STUDIES ON THE CUTANEOUS SENSORY SPOTS

CUTANEOUS SENSORY PATTERNS TO MECHANICAL STIMULATION AND “SPECIFIC” SENSORY SPOTS

Yo Katô

1st Department of Internal Medicine, Nagoya University School of Medicine
(Director: Prof. Susumu Hibino)

Experimental investigations on cutaneous sensations were first undertaken in the middle of the nineteenth century. In the 1880’s, when small stimuli became available, sensory spots were discovered independently first by Blix (1882), by Goldscheider (1884), by Donaldson (1885), and since then many esthesiopsychological and -physiological studies of cutaneous sensitivity have been made.

Many investigation of the histological basis of cutaneous receptive mechanisms have also been made in experimental animals and human cases. With the progress of electronic technique electrophysiological studies have contributed much to elucidate sensory mechanisms, but by reason of their technical limitations these studies have been limited chiefly to animal experiments.

However, to investigate the relations between sensory perception and morphological and electrophysiological findings, it is essential to study clinico-physiologically the sensory experiences in humans.

In this paper cutaneous sensitivity to mechanical stimulation was studied in human subjects in the form of stimulus-response relationship.

In most investigations of this kind in the past, stimuli employed were not determined quantitatively, therefore a quantitative consideration was impossible. Furthermore, most of these previous studies were performed by qualitatively different stimuli for touch and pain (e.g., v. Frey hairs or nylon threads for touch and “fine sharp needles” for pain), and it was difficult to investigate the relation between the thresholds for these two senses.

In this study the newly devised Abe’s esthesio-algesiometer (1958) was used. This apparatus enabled us to perform quantitative stimulation of the same quality for both touch and pain sensations, permitting more detailed examinations of these sensations.

“Specific” cutaneous sensory spots were found and investigated that gave the sensations of peculiar quality to needle stimulation that did not seem to belong to any of the modalities of touch, warmth, cold and pricking pain, which are customarily recognized as elementary cutaneous sensations.

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SUBJECTS AND METHODS

The subjects used were healthy young male adults, the majority being physicians experienced in the perception of sensory stimuli.

The regions investigated were the forearm (volar aspect), the popliteal surface, the forehead, the cheek, the distal phalanx of the middle finger (palmar aspect), the back, the thigh (anterior aspect), the sole, and the glans penis. Many observations were made on the volar aspect of the forearm, since this region has been the site of election for sensory experiments in the past, and has thus aquired the status of a standard area. The popliteal surface and other regions were chosen because each was characteristic in cutaneous sensory pattern.

A wooden stamp was made consisting of two sets of 6 lines at one millimeter intervals and at right angles to each other (Fig. 1). To investigate cutaneous sensory patterns, this stamp was used to impress an inked "grid" on the area of the skin to be tested, care being taken to avoid any large veins, and each of the 36 crossing points of the grid was examined. The total number of points examined was 2412.

The area to be tested was shaved thoroughly about 12 hours before the experiment, and confirmed for absence of lanugo under the magnifying glass just before the experiment.

For the stimulus, the newly deviced Abe's esthesio-algesiometer (Abe, Kita-hara, Ando and Katô, 1958) was used. This Abe's esthesio-algesiometer was designed to provide fine and quantitative mechanical stimuli with a sharp needle. This meter utilizes the principles of Barrow's parallel laminae (Barrow, 1926-27) and of the optical lever (Fig. 2). "Barrow's parallel laminae" is a hard plate (H) to both ends of which are attached spring laminae (Sp). The end of one laminar spring is fixed to an arm (A) and to the end of the other spring is attached the stimulating needle (N) (Fig. 3). When the arm is depressed and the point of the stimulating needle presses down on the skin, the hard plate inclines. A small mirror (M) is set on the hard plate and the inclination of the hard plate is magnified by an optical lever system (Fig. 4).

The calibration graphs of the scale readings (cm) plotted against grams of force acting on the point of the stimulating needle are linear according to the law of elasticity, and shows the possibility of stimulation of the finest quantity (Fig. 5). Selected springs of parallel laminae permit desired range of strength of stimulation. In the present study stimulators of ranges from 0.25 to 5.0 g and from 0.05 to 1.0 g were used.

The points of the standard stimulating needles were 10 micra in radius of curvature, and the sharpness of the point was checked periodically under the microscope by comparison with a standard.

The quantities of stimulus were expressed in terms of grams of force acting on the stimulating needle. Because the effect of stimulation is dependent
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FIG. 2a. Principle of Barrow's parallel laminae.

FIG. 2b. Principle of optical lever.

FIG. 3. Stimulator of Abe's esthesio-algesiometer.

