CICATRIZATION OF WOUNDS.

I. THE RELATION BETWEEN THE SIZE OF A WOUND AND THE RATE OF ITS CICATRIZATION.

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In the course of experiments made in 1908 at The Rockefeller Institute certain relations existing between the size of a wound and the rate of cicatrization were studied. The experiments showed that the rate of repair was greater at the beginning than at the end of cicatrization, and depended not on the age of the wound but on its size, being directly proportional to it.[1] The skin of mammals seemed therefore to regenerate according to a law similar to that found by Spallanzani for salamanders. The experiments made lately by Spain and Loeb showed that in the guinea pig the same relation existed between the size of a wound and the rate of repair.[2] The object of the following experiments was to find a technique by which the size of a wound could be measured accurately, to ascertain whether the curve representing the cicatrization was geometric in form, and to study the relations between the size of a wound and the velocity of repair, as well as the relative importance of the processes of contraction and epidermization.

EXPERIMENTAL.

The experiments were made in the following manner. In the sternal region or in the anterior abdominal region of anesthetized guinea pigs and cats, wounds were obtained by resection of a strip of skin geometric in form. In order that the edges of the cicatrix

[1] Carrel, A., *J. Am. Med. Assn.*, 1910, lv, 2148.

[2] Spain, K. C., and Loeb, L., *J. Exp. Med.*, 1916, xxiii, 107.

might be seen distinctly, animals with a black skin were used, or the edges of the wound made on white animals were tatooed with India ink. The skin of the cat and, as had been previously noted, of the dog not being adherent to the aponeurosis, errors occurred in the measurement, if, in consecutive observations, the animal was not placed in an identical position. The guinea pig was generally employed because the skin of the abdominal wall of this animal is more adherent to the aponeurosis than that of the cat or dog. In human beings wounds of regular shape were selected, located on patients confined to bed. When both the wound and the cicatrix were to be studied, cases were chosen in which the outer edge was well colored and easily discernible from the surrounding skin. Observations were also made on the healing wounds of soldiers.

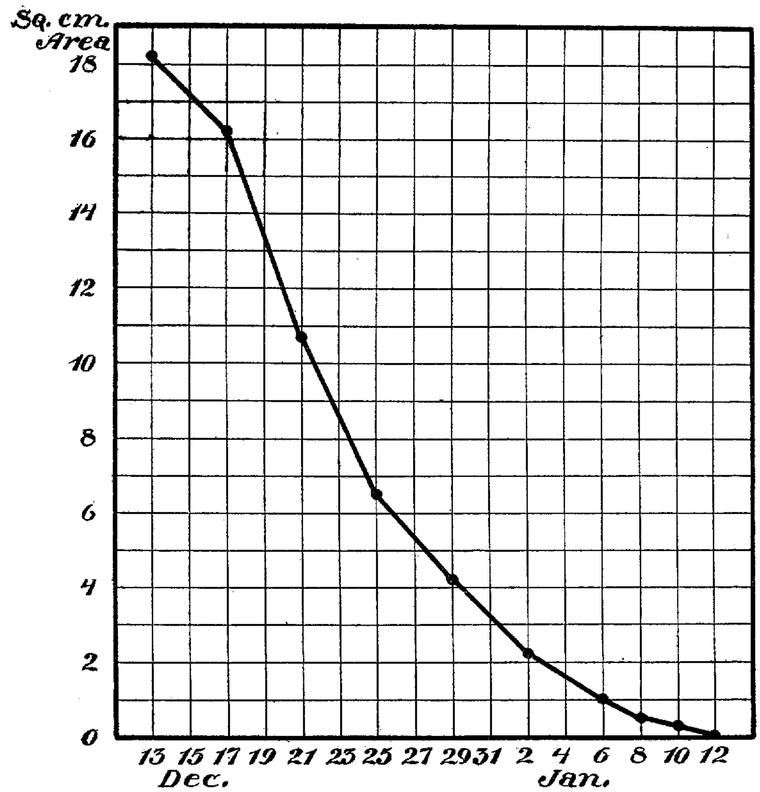
During the period of observation the wounds were kept by means of antiseptic and aseptic dressings in as constant a bacteriological condition as possible. Every day films of the secretions, taken in different parts of the wounds, were examined. When the films contained bacteria the wound and the surrounding skin were cleaned with a cotton sponge and neutral sodium oleate. Then, for a few hours, 0.5 per cent of Dakin's hypochlorite or 1 per cent paratoluene sodium sulphochloramide was instilled on the wound. As soon as the bacteria had disappeared, aseptic dressings or compresses moistened with 0.2 per cent paratoluene sodium sulphochloramide were applied. The wound remained aseptic for several days. If bacteria appeared again on the granulating surface, chemical sterilization was used.

The measurements of the wound were taken at regular intervals, as a rule every 4 days. The procedure was as follows: After the surface was thoroughly dried by antiseptic gauze or by filter paper, a sheet of thin, transparent cellophane was applied with a sponge directly over the granulations and the epithelial edge. The inner edge of the epithelium could then be clearly discerned, and was even felt under the point of the wax pencil by means of which it was drawn on the cellophane. The outer edge of the pencil mark corresponded to the line of union between the epithelium and the granulating surface. Two drawings were made at each examination. The outer edge of the cicatrix was also outlined. The drawings obtained on cellophane were then reproduced in ink on a sheet of paper. This second drawing was used for the measurements. By means of a planimeter the area of the wound (S) and the area of the wound and the cicatrix ($S + C$) were estimated in square centimeters. The daily rate (R) of cicatrization was obtained by dividing the differences of two consecutive surfaces by the time which had elapsed between the two observations. The value of the rate of cicatrization in its relation to the area was obtained by the formula $\frac{S}{V}$.

Through the values of S and R a curve was established in which the time was carried in abscissæ, and the area in ordinates. The tracing representing the variations of the surface located within the outer edge of the cicatrix was drawn above the curve of the surface of the wound. The interval between both curves represented the area of the cicatrix in square centimeters. Thus it was possible to ascertain daily, in square centimeters, the size of the wound, the size of the cicatrix, and the velocity of the process of repair. By means of this technique, the relations which exist between the size of a wound and the rate of cicatrization, and the respective value of contraction and of epidermization in the process of repair, were studied.

The Relation between the Size of a Wound and the Velocity of Repair.

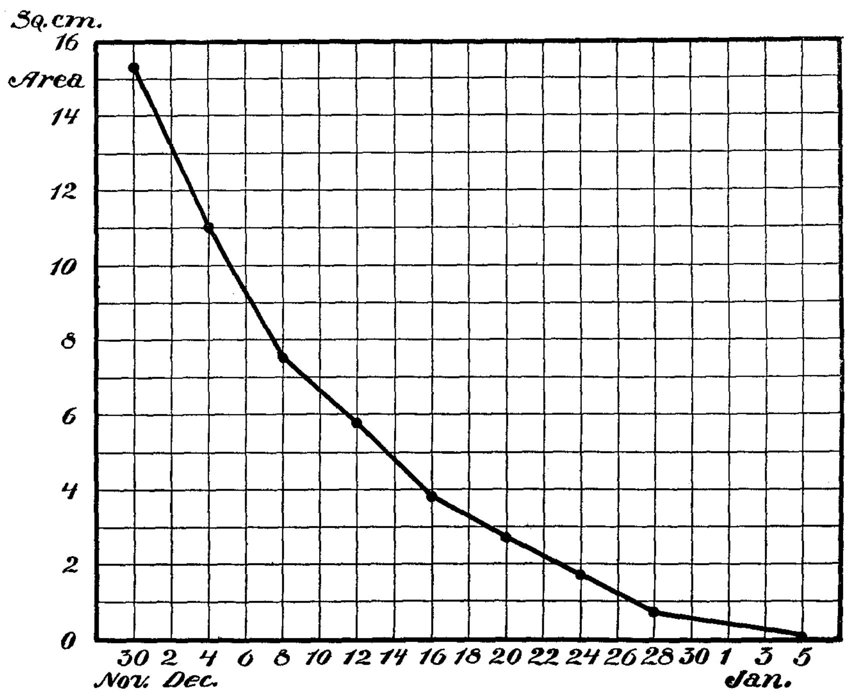
The observations were made on men and on guinea pigs. The wounds were in a condition of slight infection and healed both by contraction and by epidermization.



