vessel was thickened; its structure was largely destroyed by the inflammatory action.

*Autopsy.*—No blood-clots were found in the brain and none in the artery through which circulation had become re-established.   The other vessel was closed by excessive swelling and the edema of its walls.

11. September 2, 1897.—Mongrel bitch; weight, seventeen and one-half pounds; young and in good condition. The right carotid was closed under surgical precautions and a moist bichloride dressing was applied to the wound. The clamp was removed at the end of thirty-six hours, at which time it seemed that the vessel would not recover itself so as to perform its usual functions. The walls of the vessel were much swollen, and the imprint left from the blades of the clamp were so striking that it was not expected it would disappear in time for the re-establishing of the blood-current. After the wound had entirely healed the animal was killed, and it was found that the circulation had been re-established. There were no clots in the brain, but the wall of the vessel was distinctly damaged and the lumen narrowed.

12. October 10, 1897.—Water spaniel; young and in fair condition. The right carotid artery was closed by means of the clamp, which was intended to be left on for forty-eight hours, but the animal made an escape from the kennel, taking with it the clamp.

13. November 10, 1897.—Spaniel; weight, thirty-four pounds. Both arteries closed. Nothing unusual observed during the operation nor directly afterwards. The following day the animal was very stupid. He refused to eat, the neck swelled, there was a violent infection, and on the third day it was necessary to reopen the wound. When the clamps were removed hot applications were applied. The clamps had been allowed to remain sixty hours. On removing them the circulation was not re-established, and the vessels were extremely swelled and edematous. After a tedious recovery the animal was killed, when the vessels were found to have been practically destroyed at the point of clamping, as the lumen at these points was entirely obliterated and the vessels above felt like fibrous cords.

14. February 15, 1899.—Yellow mongrel; weight, twenty-seven pounds; ether anesthesia. Experiment began
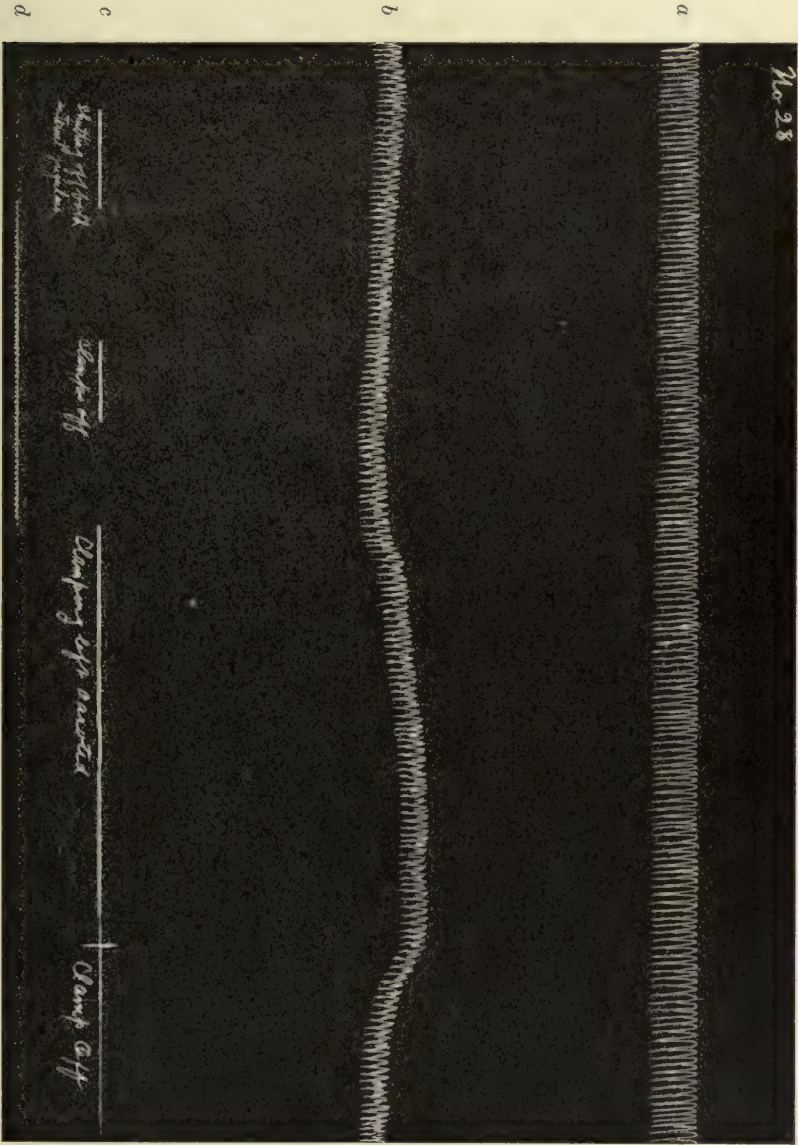