FIG. 4. Scheme of Abe's esthesio-algesiometer. Details in text.
not only upon the force applied, but also upon the curvature of the point of the needle and the rate of descent of the needle, stimulating needles of the same size and form were used, and the rate of descent of the needle was kept as constant as possible.

\[ \begin{align*}
&\text{Stimulator No. 3} \\
&\text{Stimulator No. 4}
\end{align*} \]

![Figure 5. Calibration graph of the stimulators.](image)

**RESULTS**

§ 1. Responses of Single Cutaneous Point to Mechanical Stimulation

When a single point of the skin was stimulated with needle stimuli progressively increased in strength, various types of responses were obtained according to the point tested. In Fig. 6 examples of these various response types are presented; open circle representing touch response, filled circle pricking pain, and cross no response. On one and the same point five stimulations were repeated at a given strength, and the threshold of sensations was defined as that strength of stimulus at which all the five repeated stimulations aroused responses with the same sensory experiences.

At point A, very weak stimuli (0.05 g) all responded with touch sensations, so the tactile threshold was 0.05 g or less. As the strength of stimulation was increased tactile impressions became progressively stronger, and when the stimuli reached a definite value (1.1 g), pain responses began to appear, and with stronger stimuli (1.25 g) five pain responses were obtained. So the pain threshold of this point was 1.25 g. Thus, the cutaneous point which gave the tactile sensation at weaker stimuli was designated a "tactile point".

Point B, stimulated with stimuli progressively increased in strength, gave rise first to tactile sensations as point A. But its tactile threshold was slightly higher, 0.63 g. Then it gave pain sensations with stronger stimuli, its pain
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At point C, as the stimuli were increased in strength, tactile responses appeared first as at points A and B, but pain responses began to appear at a strength of stimuli (0.42 g) at which five tactile responses were not yet obtained, and as the stimuli further increased in strength (0.58 g), pain responses were completed. In this case, therefore, the tactile threshold could not be determined. Such points as this were called "points of the second type response".

At points D and E only pain responses were obtained with strengths of 0.55 and 0.22 g, respectively, and without tactile response. These were designated "pain points", less sensitive and sensitive, respectively.

Point F is the "specific" sensory point and this will be discussed later, in § 3.

Many points on the skin were classified according to their types of response as shown above, into tactile points (points A and B), points of the second type response (point C), and pain points (points D and E). There was no point that gave touch responses with stronger stimuli, and showing pain responses with weaker ones.

Thermal sensations such as warmth and cold did not arise with needle stimuli of Abe's esthesio-algesiometer. When the needle touched a sensitive cold spot, occasionally a cold sensation was experienced. In this case, however, the cold needle did not act as a mechanical stimulus but did as a cold one, therefore this phenomenon, of course, is different from the arousal of thermal sensation by the mechanical stimulation of a thermal receptor (Goldscheider, 1926; Woollard, Weddell and Harpman, 1940).

While touch, warmth, cold and pricking pain had been considered as

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**Fig. 6.** Response types of single cutaneous points. ✕, represents no response; ○, touch; ●, pain; and ▲, "specific" sensory response.
fundamental or elementary sensations of the skin, spots giving peculiar sensations, which did not seem to belong to any of these elementary sensations, were found by Abe's esthesio-algesiometer. These spots were named "specific" sensory spots and their characteristics were investigated below.

§ 2. Relationship between Thresholds for Touch and for Pain of a Single Cutaneous Point.

To investigate the relationship between tactile and pain thresholds of each single cutaneous point, the "grid stamp" was impressed on the area to be examined, and thresholds of each of the 36 crossing points of the test grid were measured.

In Fig. 7 an example measured on the volar aspect of the forearm was shown. Each column represented the threshold values for touch (solid column) and for pain (white column) of each point, ordinates being strengths of stimuli in grams. Of 36 points, 27 were "tactile points" and 9 were "pain points". In this case "point of the second type response" was not observed. As shown in this figure, there seemed to be no correlation between tactile and pain thresholds of a given point. This fact is shown more clearly in Fig. 8, in which the pain thresholds were plotted against the tactile thresholds.

More detailed threshold measurements were carried out on the points at shorter intervals (0.25 mm) along a straight line on the volar surface of the forearm (Fig. 9). Thresholds for both pain and touch represented independent curves. The pain threshold curve was continuous, whereas the tactile threshold curve was interrupted at several regions, on the points on which the response type was of "pain point" or of "point of the second type response".