TEXT-FIG. 1.

Experiment 1.—Patient 221, age 27 years (Text-fig. 1). Old wound of the left foot; aseptic. Normal cicatrization.

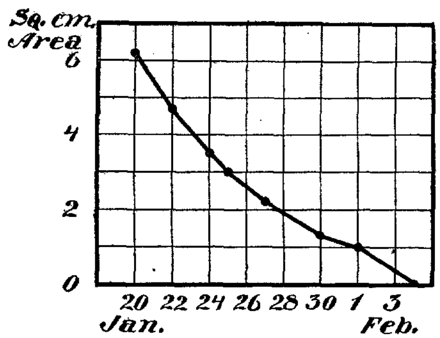
	Dec. 13	17	21	25	29	Jan. 2	6	8	10	12
S........	18.2	16.2	10.7	6.5	4.2	2.2	1.0	0.5	0.3	0
R........		0.5	1.37	1.05	0.55	0.5	0.3	0.25	0.1	0.15
$\frac{S}{R}$........	36.0	11.8	10.1	11.8	8.4	7.3	3.0	5.0	2.0	



TEXT-FIG. 2.

Experiment 2.—Patient 217, age 36 years (Text-fig. 2). Wound of the left iliac region; slightly infected. The appearance of the curve is normal although the rate of repair was slow.

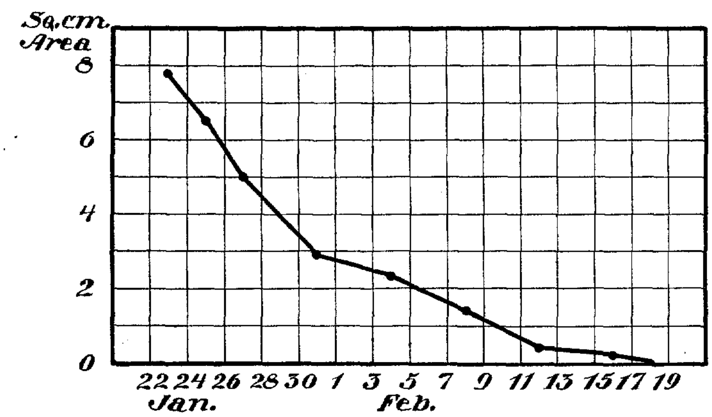
	Nov. 30	Dec. 4	8	12	16	20	24	28	Jan.
S..............	15.3	11.0	7.5	5.8	3.8	2.7	1.7	0.7	0
R..............		1.07	0.87	0.42	0.5	0.17	0.25	0.25	0.1
$\frac{S}{R}$..............	14.3	12.6	17.8	11.6	22.0	10.8	6.8	7.0	



TEXT-FIG. 3.

Experiment 3.—Patient 354, age 40 years (Text-fig. 3). Old wound on a stump; slightly infected. Normal cicatrization. The irregularity of the curve on Feb. 1 was due to the dressing.

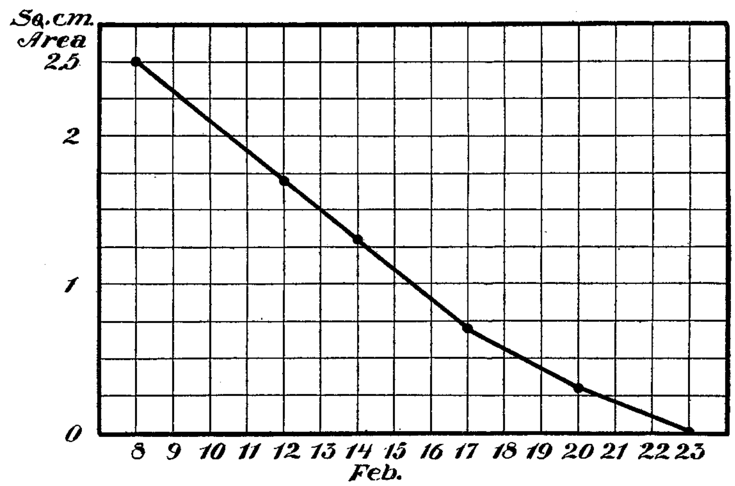
	Jan. 20	22	24	25	27	30	Feb. 1	4
S........................	6.2	4.7	3.5	3.0	2.2	1.3	1.0	0
R........................		0.75	0.60	0.50	0.40	0.3	0.15	0.33



TEXT-FIG. 4.

Experiment 4.—Patient 330, age 32 years (Text-fig. 4). Wound following the amputation of the index finger and of a part of the metacarpus; slightly infected. From Jan. 31 the rate of cicatrization decreased on account of infection.

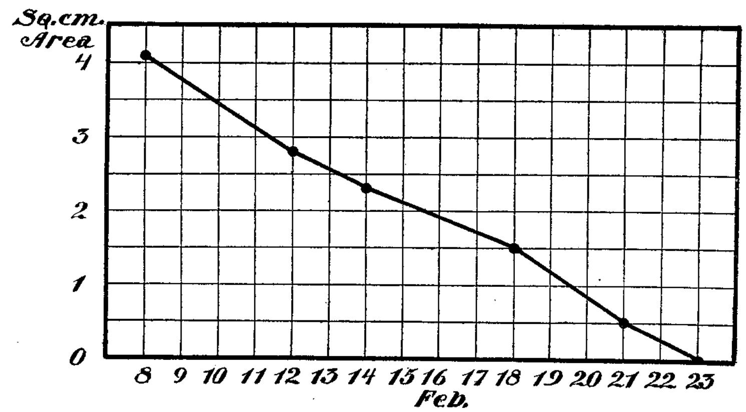
	Jan. 23	25	27	31	Feb. 4	8	12	16	18
S................	7.8	6.5	5.0	2.9	2.3	1.4	0.4	0.2	0
R................		0.65	0.72	0.52	0.15	0.22	0.25	0.05	0



TEXT-FIG. 5.

Experiment 5.—Guinea Pig 1 (Text-fig. 5). Wound of the anterior abdominal wall; slightly infected. Normal cicatrization.

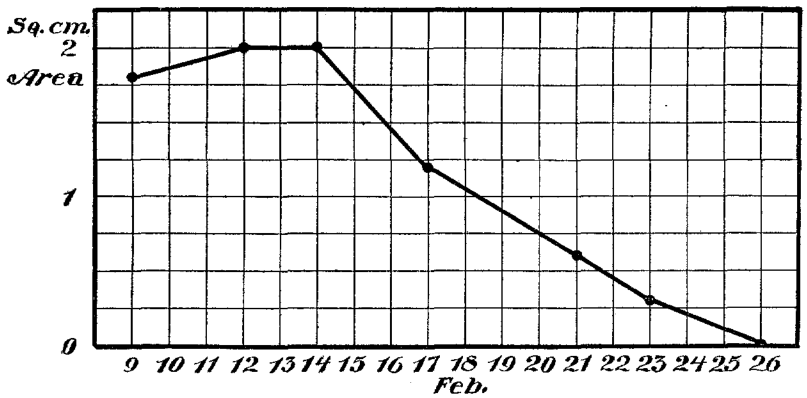
	Feb. 8	12	14	17	20	23
S..................................	2.5	1.7	1.3	0.7	0.3	0
R..................................		0.8	0.2	0.2	0.15	



TEXT-FIG. 6.

Experiment 6.—Guinea Pig 2 (Text-fig. 6). Wound of the anterior abdominal wall. The curve is nearly regular in spite of a slight infection. The slackening of the rate of cicatrization on Feb. 18 was due to a more marked condition of infection.

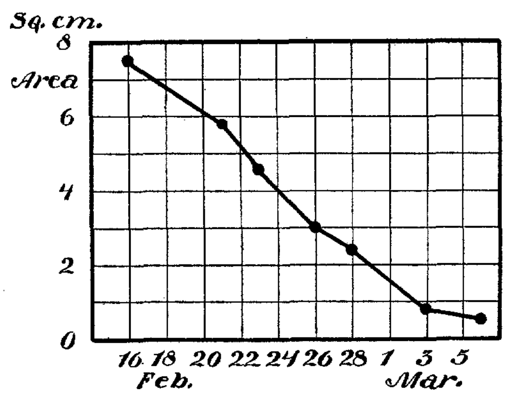
	Feb. 8	12	14	18	21	23
S....................................	4.1	2.8	2.3	1.5	0.5	0
R....................................		0.32	0.25	0.20	0.3	



TEXT-FIG. 7.