Fig. 23.—a, respiration; b, blood-pressure; c, signal; d, seconds; 1, clamping both jugulars; 2, unclamping,—no effect upon blood-pressure; 3, clamping left carotid,—note rise in pressure; 4, unclamped carotid,—note fall to previous level.

at 4 P.M.   At 4.20, clamped the right carotid.   An immediate rise in blood-pressure occurred, it remaining up

until clamp was removed at 4.25. No change in respiration. On removing the clamp the blood-pressure dropped to previous level.

15. February 15, 1899.—Cur dog; weight, twenty-one pounds; ether anesthesia. Cannula in right femoral artery. Closing both jugular veins produced no appreciable effect. Clamping the left carotid caused an immediate, marked, and steady rise in blood-pressure. Amplitude of respiration slightly increased. On removal of the clamp the blood-pressure fell to former level.

16. February 16, 1899.—Carotid experiment. Fox terrier; weight, sixteen pounds; ether anesthesia. Cannula in right femoral artery. Clamping of left carotid caused immediate marked rise in the blood-pressure. After three minutes the right carotid was clamped and there was an immediate rise, but not so marked as that of the left. No change in respirations. Upon releasing the left carotid there was marked fall in the blood-pressure, and on removing the clamp from the right there was a fall to the point it occupied when the first clamp was applied. Post-mortem showed no changes in brain or lungs. In fact, post-mortem was negative.

17. February 17, 1899.—Jugular experiment. Yellow cur dog; weight, sixteen pounds; ether anesthesia. Cannula in the right femoral artery. Experiment began at 3.06. At 3.19 the left external jugular vein was clamped. No change in blood-pressure or respiration. At 3.20, the right external jugular vein was clamped, but no effect in blood-pressure or respiration was noted. At 3.22, the clamp was removed from the left jugular vein, and at 3.23, from the right jugular. No change in either blood-pressure or respiration.

18. February 19, 1899.—Jugular experiment. Bull pup; weight, twenty-six pounds. Cannula in right femoral artery. Left internal jugular clamped. No effect upon either the blood-pressure or the respiration. Right internal jugular clamped without producing any effect upon blood-pressure or respiration. After a few minutes both clamps were released. No change noticed in either blood-pressure or respiration. The same experiment was repeated a number of times with like results.

19. February 20, 1899.—Jugular experiment. Collie dog; weight, twenty pounds; ether anesthesia. Cannula in femoral artery. Same experiment as above. No change in either the blood-pressure or the respiration.

### SUMMARY OF EXPERIMENTAL EVIDENCE.

*Histologic.*—The gross specimens presented an oval outline on section at the constricted portion. This flattening of the artery was more marked in those carotids which had been clamped for some hours and in those in which the clamps had been tightly adjusted. The histologic appearance of arteries clamped for short periods and examined at once showed but slight change. Arteries clamped for periods of from fifteen minutes to half an hour showed little effect other than a slight tearing of endothelium at the extremities of the oval. Those clamped for an hour showed a greater amount of distortion of the endothelium at the margins of the oval with some separation and endothelial cells, which were massed between folds of fenestrated membrane. The elastic layers were slightly distorted at the constricted portion. The elements of the middle layer were massed at the extremities and somewhat disarranged. The adventitia was unchanged. The histologic appearance of

the carotids from the recovery experiments varied with several conditions. The amount of pressure exerted by the clamp, the presence or absence of wound infection, and the length of time the clamps were allowed to remain on the artery modified the results.