![Fig. 7. Relations between thresholds for touch and pain of single cutaneous points.](image-url)
The relation between tactile and pain thresholds of a given point is not constant but vary depending upon various factors, among which the sharpness of the stimulating needle may be the major one. The influence of the sharpness of the needle upon the thresholds for touch and pain was represented in Figs. 10 and 11. Fig. 10 top shows the thresholds for touch (solid column) and for pain (white column) of each of 36 points of the test grid on the volar aspect of the forearm to the standard stimulating needle with the point 10 micra in radius of curvature, and Fig. 10 bottom thresholds of the same points to the duller needle with the point 60 micra in radius of curvature. The relation between tactile and pain thresholds shifted. In Fig. 11 the "shift" of the thresholds for touch (left) and for pain (right) is shown. The tactile thresholds to the duller needle were equal to, or

![Correlation between touch and pain thresholds.](image1)

![Threshold curves for touch and pain.](image2)
FIG. 10. Comparison of touch and pain thresholds measured with the standard and the duller needle (A). Top: Threshold values measured with the standard needle. Bottom: Threshold values measured with the duller needle. White columns show pain thresholds, and solid ones touch thresholds. * indicates point of the second type response.

FIG. 11. Comparison of touch and pain thresholds measured with the standard and the duller needle (B). "Shift" of the thresholds for touch (left) and pain (right) is illustrated.
slightly lower than those to the standard needle. On the contrary, most pain thresholds to the duller needle were considerably higher than those to the standard needle. Consequently, change of response type of the cutaneous point occurred; namely, in the case of the standard needle, out of 26 points 23 were "tactile points", 12 were "pain points" and one a "point of the second type response" (point iv-6, indicated by (*) in Fig. 10 top), while in the case of the duller needle, 34 tactile points, 2 pain points and no point of the second type response were found, with 10 pain points and the point of the second type response changing into the tactile points.

§ 3. On the "Specific" Sensory Spots

Definition of the "specific" sensory spots:

"Specific" sensory spots, as described above, were defined as such spots that, stimulated with needle stimuli, gave sensations with peculiar qualities which could not be classified into any of the elementary cutaneous sensations, such as touch, warmth, cold and pricking pain.

Sensory experiences aroused from the "specific" sensory spots were expressed as "itch", "itchy pain", "penetrating pain", "burning pain", etc., and accompanied by unpleasant affective component; and when these responses were strong, concomitant reflex phenomena such as irresistible withdrawal response, cold sweat or shudder were observed with relatively small quantity of stimuli at which the ordinary pricking pain spots gave never such affective component or reflex phenomena. The "specific" sensory spots also tended to show after-sensations and radiation of sensation.

Response pattern of the "specific" sensory spots was shown in Fig. 12. Three "specific" sensory spots (1, 2 and 3) were chosen on the volar aspect of the forearm and the relation of sensory experiences to strength of stimuli was examined. With stimuli progressively increasing in strength these "specific" sensory spots, giving neither touch nor prick-
ing pain responses, began to give the above-mentioned peculiar sensory responses from the beginning, and with a given strength of stimuli (0.05, 0.23, and 0.37 g, respectively) the “specific” sensory responses were completed to all five stimulations; and if the strength of stimuli was further increased, the responses of these spots was not replaced by ordinary bright pricking pain but only their characteristic sensations became exaggerated, and concomitant reflex phenomena described above became more and more evident.

In Fig. 6-F, response pattern of the “specific” sensory spot was shown in comparison with that of other cutaneous points.

§ 4. Cutaneous Sensory Pattern of Various Regions of the Body

To obtain information on patterns of varied sensitivity of cutaneous points in various regions of the body, the following comparison was made. Thresholds of 36 crossing points of the test grid were measured in various regions, and these tactile and pain threshold values were separately rearranged in order of quality for convenience of comparison. In Fig. 13, the sensory patterns of the forehead, the cheek, the forearm (volar aspect), the tip of the middle finger (volar aspect), the back, the thigh (anterior aspect), the popliteal surface, the sole and the glans penis were presented.

At first sight it was apparent that the sensory pattern of each region has its characteristics. On the forehead, 36 points were all “tactile points” (average threshold = 0.19 g) and pain thresholds were relatively high (avg. = 1.5 g). On the cheek every point gave touch response to stimuli of 0.1 g, so this region, together with the fingertip, was most sensitive as concerns tactile sensation; the pain thresholds in this region were relatively low (avg. = 0.45 g). On the volar aspect of the forearm, nine of 36 points were “pain points”, and the pain thresholds were of medium quantity (avg. = 0.92 g). The sensory pattern of the finger pad was very characteristic. All 36 points responded with touch sensations at 0.1 g, as on the cheek, but pain thresholds were all very high, more than 5.0 g, and above the range of measurement of the stimulator employed. On the back it was characteristic that there were few tactile points. The average pain threshold was 0.71 g. On the thigh (anterior aspect) there were relatively few tactile points (15/36), ranking next to the back; and the pain threshold was 0.53 g on an average, thus this region was pain-sensitive, second to the cheek. The popliteal region was most peculiar. The tactile point was hardly found, ordinary pain points were few, and the majority of points were “specific” sensory points. “Specific” sensation in this region was very marked and, as the stimuli were further increased in strength, the subject felt the “specific” (itch, itchy pain, penetrating or burning pain) sensations irradiate even to the toe-tips, showed reflex withdrawal of the leg, and experienced irresistible desire to scratch the region stimulated. On the sole all 36 points were tactile points but the tactile thresholds were relatively high (avg. = 0.81 g), and the pain thresholds of all points were very high (over 5.0 g), as on the finger-pad, above the range of measurement of the apparatus. The glans penis was unique, where no tactile response was obtained and out of 36 points some were like “specific” sensory points, giving less localized penetrating pain
with affective component but without itching, and the remaining were less sensitive pain points.