Experiment 7.—Guinea Pig 3 (Text-fig. 7). Wound of the anterior abdominal wall; slightly infected. The horizontal part of the curve from Feb. 9 to 14 represents the period normally preceding the beginning of contraction.

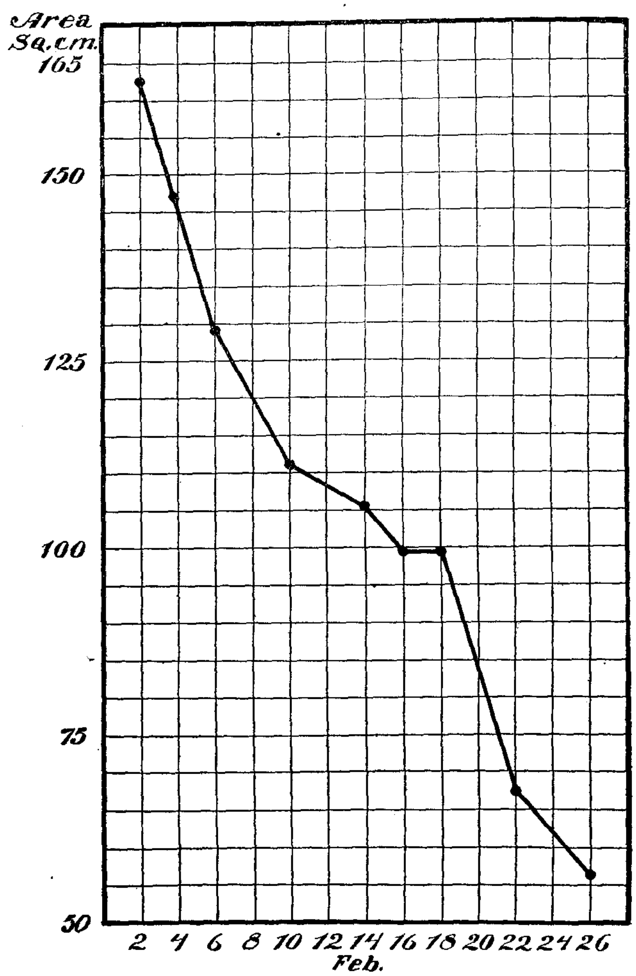
	Feb. 9	12	14	17	21	23	26
S..............................	1.8	2.0	2.0	1.2	0.6	0.3	0
R..............................				0.26	0.15	0.15	0.1



TEXT-FIG. 8.

Experiment 8.—Guinea Pig 4 (Text-fig. 8). Wound of the anterior abdominal wall. The slow rate of cicatrization from Feb. 16 to 21 was due to the period preceding the beginning of contraction.

	Feb. 16	21	23	26	28	Mar. 3	6
S..............................	7.5	5.8	4.6	3.0	2.4	0.8	0.5
R..............................		0.34	0.55	0.36	0.56	0.3	0.4



TEXT-FIG. 9.

Experiment 9.—Patient 360, age 21 years (Text-fig. 9). Wound of the abdominal wall. The horizontal part of the curve from Feb. 16 to 18 represents a period of infection. As soon as the wound was sterilized chemically, the curve descended abruptly.

	Feb. 2	6	10	14	16	18	22	26
S....................	162.5	129.4	111.0	105.5	99.5	99.5	67.5	57.0
R....................		8.25	4.6	1.3	3.0	0	8.0	2.6

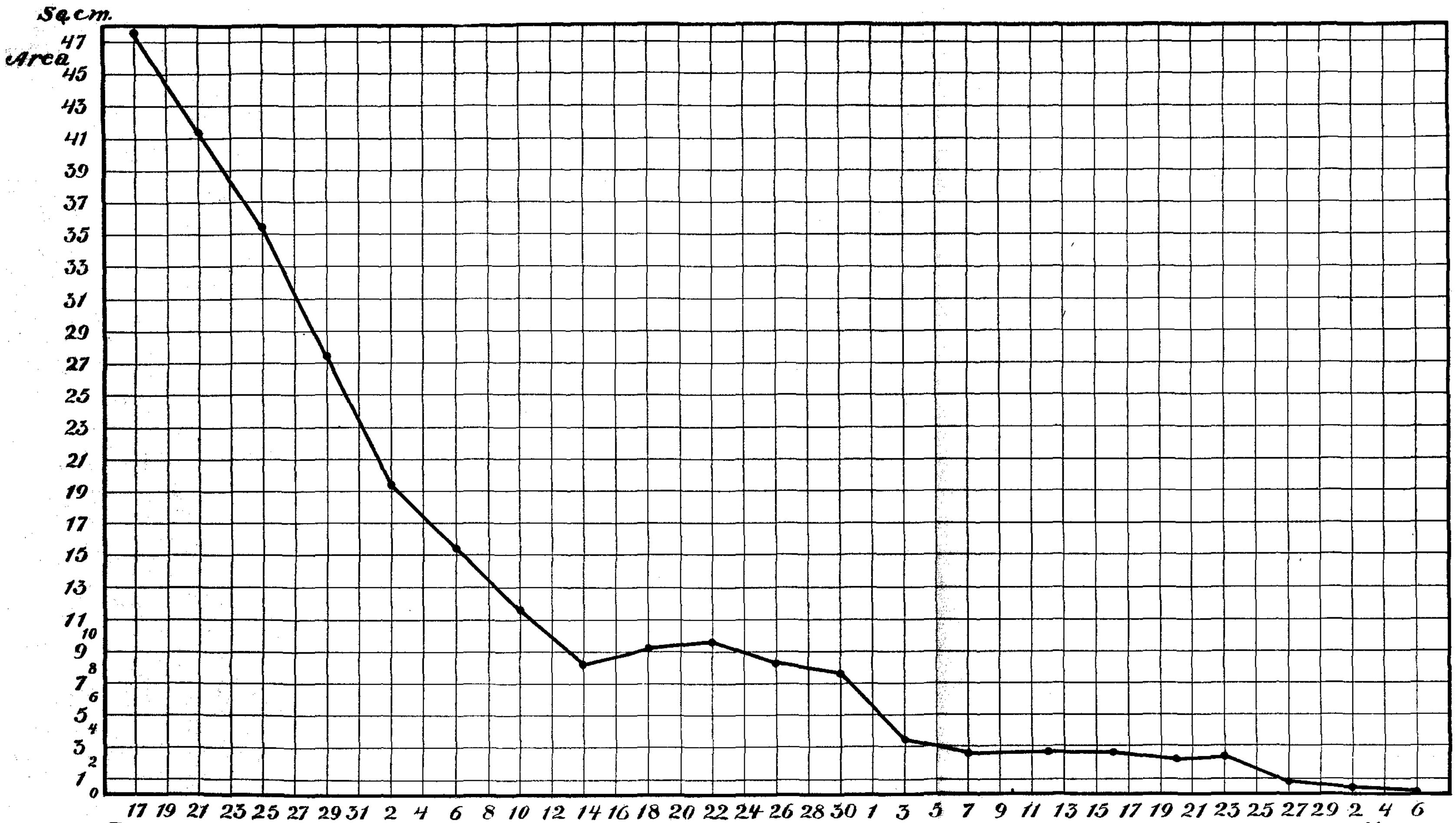
The curves representing the progress of cicatrization in these experiments assume a geometric appearance. It seemed probable, therefore, that the relation between the size of a wound and the rate of repair may be expressed mathematically.[3]

The regularity of cicatrization depends in a large measure on the bacteriologic condition of the wound. The more aseptic the wound, the more regular is the curve of cicatrization. In Experiment 1 the wound was aseptic during the greater part of the period of repair. Agar and bouillon, inoculated with the secretions of this wound, remained sterile. In the other experiments the wounds were slightly infected. After a wound was chemically sterilized the rate of cicatrization increased (Text-fig. 9).

When an aseptic or slightly infected wound was infected, the curve of cicatrization became horizontal or inflected upwards, showing that arrest or retrogression of the repair occurred. In the following experiment a wound accompanying a fracture of the humerus had been almost completely sterilized and was cicatrizing normally, when a slight infection occurred. Cicatrization stopped and the wound enlarged (Text-fig. 10).