Some specimens clamped too tightly for four or six hours showed marked degeneration of the middle coats with edema and a thickening and disarrangement of the intima, with loss of endothelium and a very perceptible narrowing of the lumen; others were thrombosed, some were necrotic; but in those carotids in which care was taken to so adjust the clamps as to exert only sufficient pressure on the artery to close its lumen, the histologic changes were unimportant. A clamp adjusted too tightly caused pressure necrosis in a few hours, while other carotids were clamped for from twenty-four to forty-eight hours without notable damage to the arterial walls. The intima and elastic membrane were but slightly affected, though the media showed some evidence of degeneration. The adventitia was but slightly altered.

The presence or absence of infection of the wound was of great importance. In those cases in which an infection appeared the arteries showed the greatest changes. In many instances the artery was necrotic at the clamped portion, and in some instances it was severed. The media and adventitia both above and below the constricted portion showed round-celled infiltration, and in some areas necrosis. The intima and inner elastic membrane were disorganized and distorted. In those thrombosed, the lumen was narrowed owing to edema and thickening of the walls.

The experiments showed that a properly adjusted clamp could be left in position, closing the artery for from twenty-four to forty-eight hours, without serious injury to its walls.

*Physiologic.*—The immediate effect on the circulation of temporarily closing one carotid artery was to increase the blood-pressure, but usually a compensation followed, and the pressure returned to its normal level. No effect upon the respiration was observed. Simultaneously closing both carotid arteries produced a greater rise in the blood-pressure, which by physiologic compensation usually soon returned to the normal level. In many of the experiments there was a decrease in the respiratory action, although the effect was very slight. In no instance were there any striking results noted. In the recovery experiments in the cases in which the clamps were allowed to remain on the arteries, closing them, and the wound pursued an aseptic course, no effect upon the animal was observed beyond that attributable to the anesthesia and the operation. The animals seemed playful and strong. Even after twenty-four hours of complete closure there was not much macroscopic evidence of injury to the vessel wall. The circulation through the clamped portion was readily re-established. However, in cases in which, during the application of the clamps for a considerable length of time, say two days, the animal in the mean time had suffered infective inflammation of the wound, the damage of the vessel walls was very considerable and the lumen was in some instances occluded. As to the after-effects, in no case was there clotting; the aseptic cases made good recoveries; the circulation was re-established; and no impairment of consequence was observed. The circulation of the brain was carefully observed at the post-mortem, and in no case was there either emboli or thrombi found, or any effect on the brain noted. After considering several devices, the most accurate, efficient, and safe one seemed to be that of applying a clamp, so constructed that its blades could be adjusted by means of a set screw, and when they were approximated so as

to close the vessel, but not compress its walls, the blades were parallel to each other. One blade was made longer than the other, and its end turned up so as to prevent the escape of the artery. Over these blades were stretched pieces of rubber tubing, thereby minimizing the effect of contact with the vessel wall. In applying the same, it is necessary to bear in mind that the walls need only be approximated, not compressed. The adjustable screw gives so perfect a mechanical control of the lumen of the vessel as to enable the surgeon to perform the operation and secure the bleeding vessels with a minimum loss of blood.