While the "specific" sensory responses on the popliteal surface were very typical, some pain responses on the back, the cheek and the thigh, although simply classified as "pain" in Fig. 13, seemed to be tinged with the quality of "specific" sensory responses. There may be transitional or intermediate types of points with tinge of "specific" sensation between the typical bright pricking pain points such as those on the forearm or the forehead and the typical "specific" sensory points as in the popliteal region. Overall tinge of "specific" sensory response was most marked on the back, then in order, on the cheek and the thigh.

In addition, for purpose of comparison, the simultaneous two-point threshold obtained by the usual compass test (Head and Holmes, 1911) for each area examined was added in Fig. 13. This was especially low on the finger pad, relatively low on the cheek, sole and forehead, and high on the popliteal surface, forearm, thigh and back. Thus, the acuity of the two-point discrimination was closely related to the tactile sensitivity of a given region of the body.

§ 5. Differential Nerve Block Experiments

For the purpose of comparing characteristics of the "specific" sensory responses with those of tactile and pain responses, the following differential block experiments were performed.

1) Compression experiments with pressure above the systolic blood pressure

Typical "specific" sensory, tactile and pain points were chosen on the volar aspect of the forearm, and then nerve compression was induced by a sphygmomanometer cuff inflated to a pressure of 200 mmHg (above the systolic pressure) round the arm just above the elbow. (Repeated examinations revealed that incidence of the "specific" sensory points on the forearm was about 2% of points examined.) A rubber bag 23 cm by 12 cm was used in a wide sleeve so that the arm was uniformly compressed. The threshold changes of each point during and after compression were graphically presented in Fig. 14, ordinates being threshold values in grams and abscissae minutes after application and after removal of the cuff.

The tactile point showed no threshold change up to 20 minutes after the start of the compression, when the threshold was elevated abruptly and largely, exceeding the range of the scale of the esthesio-algesiometer, and after the compression was released the threshold returned rapidly to the value before the compression. On the contrary, the thresholds of both "specific" sensory and pain points showed a relatively similar pattern of variation, being elevated slowly several minutes after the start of the compression and returning relatively slowly after the compression was released.
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2) Compression block with the pressure intermediate between the systolic and diastolic blood pressures

During the compression block experiment development of spontaneous dysesthesia was most marked when the pressure was maintained intermediate between the systolic and the diastolic blood pressures. So, to investigate whether the "specific" sensory points behaved differently from the pain or the tactile points under this condition, the intermediate-pressure compression experiments were carried out. The results, shown in Fig. 15, were almost identical with those of the compression experiment with the greater-than-systolic pressure; the thresholds of the "specific" sensory points showed similar curves of anesthetization and recovery to those of the pain points. Only difference between the results of the compression block with the greater-than-systolic pressure and those with the intermediate pressure seemed to be that in the latter threshold elevation of the "specific" sensory and the pain points was larger, and gradient of threshold change was steeper than in the former.

3) Procaine block

On the region of the forearm innervated by the ulnar nerve, the "specific" sensory, the tactile and the pain points were chosen, and then the ulnar nerve was blocked in the ulnar groove at the back of the elbow. 0.7 ml of 0.5% Procaine solution was infiltrated round, but not into, the nerve trunk. Fig. 16 showed the variations of threshold of each point. Several minutes after the infiltration of the anesthetic occurred hypalgesia of the pain points, and the thresholds of the "specific" sensory points were also elevated concomitantly but more markedly; while the threshold of the tactile points remained...
FIG. 15. Compression block with the pressure intermediate between the systolic and the diastolic blood pressure.

FIG. 16. Procaine block (Ulnar nerve).

unchanged.

Furthermore, it was noteworthy that, when the threshold of the “specific” sensory and the pain points were markedly elevated, the “specific” sensory point (A and B) and the pain point (D) showed tactile responses to the stimuli with strengths between their threshold values before anesthetization and those for “specific” sensory responses or pain responses, respectively, at a given
point of time, behaving as "tactile point" (specific sensory point A at the 17th min., point B at the 15th and 20th min.; indicated by circles in the figure) or "point of the second type response" (pain point D at the 13th, 18th, 37th, 42th, 57th, and 73th min.; indicated by downward arrows in the figure).