Some of the sterile wounds became infected while under observation. As soon as bacteria appeared the process of repair was retarded

[3] du Noüy, P., *J. Exp. Med.*, 1916, xxiv, 451.



TEXT-FIG. 10.

Experiment 10.—Patient 266, age 33 years (Text-fig. 10). Wound and fracture of the left arm. The wound was slightly infected from Dec. 17 to Jan. 14. On Jan. 14 the infection caused the curve to become irregular.

	Dec. 17	21	25	29	Jan. 2	6	10	14	18	22	26	30
S.....	47.3	41.3	35.4	27.3	19.4	15.4	11.7	8.2	9.2	9.6	8.3	7.6
R.....		1.5	1.5	2.0	1.97	1.0	0.92	0.87	0.2	0.1	0.3	0.1

and sometimes stopped. However, infection, when it was of short duration, had no marked disturbing influence on the curve representing the cicatrization of the wound. As soon as normal conditions were reestablished, the progress of cicatrization was hastened (Text-fig. 9). After a period of inactivity an automatic mechanism seemed to accelerate the healing process. This explains why short periods of infection did not produce marked irregularities in the curve of cicatrization. Again, a period of greater activity was generally followed by a period of slow repair which reestablished the regularity of the curve.

In all the experiments cicatrization was more rapid at the beginning than at the end of the period of repair. At the beginning of the process of contraction, the curve inclined rapidly downwards (Text-fig. 7), then the inclination diminished and finally the curve became almost horizontal. The greater activity of the beginning of the granulating period has already been observed. It was generally attributed to the aging of the wound. In previous experiments[1] we found that during the period of contraction, a wound 60 to 70 mm. wide diminished from 9 to 10 mm. in 24 hours. When it was not more than 20 mm. wide the velocity of cicatrization decreased markedly and became very slight when the edges of the wound were located at a distance of only 10 to 12 mm. from each other. In recent experiments the variations of the size of a wound and not only of one of its dimensions were examined. The absolute value of the rate of cicatrization, that is, the surface lost by the wound in 24 hours, depended mainly on the size of the wound. Wounds of from 120 to 150 sq. cm. decreased from 4 to 7 sq. cm. in 24 hours, while the daily diminution of wounds from 10 to 20 sq. cm. was but 1 to 2 sq. cm. In Experiment 1 the wound followed the same law. When its area was 16.2 sq. cm., it diminished at a speed of 1.37 sq. cm. When it attained 1 sq. cm. its velocity became 0.3 sq. cm. It was therefore evident that the rate of repair was proportional to the size of the wound.

The rate of cicatrization, however, was not exactly proportional to the size. For example, in Experiment 1 the area which on Dec. 17 was 16.2 sq. cm. became 1 sq. cm. on Jan. 6. If the equation

$$\frac{S}{S'} = \frac{R}{R'}$$

represented the rate of cicatrization, the rate R' would be expressed thus:

$$R' = \frac{RS'}{S}$$

and its value in Experiment 1 would be $R' = 0.08$. However, it was found that the rate of cicatrization when the size of the wound was 1 sq. cm. decreased only to 0.3 instead of 0.08, and that the complete healing occurred at the end of 6 days. Similar results having been obtained in other experiments it may be concluded that the rate of cicatrization diminishes at the same time as the size but less rapidly. On the other hand, comparison of the figures representing the rate and the area shows that the value of the rate in relation to the size augmented progressively. In Experiment 1 the velocity of cicatrization was successively $\frac{1}{36}$, $\frac{1}{11}$, $\frac{1}{10}$, $\frac{1}{11}$, $\frac{1}{8}$, $\frac{1}{7}$, $\frac{1}{3}$, $\frac{1}{5}$, and $\frac{1}{2}$ of the area. It was found also that the value of the rate in relation to the surface was always greater in a small than in a large wound. If it were otherwise cicatrization would be extremely slow and wounds would not heal.

As stated above, the diminution of the velocity of cicatrization as healing progresses has been generally attributed to the aging of the wound. In reality the phenomenon depends on the reduction of the size of the wound. Former experiments have shown that during a similar period large wounds cicatrized with greater velocity than small ones. In recent experiments made on men and on guinea pigs the rates of cicatrization of wounds of equal area and of different age were compared. Table I shows that wounds of an area of 2 sq. cm. cicatrized completely in from 8 to 10 days and that no relation existed between their age and the velocity of cicatrization.

TABLE I.

Case No.	Age of wound.	Size of wound.	Day of healing.
		sq. cm.	
290	42 days.	2.2	8
354	7 mos.	2.2	8
256	2 "	2	9
330	13 days.	2.1	8
217	2 mos.	2.2	10
221	5 "	2.2	8

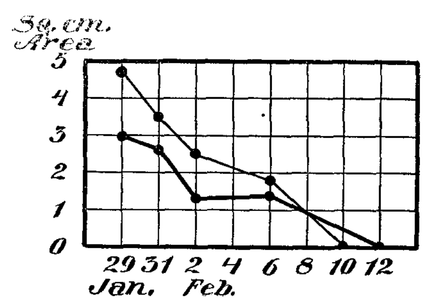
The observations made on guinea pigs gave similar results (Table II).

TABLE II.

Guinea pig No.	Age of wound.	Size of wound.	Day of healing.
	days	*sq. cm.*	
1	7	1.1	8
5	5	1.1	6
2	11	1.1	4
3	11	1.1	5

Since wounds of equal size but of different age cicatrized with variable velocity independently of the age of the wound, the slackening in the speed observed at the end of the period of cicatrization was probably the result of the diminution of the size.

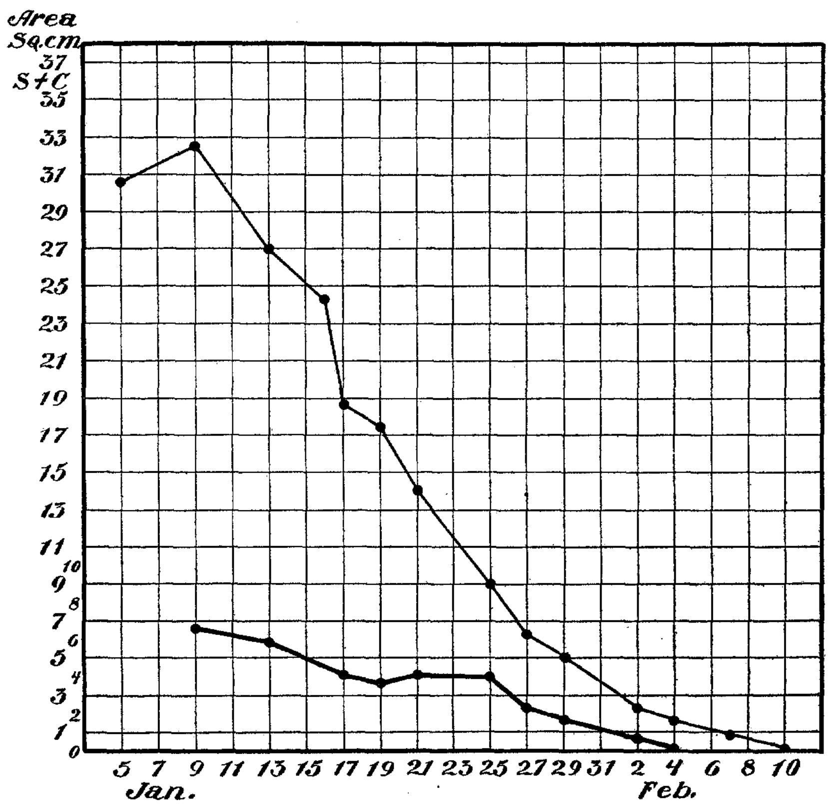
To complete the demonstration of this fact, we have studied wounds of equal age and unequal size. Previous experiments had shown that if two wounds were made at the same time on a dog, the rate of repair of the larger wound was greater than that of the smaller one. So in trapezoidal wounds the reduction of the smaller side was slower than the diminution of the larger side. After a few days, therefore, a trapezoidal wound showed a tendency to become rectangular, circular, or oval. These results were confirmed in the following experiments.



TEXT-FIG. 11.

Experiment 11.—Patient 286, age 30 years (Text-fig. 11). Shell wounds of the clavicular region. The interval between the curves of the larger and smaller wounds became progressively shorter, showing that the rate of repair of the larger wound was greater than that of the smaller one. The larger wound healed before the smaller one.