### CLINICAL APPLICATION.

#### A NEW METHOD OF CONTROLLING HEMORRHAGE IN CERTAIN OPERATIONS ON THE HEAD AND NECK.

*Technique.*—Twenty minutes previous to making the incision one one-hundredth of a grain of atropin should be injected, in cases in which the technique is likely to involve the trunks of the vagi or their superior laryngeal branches, for the purpose of preventing possible inhibitory action upon the heart. Each common carotid artery is closed by means of a small clamp, whose blade
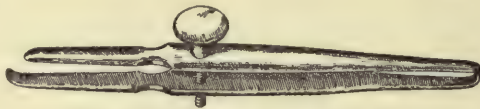


FIG. 24.—Clamp for closure of carotids.

is long and protected by a thin rubber tubing. The lower blade is slightly longer than the upper, and turns up at its free end so that its grasp upon the artery will be more secure. The spring end of the clamp is so arranged that when the blades are closed sufficiently to approximate the walls of the vessels they become parallel. The closing of the blades is accomplished by an adjustable thumb-screw, making definite closure. In

operations in which blood may enter the pulmonary tract, the patient should be placed in the Trendelenburg posture. This partially compensates the lowered cerebral blood-pressure resulting from closing the carotids. While this posture somewhat increases the venous and capillary hemorrhage, the increase of the venous pressure diminishes the danger of the entrance of air into the larger venous trunks, should they accidentally be injured. Fortunately, venous and capillary hemorrhages, except in cases involving the larger veins, are relatively of little consequence. On completion of the operation, in cases in which the Trendelenburg posture is employed, it is safer to restore the patient to the horizontal position before releasing the carotids, as in the inclined posture the normal blood-pressure of the brain is increased by the mechanical factor, and releasing the clamps in this position would raise the pressure above the normal. The release of the clamp should be made slowly while inspecting the field of operation to detect any vessels that might have been overlooked. The control of the arterial hemorrhage is absolute, except in such vessels as receive direct collateral pressure from the vertebral arteries. According to the researches of Bayliss and Starling, there are no vasomotor nerves supplied to the vessels of the brain. The circulation being largely mechanical, the blood-vessels of the brain should be more favorable to the employment of such technique than the vessels of almost any other organ of the body, in which the blood-supply is more or less regulated by the vasomotor mechanism.

*Reports of Cases.—Case* 1.—*Both common carotids closed. Recovery. Operation was performed January,* 1897.

The patient upon whom this technique was employed was a colored man, forty-six years of age, admitted to St. Alexis Hospital on account of a large fibrosarcoma filling the mouth so as to render its complete closure

impossible. Breathing was so obstructed as to threaten suffocation, and at night was so heavy and labored that it could be heard at a considerable distance. Under cocain, tracheotomy was performed for the double purpose of removing the danger of asphyxia and as a part of the technique to be employed. Aside from emaciation from the necessary liquid diet, the patient was in good condition. The tumor was first observed six years previous in the posterior part of the hard palate. A year later it was removed, but recurred, and had been growing since that time. On account of its size, the extent of its attachments when I first saw him, could not be determined. Its translucent surface displayed a rich supply of blood-vessels, some of considerable size. In the operation the technique here described was employed. The tumor was delimited by an incision in the healthy mucous membrane. The hard palate was divided along this line. The vomer was severed along the floor of the nose and the entire mass turned out. After the necessary revision of the wound the principal vessels were secured, and everywhere the wound was touched with the thermo-cautery. After the operation had been completed, the wound dressed, and perhaps ten minutes had elapsed, respiration suddenly failed. Artificial respiration was maintained during twenty-five minutes. The application of ice, alternated with a brisk rubbing with a warm towel, proved an efficient stimulus to respiration. The entire mouth was packed with iodoform gauze, which was allowed to remain for twenty-four hours, after which boric acid solution with sufficient thymol to correct the disagreeable odor was used in a mouth-wash. The tracheal tube was removed after two weeks, when it was thought that the danger of pulmonary infection had passed. The patient was soon able to leave his bed, and made an uneventful recovery. Four years later there was no recurrence.