4) Refrigeration anesthesia by local ethyl chloride spray

On the popliteal surface the "specific" sensory, the tactile and the pain points were marked, and then ethyl chloride was sprayed from a distance of about 30 cm for about 20 seconds, and the thresholds of each point were measured periodically (Fig. 17). The thresholds of all the points were abruptly elevated, exceeding the range of the apparatus, and the process was too rapid for a definite order of sensory loss to be stated. The threshold of the tactile point returned very rapidly, but that of the "specific" sensory and of the pain points showed similar curves of gradual recovery.

§ 6. Cutaneous Scar and "Specific" Sensory Responses

Weddell, Sinclair and Feindel (1948) stated that, in the course of recovery of traumatic lesions of peripheral nerves, and in certain cutaneous scars, the pain aroused by a needle-prick in the area of the skin involved was characteristically unpleasant, and was quite different from the sensation of pain which was produced in the normal skin.

To obtain information on relations between recovering nerve lesions or cutaneous scars and the "specific" sensory responses, small scars produced by cutaneous biopsy on the volar aspect of the forearm were examined three months after operation (Fig. 18). The scars themselves were insensitive, but on the skin area adjacent to the scar in case 1, where the wound healed some-
what irregularly, many “specific” sensory points were found. On the skin area neighboring the scar in case 2, where the wound healed very regularly, only one of 121 points explored was a “specific” sensory point.

In the cuff compression experiment with the pressure intermediate between the systolic and the diastolic blood pressures, the threshold curves of the "specific" sensory points in the vicinity of the scar were identical with those

FIG. 18. Cutaneous scar and “specific” sensory response.

FIG. 19. Intermediate-pressure compression block on the cutaneous area adjacent to the scar.
in the case of normal skin area. The threshold of the tactile points here, however, contrary to that in the normal skin area, behaved similarly to that of the "specific" sensory or pain point, showing relatively a steep elevation early in the course of compression and relatively slow recovery after the cessation of compression (Fig. 19). Occasionally, during and several minutes after the compression, some responses of these points were tinged with itch sensation, resulting in "touch-itch" responses.

§ 7. Underlying Histology of the "Specific" Sensory Spots

The "specific" sensory spots were marked on the volar surface of the forearm with India-ink tattoo, and then were removed for histological examination. Microscopic examination of sections stained with Nonidez' method revealed no organized or encapsulated endings but several unmyelinated nerve fibers gathered together in a bundle close beneath the tattoo mark which indicated the position of the "specific" sensory spot (Fig. 20).

DISCUSSION

Though it has long been known that the sensitivity of the skin to external stimuli show local differences, the so-called sensory spots were discovered in the 1880's by three investigators independently. Blix (1882, 1884), attempting faradic stimulation of the skin, found separate spots that responded independently with the qualities of pressure, cold, warmth and pain. (But later (1885), he rejected pain spots and pain as a modality). Goldscheider (1884), using various stimulations, mapped the skin for spots. What he found were separate warm spots, cold spots and pressure spots. He also, in his early work, found pain spots; but, later, in the 1890's, when v. Frey was arguing that pain is a fourth cutaneous modality, he, reversing his original position, vigorously supported the opposing intensive theory. Donaldson (1885) was the third independent discoverer of temperature spots. v. Frey (1894) made the argument for pain as a fourth separate modality in the skin, demonstrating the existence of pain spots. He also found for each of the four modalities a specific end-organ (1895): for pain the free endings between epithelial cells, for cold the Krause bulbs just beneath the skin, for warmth the Ruffini endings deeper down, for pressure the free-endings around the hair-follicles or in the palms and soles where there are no hairs, the Meissner corpuscles.14

The concept of the sensory spots was regarded to have been established, and since then has been a predominant theory in the field of cutaneous esthesiology. Thereafter, many studies on the peripheral receptive mechanisms were performed from the viewpoint of sensory spots, for example, numerous investigations of Goldscheider's school15 2021 and of v. Frey, Strughold and their collaborators12 22 23 24 31 60 61 62 studies in nerve division by Rivers and Head (1908)15 22 Trotter and Davies (1909)19 and Foerster (1927)19 experimental and histological studies of Dallenbach (1927), Pendleton (1928), Bazette et al. (1932)15 Waterston (1923, 1933a and b),19 70 71 and Bishop1 8 9 10 11 12 studies on the relationship between spot density and intensity of the stimulus (Guilford and
Lovewell, 1936); extensive histological studies of the Oxford school, such as Woollard, Weddell, Feindel, Sinclair and others, electrophysiological studies of Tower (1935, 1940 and 1934), and others.

Thus many studies on sensory spots have been performed; but in most of these studies, quantitative consideration of stimulation was not usually paid, and chiefly the simple v. Frey hairs, “fine, sharp needles” and the like, of which the shape and size of the point and quantity of stimulation were not detailed, were used.