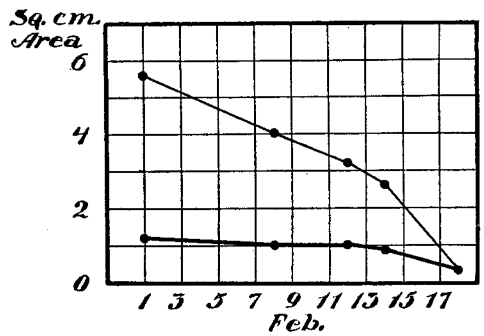
	Area (S) of larger wound.	Area (S') of smaller wound.	$S-S'$	$\frac{S}{S'}$
Jan. 29	4.7	3.0	1.7	1.5
Feb. 6	1.7	1.4	0.3	1.2



TEXT-FIG. 12.

Experiment 12.—Patient 290, age 31 years (Text-fig. 12). Shell wounds with fracture of the radius and cubitus. The curves of both wounds tend to unite.

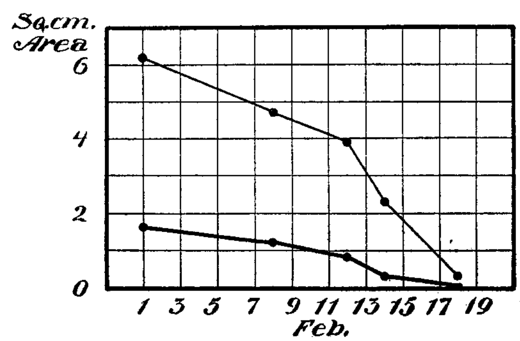
	Area (*S*) of larger wound.	Area (*S'*) of smaller wound.	$S-S'$	$\frac{S}{S'}$
Jan. 9	32.5	6.7	25.8	4.8
Feb. 2	2.3	0.6	1.7	3.8



TEXT-FIG. 13.

Experiment 13.—Cat 1 (Text-fig. 13). Wounds of the abdominal wall. The curves of both wounds unite at the end of the period of cicatrization.

	Area (S) of larger wound.	Area (S') of smaller wound.	$S-S'$	$\frac{S}{S'}$
Feb. 1	5.6	1.2	4.4	4.6
" 18	0.3	0.3	0	1



TEXT-FIG. 14.

Experiment 14.—Cat 2 (Text-fig. 14). Wounds of the abdominal wall. The curves of both wounds tend to unite.

	Area (S) of larger wound.	Area (S') of smaller wound.	$S-S'$	$\frac{S}{S'}$
Feb. 1	6.2	1.6	4.6	3.8
" 18	0.3	0	0.3	

The graphic expression of these experiments shows that wounds of unequal dimensions have a tendency in the course of cicatrization to become equal in curve. In Experiment 13 a wound of 5.6 sq. cm. and another wound of 1.2 sq. cm. were both reduced after 17 days to

0.3 sq. cm. (Text-fig. 13). It is evident that the lessening in the rate of cicatrization at the end of the period of repair is due to the progressive diminution of the size of the wound and not to its age.

The Value of Contraction and of Epidermization in the Healing of Wounds.

In order to study the relation of contraction and epidermization and the comparative value of both processes, not only the area of the wound had to be known but also that of the cicatrix. The area of the cicatrix was determined by the use of a planimeter on cellophane tracings. The curves expressing the area of the wound and the area of the cicatrix and the wound were separated by an interval which represented in square centimeters the area of the cicatrix at a given time. The value of the epidermization and of the contraction could thus be ascertained every day.

In these experiments errors might arise from lack of distinctness in the outer edge of the cicatrix. It was necessary, therefore, to select wounds whose measurements could be made with sufficient accuracy. The experiments were made on eight wounds on patients of different ages, on a wound made on a guinea pig, and on two wounds made on cats.

Experiment 23.—Cat 1. Wound of the abdominal wall.

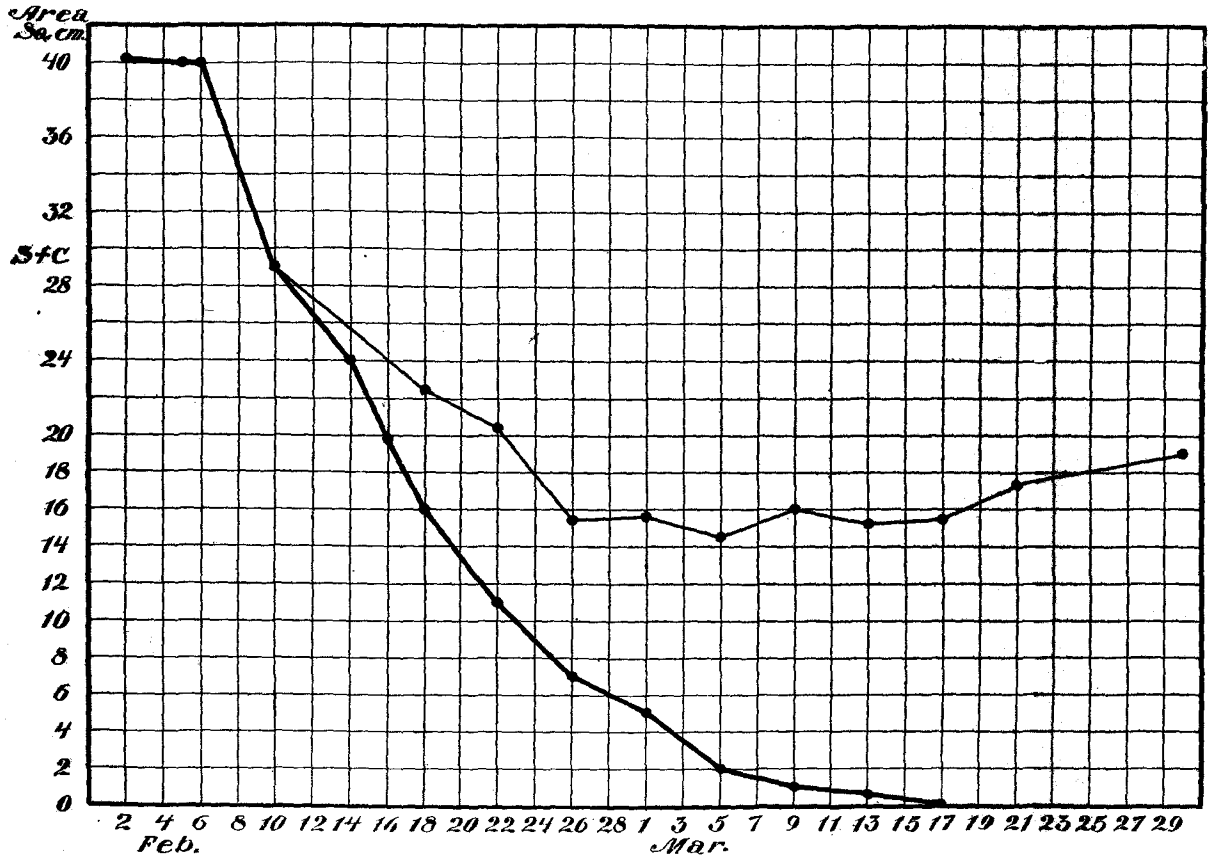
	Feb. 1	8	12	14	18	23
S	5.6	4.0	3.2	2.6	0.35	0
$S + C$	5.6					1.3

Experiment 24.—Cat 2. Wound of the abdominal wall.

	Feb. 11	12	14	18	21	23
S	6.2	3.9	2.3	0.35	0.1	0
$S + C$	6.2					0.5

Experiment 25.—Patient 354, age 40 years. Old wound on a stump.