*Case 2.—The removal of a large congenital tumor of the neck. Closure of both common carotid arteries. Recovery.*

Female, twenty-one years of age. At birth it was large and more developed on the right side than on the left, greatly increasing in size as she grew older. At the time of operation the tumor occupied the entire anterior and much of the lateral portion of the neck. On the left side it extended past the line of the ear. On the right, over the outer border of the sternomastoid muscle. It extended from the sternum to the chin. The whole tumor was very large and pendulous, and there was a free discharge of a glairy mucus from several sinuses. Into these sinuses a probe could be passed down to the level of the larynx. The tumor mass was of varied consistency, at places cystic and moderately fluctuating, at others giving the resistance of fleshy tissue. The sinuses did not communicate with the interior of the larynx. A laryngoscopic examination showed that the trachea was markedly flattened in its antero-posterior diameter. Both voice and respiration were impaired. The danger of hemorrhage was so great that the patient had previously been advised against operation.

*Operation.*—The carotid arteries were found pressed back against the vertebral column. They were closed by means of the clamps, after which the operation was carried out almost bloodlessly. The only blood loss was in making the incisions in the portion supplied by the inferior thyroid arteries, which were not closed. When the common carotid arteries were clamped the face became blanched and the pulse disappeared from all portions of the head. In experiments on animals we have been able to show that the intracranial pressure is kept sufficiently high for the functioning of the bulbar centres by the vertebral arteries alone. If, however, the closure of the common carotids is permanent, cerebral softening is likely to ensue; if temporary, no

untoward effects follow. The patient made a good recovery, and there is but a minimum scar on the neck. Both of the external jugular veins were excised with the tumor. All of the deeper structures were laid bare. The tumor was in anatomical relation with the sheaths of the common carotid arteries, the trachea, the larynx, and all of the deeper structures of the neck. There was no capsule. At first I was inclined to believe that one of the recurrent laryngeal nerves was sacrificed. She spoke in stridulous tones. Later the voice cleared.

*Case 3.—Clamping of both common carotids. Partial resection of the tongue; removal of the floor of the mouth; excision of the submaxillary and sublingual glands; resection of the parotid; excision of the superficial and deep cervical lymphatics on the left side; excision of the jugular vein; resection of the buccal aspect of the inferior maxillary bone. Recovery.*

*Diagnosis.*—Typical epithelioma situated on the floor of the mouth, extending from the left side of the tongue to the inferior maxilla. Slight enlargement of several lymphatic glands could be palpated. Age, forty-eight; previous health, good; obese and plethoric; weight, two hundred and thirty-six pounds; neck short, thick, and fat.

*Operation.*—Chloroform-morphine anesthesia. One one-hundredth grain of atropin was given half an hour before the operation to prevent cardiac inhibition from probable mechanical irritation of the superior laryngeal or of the vagus. Both common carotids were closed by means of the rubber-tipped screw-clamps. The incision on the right side being an inch long, fibres of the sternomastoid were separated. On the left side the vessel was secured in a like manner. The incision was carried upward, then outward, parallel with the jaw to the parotid gland, and an inner incision was carried to the median line. Re-

flecting the skin exposed the entire cervical field. The superficial chain of glands was first removed, then the deeper. The submaxillary gland was encroached upon by a metastasis of the adjacent lymphatics, and was accordingly removed. Metastases were found in the deep cervical, in the parotid region, and along the jugular vein. The jugular together with the glands was excised. While dissecting out the deeper glands the pulse increased rapidly to 162, due to the increased stimulation of the sympathetic, while the vagal action was prevented by the atropin. The cause being recognized, no stimulation was given. The pulse soon returned to the previous rate. The extensive cervical dissection was then packed with gauze. The tongue was held well over and the mouth lightly packed with gauze. The base of the tongue, the entire floor of the mouth of the left side, and about half of the adjacent jaw was removed. The resection of the tongue included about one-third of its left half and base. There was free communication between the mouth and neck.