Quantitative tactile and pain stimulations hitherto employed were outlined in Tables 1 and 2, respectively. Of various methods described in the tables the methods yielding quantitative punctiform stimuli necessary for studying sensory spots are the v. Frey hairs and bristles with thorn, quantitatively controllable needle stimulators and punctiform electric stimulators (needle electrode or electric sparks).

### Table 1. Methods used for Quantitative Examination of Touch Sensibility

<table>
<thead>
<tr>
<th>Method</th>
<th>Year</th>
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<tbody>
<tr>
<td>Graduated hairs</td>
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<tr>
<td>Spring-driven limen-gauze</td>
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</tr>
<tr>
<td>Pressure aesthesiometer (loaded steel rod)</td>
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<tr>
<td>Using principle of balance</td>
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<tr>
<td>Moving glass perle (load and speed variable)</td>
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<tr>
<td>Weighted lever with an attached point</td>
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<tr>
<td>Electronic stimulator (electric spark)</td>
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<tr>
<td>Graded needle aesthesiometers</td>
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<tr>
<td>Electric stimulus generator</td>
<td></td>
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<tr>
<td>Simple electronic stimulator</td>
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### Table 2. Methods used for Quantitative Examination of Cutaneous Pain Sensibility

<table>
<thead>
<tr>
<th>Method</th>
<th>Year</th>
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<tbody>
<tr>
<td>Spring-algesimeter (needle stimulation)</td>
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<tr>
<td>Bristles with thorn of a thistle (Carduus acanthoides)</td>
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<tr>
<td>Principle of balance (needle stimulation)</td>
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<tr>
<td>Electrically heated platinum loop and thermode (heat pain)</td>
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<tr>
<td>Metal grater incorporated in a sphygmomanometer cuff</td>
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<tr>
<td>Radiant heat dolorimeter</td>
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<tr>
<td>Electric current</td>
<td></td>
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<tr>
<td>Electronic stimulator (electric spark)</td>
<td></td>
</tr>
<tr>
<td>Electric stimulus generator</td>
<td></td>
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<tr>
<td>Microwave and infrared radiation</td>
<td></td>
</tr>
<tr>
<td>Simple electronic stimulator</td>
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<tr>
<td>Pressure algometer</td>
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<tr>
<td>Calibrated needle algesimeter</td>
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<tr>
<td>Cutaneous needle scratch method</td>
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</table>
Radiant heat dolorimeter of Hardy, Wolff and Goodell (1940), though convenient for areal stimulations of pain, is not suitable for punctiform stimulation.

v. Frey's tactile hairs and bristles with thorn for pain, though used generally, are very imperfect. Hairs of different diameters and lengths are chosen, held in a wooden holder at one end and graded as to the weight needed to cause bending, and then are applied to the skin in the same condition. Practically, however, making hairs bend to a constant degree is very difficult, and slight difference in the bending results in considerable difference in the quantity of stimulus. And owing to the bending of the hairs it is rather difficult for them to be applied perpendicularly to the skin, while the difficulty in avoiding "skidding" on the surface is another defect. Further, the influence of atmospheric humidity upon hairs can not be disregarded. Again, because studying relations between touch and pain sensation is one of the purposes of the present studies, stimulations of different qualities for touch and pain, hairs for touch and thorns for pain, are unsuitable.

Both pain and touch responses are elicited by electric stimulations, especially, Bishop's apparatus (1943) using electric sparks is excellent, making no contact with, and so no deformation of, the skin. In the electric methods, however, the stimulating current is so variable with variations in impedance of the skin and in condition of contact of the electrode or in spark distance, so that quantitative stimulation is not always so easy. Moreover, tactile and pain stimuli in actual human life are almost always not electric but mechanical.

On the grounds described above the needle stimulation of Abe's esthesiometer was chosen in the present study. For the stimulation needle the sewing needle for silk was used, the point of which was 10 micra and in part 60 micra in radius of curvature. This size is of the same order as the extent of sensory spot, described by Weddell (1941 b), permitting stimulation of a single sensory spot. Tactile and pain thresholds were measured by the same needle, so that it was convenient to study the relations between both senses. Using Barrow's parallel laminae, the needle is directed perpendicularly to the skin, and tendency for needle to skid is brought to a minimal. By means of fine spring laminal and the principle of optical lever the finest qualities of stimuli become available. In short, this apparatus fulfills most conditions necessary for the algesiometer described by Hardy, Wolff and Goodell (1952): 1) measurability of the stimulus with reproducibility, 2) controllability, 3) adequate range from "threshold" to "ceiling", 4) the production of minimal damage to tissue, 5) convenience, 6) the production of clear-cut perception of pain; and, in addition, it gives punctiform stimuli which are essential for studying sensory spots.