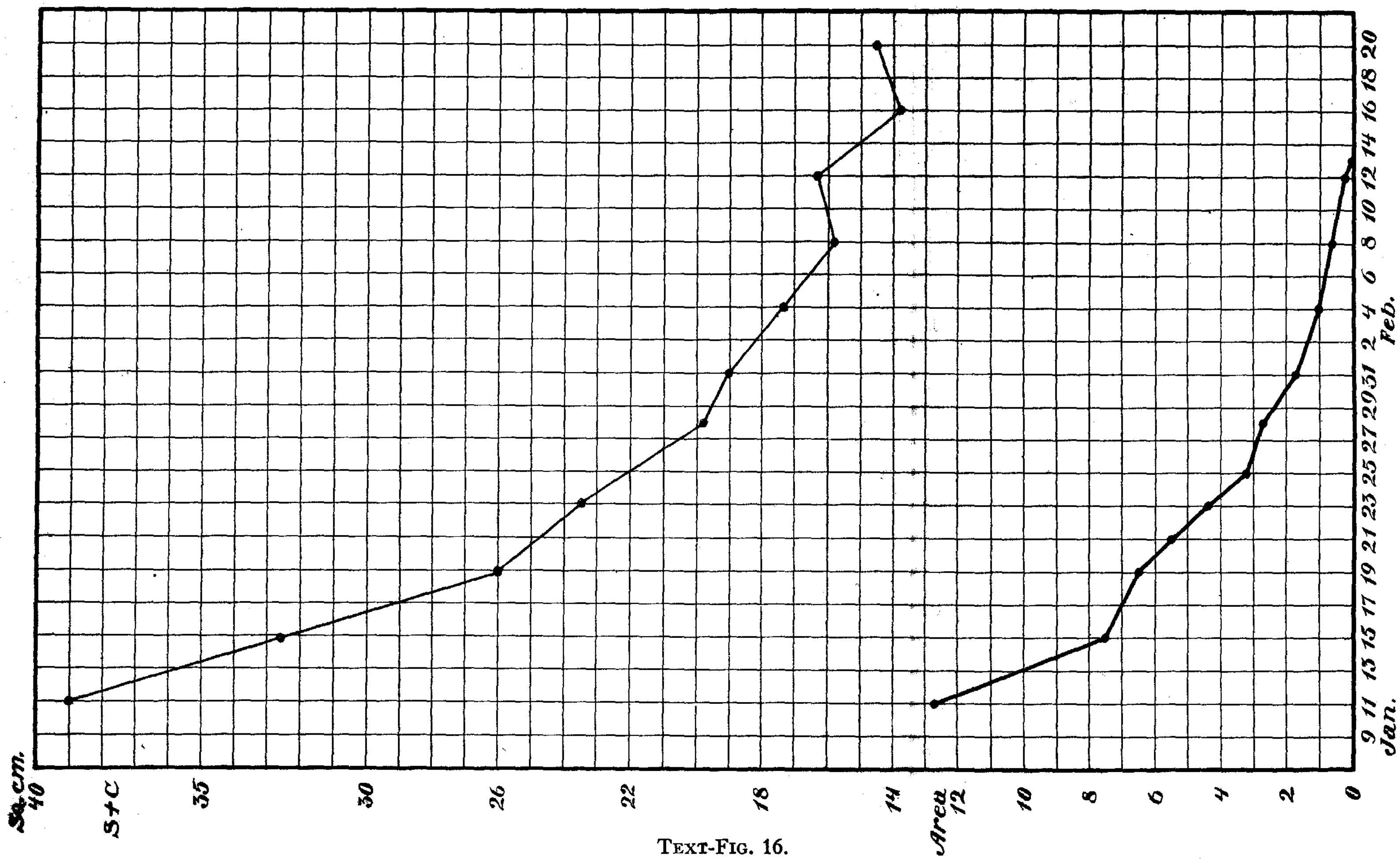
	Jan. 20	22	24	25	27	30	Feb. 1	4	6
S	6.2	4.7	3.5	3.0	2.2	1.3	1.0	0	
$S + C$	42.8				40.0		37.0		40.7



TEXT-FIG. 15.

Experiment 15.—Patient 361, age 21 years (Text-fig. 15). Shell wound of the posterior thoracic region. The lower curve represents the area of the wound, and the upper curve the area of both wound and cicatrix. The curve of the wound was horizontal until Feb. 6. Afterwards it descended regularly. The upper curve became horizontal on Feb. 26, showing that the last part of the healing was due to epidermization alone and not to contraction.

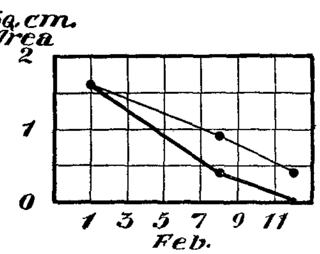
	Feb. 2.	6	10	14	16	18	22	26	Mar. 1
S...............	40.2	40.0	29.3	24.0	19.8	16.0	11.0	7.1	5.0
$S + C$...........						22.5	20.5	15.5	15.6



TEXT-FIG. 16.

Experiment 16.—Patient 256, age 21 years (Text-fig. 16). Shell wound of the leg. Both upper and lower curves descend together. This shows that the wound cicatrized at the same time by both processes, contraction and epidermization. After healing was completed, the upper curve ascended, because the cicatrix began to repair.

	Jan. 11	15	19	21	23	25	28	31	Feb. 4	8	12	13
S.....	12.7	7.5	6.5	5.5	4.4	3.2	2.7	1.7	1.0	0.6	0.2	0
$S + C$	39.0	32.5	26.0		23.5		19.8	19.0	17.4	15.8	16.3	



TEXT-FIG. 17.

Experiment 17.—Guinea Pig 5 (Text-fig. 17). Wound of the abdominal wall. Both curves descend together showing that epidermization and contraction took part in the healing of the wound.

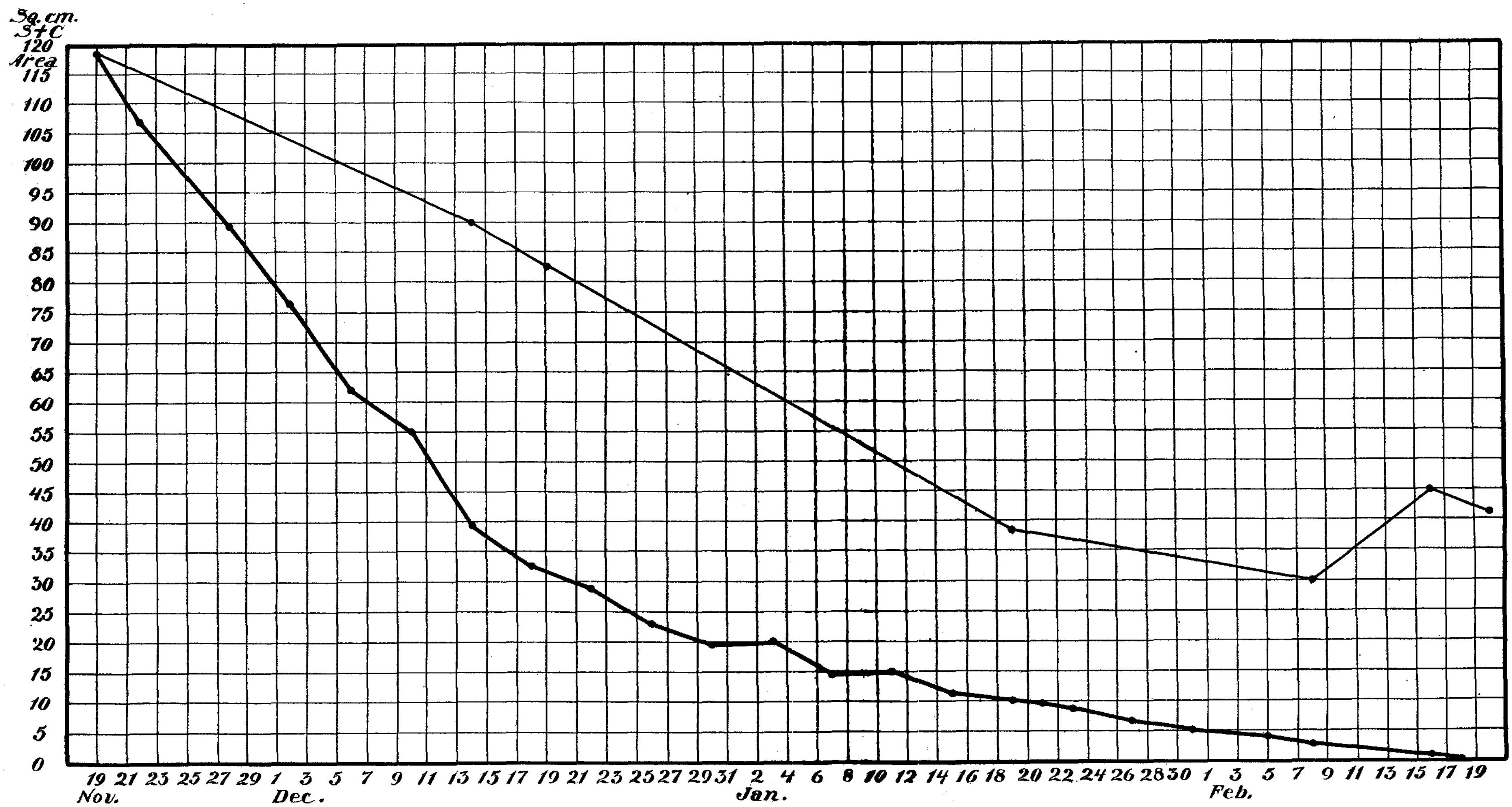
	Feb. 1	8	12
S	1.6	0.4	0
S + *C*	1.6	0.9	0.4