The clamps were now gradually unscrewed and the circulation of the mouth, face, and neck re-established. The absolute control by means of the screw-clamps made it possible to secure all the bleeding-points without appreciable blood loss. There was but trifling hemorrhage, mostly venous, and the operation was greatly facilitated by keeping a bloodless field. The patient made a rapid recovery. There were no unfavorable symptoms due to the closure of the carotids either during the operation or after it.

*Case 4.—(Abstract.) Temporary closure of common carotid. Removal of sarcoma of parotid; vagus exposed; external carotid and jugular tied; cardiac inhibition from vagal and superior laryngeal irritation; application of two*

*per cent. solution of cocain prevented further inhibition. Recovery.*

The common carotid was closed by means of the special clamp; the jugular vein and the external carotid were excised; the vagus was laid bare. On account of an insufficient dose of atropin, irritation of the vagus while separating it reduced the heart-beats from 92 to 56. The nerve being exposed, cotton saturated with a two per cent. solution of cocain was packed around it. Although it became necessary to inflict greater mechanical irritation in the further dissection than had been previously inflicted, the heart promptly returned to 90 and was not further affected. Cocain blocked the efferent impulses and protected the heart. Quick recovery followed.

*Case 5.—(Abstract.) Excision of the tongue, left floor of the mouth, middle half of the jaw, glands of the neck, submaxilla, and a portion of the parotid glands en bloc for carcinoma. Recovery.*

Male, aged fifty-eight, preliminary tracheotomy one week before the operation. Both common carotids closed by means of clamp. One one-hundreth grain of atropin given. Incision carried along the large vessels in the neck, exposing them, to the angle of the jaw, then upward to the base of the jaw; another incision parallel to the jaw. Skin-flaps reflected in all directions. Large vessels exposed at the base of the neck. All the glands and fascia removed up to the jaw. Jaw sawed through at two points, after which the entire tongue, floor of the mouth, and left tonsil were removed with the scissors. The pharynx had been previously packed with gauze. There was but a trifling hemorrhage. The patient's pulse-rate never changed during the operation, which was completed in thirty minutes. The closing of the common carotid arteries afforded a bloodless field so far as capillary

and arterial hemorrhage was concerned, and but slight from the venous sources. The atropin paralyzing the terminals of the vagus prevented any inhibition. Patient made a rapid recovery.

Case 6.—(*Abstract.*)   *Carcinoma arising from the duct of the parotid gland.  Excision; closure of common carotid. Recovery.*

Female, aged forty-two, in good physical condition. During the operation the large vessels and the upper portion of the vagus and the superior laryngeal were exposed. Although the patient had been given one one-hundred-and-twenty-fifth grain of atropin, the pulse was reduced during the manipulation of these structures from 90 to 52. A piece of cotton saturated with a two per cent. solution of cocain was packed down upon the nerve, after which the pulse returned to its previous rate in less than a minute. The operation was completed, involving continuous manipulation of the vagus and the superior laryngeal, with no effect upon the heart's action. The respirations were shortened and deepened.

Case 7.—(*Abstract.*)   *Operations for tubercular glands of the neck.  Dissection involved the jugular, deeper vessels, and the vagus nerve; cardio-inhibitory action from manipulating of vagus.  Recovery.*

Patient eight years old. While separating the glands from the vagus in its upper portion near the parotid the heart-beats dropped from 92 to 62. The field was kept bloodless, so that all the structures could be seen. The vagus had been laid bare. A two per cent. solution of cocain was applied upon the nerve, and the pulse went up immediately to 90, after which, although the dissection involved the nerve more than before, no inhibition was noted.

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*Case 8.—(Abstract.) Closure of the common carotids. Physiologic dosage of atropin; laryngeal application of cocain; excision of the tongue, epiglottis, left tonsil, floor of the mouth, lower jaw, submaxillary and parotid glands, left jugular vein, left external carotid artery, and the vagus nerve; but little shock. Easy immediate recovery. Death from secondary hemorrhage on the thirteenth day.*

Patient had had six operations for epithelioma; the disease originated in the floor of the mouth. The operations and the disease had so far destroyed the jaw and the soft parts that the patient was with increasing difficulty able to eat. The cicatricial and carcinomatous contractions and hardening fixed the lower jaw and was progressingly closing the mouth.