In the present study the threshold of sensations was defined as that strength of stimulus by which all five successive stimuli responded with the same sensory experience, in order that the reproducible results were obtained, and eliminating influences of minimal errors in sites and quantities of successive stimulations.

To investigate the pattern of cutaneous sensitivity the threshold of each
crossing point of the "test grid" 1 mm apart from each other was measured. Though, ideally, the thresholds of the skin should be measured continuously, it was technically impossible, and it was found that the threshold measurement by the "grid method" was practically sufficient to give patterns of sensitivity and of quality. If necessary, threshold measurement was performed on points of shorter intervals on the smaller region.

As shown in Fig. 6, each point on the skin is classified into any of tactile point (A and B), pain point (D and E), point of the second type response (C) or "specific" sensory point (F) (vide infra), according to the response to stimulations of Abe's esthesio algesiometer. Each point except for the "specific" sensory point, has its threshold for pain, whereas threshold for touch is determined only at the tactile point. The thresholds for pain and those for touch are distributed independently of each other as shown in Figs. 7 and 8. More continuous measurement of thresholds reveals that the thresholds for both pain and touch represent independent curves (actually curved surface on the skin area) (Fig. 9). Such spatial distribution of thresholds for touch, pain and "specific" sensation is schematically represented in Fig. 21 (for purpose of simplicity the figure shows "threshold curves" instead of three-dimensional "curved surface of threshold"). The range in which the pain responses are obtained is hatched, and the stippled area indicate the range in which tactile responses are encountered. The "specific" sensory point, as shown in Figs. 6 and 12, does not give rise to touch or pricking pain responses to any strength of stimuli, so that the range in which the "specific" sensory responses are obtainable may be indicated as a solid area in Fig. 21. Points A, B, C, D, E and F in Fig. 21 correspond to respective points in Fig. 6. A point of the second type response may be such a point where both tactile and pain threshold curves come into contact with each other as indicated in Fig. 21, point C, so that slight difference in site stimulated or in strength of stimulus may result in difference in responses, touch or pain, making the determination of tactile threshold impossible.

The threshold curve for pain is continuous except at the site of the "specific" sensory spot, while that for touch is penetrated at several regions by that for pain and for "specific" sensation. The relation between threshold curves for touch and pain is not invariable but may change according to various factors, among which the sharpness of the stimulating needle may be the major one. If the duller needle is used for stimulation, the threshold curve for pain "shifts up", while that for touch remains relatively unchanged, as shown in Figs. 10 and 11; so that the tactile response range, which is hidden by the pain response range in the case of the standard needle, are uncovered (cf. Fig. 21) and some pain points and point of the second type response change into tactile points (Fig. 10). The dissociated "shift" of the threshold curves for touch and pain and consequent change of response types of cutaneous point may be observed in differential nerve block experiments (vide infra).

"Sensory spot" is a minute skin area, where the threshold curve represents a downward peak. Most previous studies, being poor in quantitative considerations, tended to describe that skin regions other than sensory spots were
“anesthetic”. It is, of course, incorrect. In investigation with stimuli of a given strength, only dichotomy into “sensitive” and “insensitive” regions was possible; in reality, however, curved surface of the threshold mentioned above undulates beneath the “insensitive” regions. Densities of tactile or pain spots per unit skin area have been reported (Goldscheider, 1884; v. Frey, 1894, 1895; Strughold, 1924; Rein, 1925; Bazette et al., 1932; Tindall and Kunkle, 1957; and c), but they are by no means coincident. Guilford and Lovewell (1936), using v. Frey hairs of 9 different strengths, found that, the stronger the stimulus, the more numerous were the tactile spots in a given skin area, and stated that the sensory spots were not scattered on the anesthetic ground, but the “gradients of sensitivity” should be spoken of. This fact was confirmed by us using v. Frey hairs of 7 different strengths (Abe, Kitahara, Kato and Ando, 1958; Kitahara, 1958). This is also clearly shown in Fig. 21. If, in this figure, stimuli of 0.4 g strength are used for seeking sensory spot density, one pain spot, two touch spots and one “specific” sensory spot may be found; but with stimuli of 0.6 g strength two pain spots, five touch spots and one “specific” sensory spot may be encountered. Furthermore, as described above, the form of stimulation (radius of curvature of the point) alters the threshold values especially for pain, as shown in Figs. 10 and 11. Therefore, speaking of spot densities without detailed description of strength and form of stimulation may be of no value.