The tracings representing the cicatrization of these wounds demonstrate that contraction was nearly always associated with epidermization. In the experiments previously made on dogs at The Rockefeller Institute, the period of contraction started from 2 to 5 days after the resection of the flap of skin. The beginning of the contraction was preceded by a period during which the tracing had a horizontal direction. Then the curve inflected abruptly downwards and the reparation of the wound began. In Experiment 7 the period of immobility of the wound lasted for 6 days. In Experiment 15 it lasted longer although the wound was covered with granulations. A fragment of shell, remaining in the deep part of the wound, maintained the tissues in a condition of infection which prevented reparation.

After a few days the processes of contraction and epidermization always coexisted. However, there was a period when the wound healed exclusively by contraction. On the curve of Experiment 15 it is seen that during 12 days, contraction alone caused the reparation. Afterwards, epidermization started and the wound cicatrized under the influence of both processes. In most of the wounds observed on human beings contraction and epidermization worked together. Generally contraction continued until complete healing. The curves of the wounds in Experiments 16, 18, and 25 illustrate this phenomenon. However, contraction sometimes stopped before cicatrization was complete. It should be remembered that this process is dependent on contraction of the granulation tissue and on the opposite action of the tissues surrounding the wound. The resistance of the skin to granulous contraction is very slight in narrow wounds. If the defect is larger, the wound contracts until the elasticity of the surrounding skin prevents a greater reduction of its size. It is also probable that under certain conditions the granulation tissue does not possess the power of contraction. In Experiment 18 contraction did not last until complete healing. The curves representing the cicatrization of the wounds of Experiments 21 and 22 show that during the last days of repair the area of the cicatrix enlarged. In both wounds epidermization assumed almost entirely the effort of repair. As contraction was lacking, epidermization became more rapid and compensated for the dilatation of the cicatrix. It would seem that the processes of contraction and epidermization, although independent in some measure, can each make up for the other's deficiency.

Contraction always activated healing unless retrogression of epidermization occurred simultaneously. The upper curve of Experiment 23 shows a sudden and temporary acceleration of contraction. The lower curve remains parallel to the upper curve. It shows that epidermization had no influence on the rate of contraction. The lower curve indicates a sudden acceleration of the cicatrization, under the influence of a certain substance. During the same period the upper curve remained regular, showing that contraction pursued its normal course while the process of epidermization alone responded to the disturbing action of the dressing. The factors which acted on one of the processes appeared to have been without influence on the other.

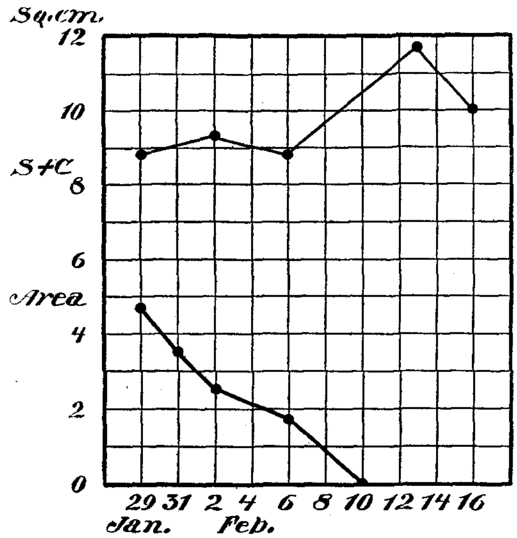
The relative importance of both processes, contraction and epidermization, was valued quantitatively by comparing the area of the cicatrix and that of the wound. The area of the cicatrix represents the result of the epidermization. The difference between the surface of the cicatrix and of the wound gives the value of the contraction. Previous experiments had shown that the cicatrix of a large wound was comparatively smaller than that of a small wound. Two rectangular wounds, one 66 mm. wide and the other 26 mm. wide, were made on the same dog under ether anesthesia. The wound of 66 mm. gave a cicatrix 22 mm. wide, and that of 26 mm. a cicatrix of 13 mm. The width of the cicatrix of the larger wound represented a third of



TEXT-FIG. 18.

Experiment 18.—Patient 263, age 36 years (Text-fig. 18). Wound of the forearm with fracture of the cubitus. Cicatrization is brought about by both processes. As soon as the healing was completed, the cicatrix became larger, as is shown by the upward inflection of the curve.

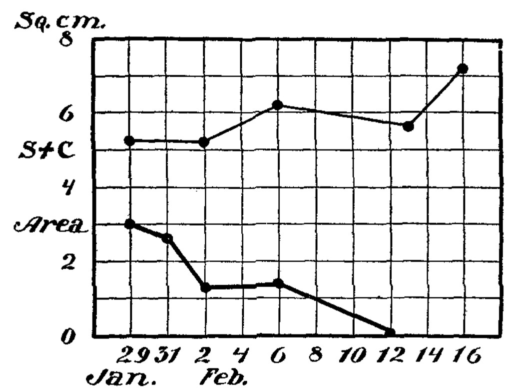
	Nov. 19	28	Dec. 6	14	26	Jan. 7	19	31	Feb. 8	16	20
S.........	118.5	89.6	62.1	39.7	23.0	14.8	10.0	5.2	2.6	0.4	0
S + C.....				90.0			38.5		30.0		41.0



TEXT-FIG. 19.

Experiment 19.—Patient 286, age 30 years (Text-fig. 19). Wound of the upper clavicular region. The upper curve remains horizontal for a while and afterwards goes up. Cicatrization was due entirely to epidermization and not to contraction.

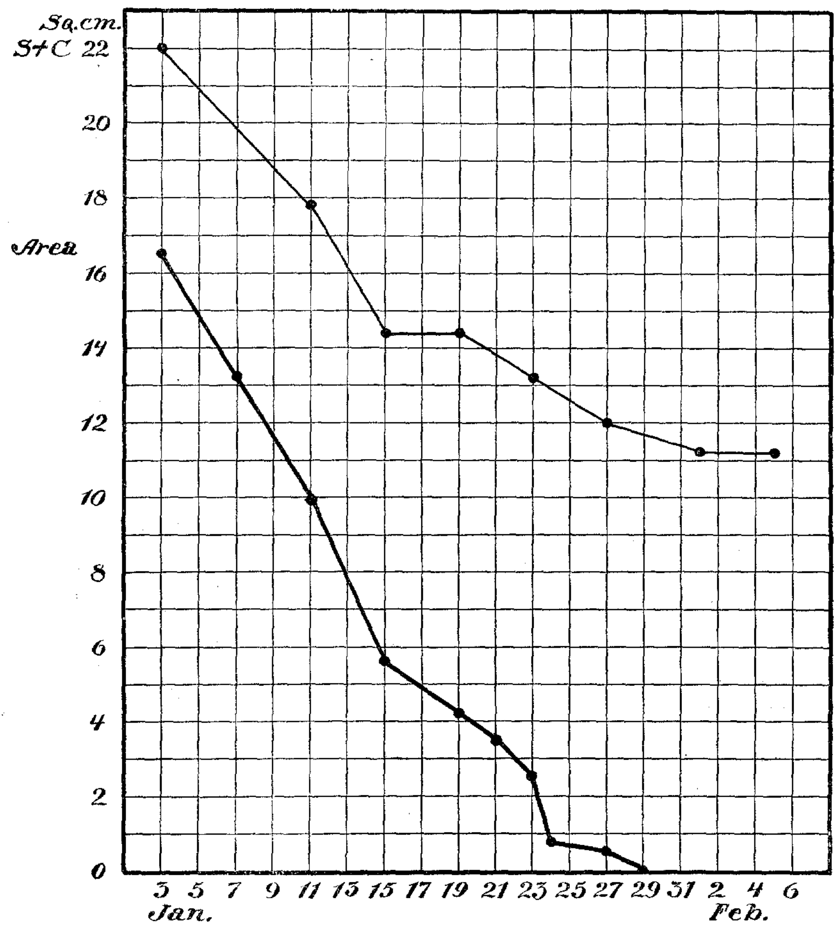
	Jan. 29	31	Feb. 2	6	13
S..	4.7	3.5	2.5	1.7	0
S + *C*....................................	8.8		9.3	8.8	11.7



TEXT-FIG. 20.