The procedure was recommended after consultations with distinguished surgeons. The preliminary preparations having been made, an incision was carried from each angle of the mouth outward and downward in relation to the growth. The jaw was disarticulated on the left side, while on the right it was severed in the upper portion of the ramus. The extent of the external part of the operation was indicated by a free skin incision. The jaw was severed first on the right side, then on the left. The tongue, tonsil, and floor of the mouth were then severed laterly and posteriorly, after which, by continuing the dissection along the vertical plane of the esophagus, larynx and trachea, all the structures, including the parotid, submaxillary, sublingual, and regional lymphatic glands, were removed. The dissection then passed through the plane of the carotid artery, jugular vein, and vagus on the left side, all of which were included in the parts removed. Especial care was taken in securing the veins. The epiglottis showing a tendency to close, the larynx in a light valve-like manner was excised. The removal *en bloc* by carrying the dissection along the

planes indicated not only facilitated dissection, but insured the removal of all the local carcinomatous tissue.

The patient bore the operation well, exhibiting a pulse-rate of 96 at the close of the operation and good respiratory rhythm.    On opening the arteries the circulation of the head was quickly restored and consciousness almost immediately regained.    The patient progressed favorably until the thirteenth day, when death from secondary hemorrhage occurred.

The absolute control of the blood-supply by means of the special device, thereby maintaining a clear field for dissection ; the prevention of cardiac collapse through either direct or reflex inhibition by the administration of a physiologic dosage of atropin ; the prevention of reflex inhibition of respiration by the application of cocain upon the laryngeal mucosa, places even so extensive an operation on a safe basis so far as the immediate operative effects are concerned.

*Case 9.—(Abstract.)    Infant, seven months old ; had an angiosarcoma of the cheek and neck of rapid growth and great vascularity.    Common carotids closed by special mechanism.    Removal of the entire growth.    Recovery.*

The extensive development of the tumor and the frailty of so young a subject almost precluded any operative procedure, but on account of the assurance of a safe and absolute control of the blood-supply an excision was attempted.    Both the common carotids were closed.    The blood-supply was absolutely controlled, and the dissection could be made in a clear field without loss of blood.    The tumor had invaded the structures of the cheek, extending down to the mucous membrane, and in the neck extending well down below the angle of the jaw, involving the parotid region.    After removing the entire growth it was impossible to bring the parts closely together.    Repair

was rapid, and the child made an uneventful recovery, the operation having been well borne.

*Case* 10.—(*Abstract.*)    *Carcinoma of the septum of the nose.    Excision.    Closing both common carotid arteries.*

Operation performed bloodlessly, involving the temporary lateral resection of the entire nose, extending to the posterior nares, the base of the skull.    Hemorrhage entirely controlled.    Nose replaced.    Good recovery.

*Case* 11.—(*Abstract.*)    *Excision of one-half the tongue, the floor of the mouth, submaxillary glands, entire chain of lymphatic glands, extending along the jugular and angle of the jaw.    Excision of the jugular vein.    Recovery.*

Preliminary tracheotomy.    Both common carotid arteries closed ; fairly bloodless field excepting a small amount of venous hemorrhage.    There was not even an appreciable alteration of the pulse and respiration.    Patient made a good recovery.

### CONCLUDING REMARKS.

The proper interpretation of a slowed or of an accelerated pulse, or of an inhibited respiration, the prevention of either direct or reflex inhibition of the heart from mechanical stimulation of the vagus or its branches by the use of atropin and cocain, the safe and absolute control of hemorrhage by temporarily closing the carotid arteries render operative procedures of the head and neck so much safer as to greatly increase surgical possibilities.

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