Experiment 20.—Patient 286, age 30 years (Text-fig. 20). Wound of the lower clavicular region. The upper curve remains almost horizontal. No contraction. Cicatrization was produced by epidermization.

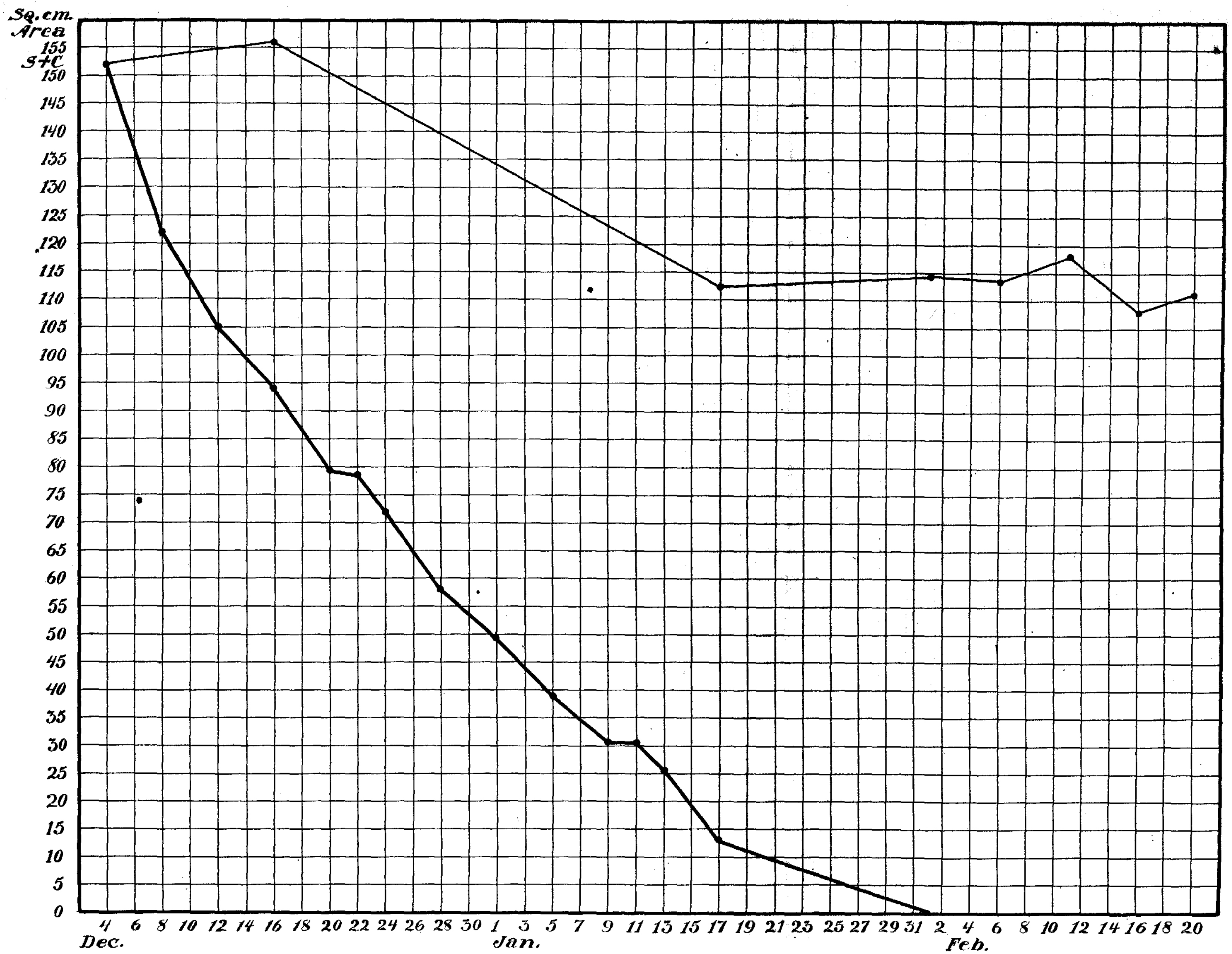
	Jan. 29	31	Feb. 2	6	12	13	16
S.............................	3.0	2.6	1.3	1.4	0		
S + *C*..........................	5.2		5.2	6.2		5.6	7.2



TEXT-FIG. 21.

Experiment 21.—Patient 289, age 29 years (Text-fig. 21). Shell wound of the external part of the leg. On Jan. 15 the downward inflection of the lower curve was the result of the acceleration of contraction. From Jan. 15 to 19, the upper curve remained horizontal while the lower curve went downward. On Jan. 24 the lower curve was irregular while the upper curve was not disturbed, showing that both contraction and epidermization were in some measure independent.

	Jan. 3	7	11	15	19	21	23	24	27	29
S........	16.5	13.2	9.9	5.6	4.2	3.5	2.5	0.8	0.5	0
S + *C*....	22.0		17.8	14.4	14.4		13.2		12.0	



TEXT-FIG. 22.

Experiment 22.—Patient 269, age 35 years (Text-fig. 22). Burn of the external surface of the right arm. The large interval between both curves shows that cicatrization was produced chiefly by epidermization. After Jan. 17 contraction ceased altogether.

	Dec. 4	8	16	24	Jan. 5	17	Feb. 5	11
S....................	152.0	122.2	94.0	72.0	39.0	12.8	0	0
S + C................	152.0		156.0			112.5	113.5	118.0

the width of the wound, and that of the smaller only a half. The cicatrix of a wound of about 1 sq. cm. in size was scarcely smaller than the wound. These facts were confirmed by Experiments 17, 24, 23, and 20. On Guinea Pig 6 three-quarters of the cicatrization was due to the contraction, and the last quarter to epidermization. In Cat 3 both processes acted in similar proportion. In Cat 2 one-twelfth of the cicatrization was due to epidermization. On the contrary, the reparation of the wounds in Experiments 19 and 20 was caused entirely by epidermization. As a rule, contraction played a more important part in healing than epidermization.

Mensuration of the cicatrix at the end of the period of repair showed that contraction stopped as soon as the wound was completely healed. From this time, the size of the cicatrix increased progressively. Thus, the period of contraction was followed by a phase of expansion, as in Text-fig. 15. The wound of Guinea Pig 6, the width of which was 4 mm. at the time of healing, measured 7 mm. 5 days later. The area of the cicatrix of Patient 354 in Experiment 25, which was 37sq. cm. the day of healing, reached 40 sq. cm. 5 days later. The cicatrix of Patient 269 which was 113.5 sq. cm. had an area of 118 sq. cm. 6 days later. Expansion was much less marked in man than in the dog. In animals whose experimental wounds were produced by resection of a large flap of skin, the dilatation of the cicatrix was much larger. It spread slowly for a long time in such a way that the scar might become as large as the original wound.

CONCLUSIONS.

1. A method for measuring the area of a wound not geometric in form is described.

2. The rate of cicatrization of a wound is greater at the beginning than at the end of the period of repair. It depends on the area rather than on the age of the wound. There is a constant relation between the size of a wound and the rate of cicatrization. The larger the wound the greater is the rate of cicatrization. Two wounds of different size have a tendency to become equal.

3. The rate is proportional to the area, but diminishes less rapidly than the area.

4. The process of contraction is the more important factor in the repair of a wound. Epidermization completes the work of contraction. After the wound is healed, the cicatrix as a rule expands.

5. The curve representing the diminution of the size of an aseptic wound while it cicatrizes is regular and geometric.