![Fig. 21. Schematic representation of threshold curves for touch, pain and “specific” sensation. In the stippled area touch responses are obtained. In the hatched area pain responses, and in the solid area “specific” sensory responses. Points A, B, C, D, E, and F correspond to respective points in Fig. 6. Further details in text.](image-url)
There has been little attempt so far to compare the sensory capacities of the skin in different body regions. Recently, Hutchinson, Tough and Wyburn testing the sensation of touch, heat and cold in the skin of the face, back of hand and abdomen, stated that “a constant feature of the test was the low threshold of skin of the face, but the overall result, contrary to the general conception, revealed only a small range of variation in the skin sensitivity of the three regions”. Hardy, Wolff and Goodell stated that, using their radiant heat dolorimeter, the highest pain threshold value was obtained on the heel, and the lowest on the lower back, buttock, and thigh, and pain thresholds on all other body areas were approximately the same as that on the forehead. Kitahara compared the thresholds for touch and pain to stimuli applied at random within a given area by means of Abe’s esthesio-algesiometer on the forehead, finger pad, chest and the anterior and posterior aspects of the leg, and found the lowest tactile threshold on the finger pad and the highest on the anterior aspect of the leg and the lowest pain threshold on the chest and the highest on the finger pad.

Regional differences in sensitivity and relative distribution of the touch, pain and “specific” sensory points are clearly shown in Fig. 13. Such differences in cutaneous sensory pattern in the various regions may depend upon various factors both peripheral and central.

The texture of the skin, more particularly its thickness and flexibility, will affect the strength of stimulus which reaches the requisite nerve endings, and will thus influence the threshold. This is particularly apparent in such contrasting areas as the sole and the cheek. The facts, however, that the finger tip has the lowest threshold for touch and the highest for pain, and that the glans penis, though its tegument is very thin and flexible, has the higher pain threshold and, moreover, gives rise to no tactile response, show that the skin texture is, of course, not the only or even the major factor governing sensory pattern.

The quantity and quality of the innervation and the number and the three-dimensional arrangement of the nerve endings in the skin undoubtedly influence the difference recorded between the areas examined. Weddell has described the general plan of cutaneous nerve plexus and has shown, moreover, that the size of the superficial nerve nets varies in different parts of the body. It is also probable that the proportion and density of touch and pain fibers differ in various parts of the body.

Recording action potentials evoked in the cerebral cortex of the monkey by cutaneous tactile stimulation, Woolsey, Marshall and Bard revealed that the extent of cortical area devoted to a given region parallels the actual acuity and innervation density of the area, and thus, a wider strip is devoted to the face and the dermatomes for C8 (thumb and forefinger in monkey) and for L6 and L7 (foot). Correspondingly, in the present series, the two-point threshold is lower on the finger, cheek, sole and forehead than on the other regions examined. Average tactile threshold is also low on the finger, cheek and forehead. On the sole, however, though all 36 points of the test grid are “tactile points”, the threshold for touch is high. On this region the peripheral
factors, especially the thickness of the skin, may be responsible for the high tactile threshold. On the other five regions the average tactile threshold can not be calculated because at some points in these regions the tactile threshold can not be measured or, in other words, the curved surface of tactile threshold is “hidden” under that of pain threshold (vide supra). Thus, the acuity of the two-point discrimination and tactile sensitivity may largely be dependent upon the degree of cortical representation (“corticalization”) of function. By cutaneous pain stimulation no evoked potentials have been recorded in the cerebral cortex. The average pain thresholds in this series, of course, do not parallel the extent of cortical representation of tactile sensibility, and the peripheral factors may more largely be responsible for the pain threshold.

As regards the cutaneous sensory modalities, Volkmann (1844), for the first time, suggested that in the cutaneous sensory nerve there were separate nerve fibers conducting pressure, temperature and tickle sensations. Schiff (1858–59), based on experiments and many clinical cases, localized the pathway for pain and touch separately in the spinal cord. The first authoritative support for the separation of pressure and temperature was agreed upon by Funke (1880) and Hering (1880). Blix (1882, 1884) and Goldscheider (1884) may be said to have established pressure, cold and warmth as three separate modalities. Both men also presented good evidence for pain as a fourth sensory system, but the “spots” were so numerous and close together that it was practically impossible to find pressure, cold or warm spots which were insensitive to pain stimuli, so that they eventually, reversing their original positions, held that pain is a common sensibility. Herzen (1885) argued for the independence of warmth and cold, by means of differential pressure block of a cutaneous nerve. v. Frey made the argument for pain as a fourth separate modality in the skin (1894), and found for each of the four modalities a specific end-organ (1895). Later touch (or pressure), warmth, cold and pain were established as four separate modalities of the cutaneous sensation.

Among four modalities, those which are aroused by Abe’s esthesio-algesiometer are touch and pricking pain. Although some authors reported thermal responses by means of needles inserted into the skin, thermal responses have never been aroused by light needle stimulations in the present experiments.

Besides tactile and pain spots peculiar spots are found which, responding to needle stimulations, give specific sensory experiences that can not be categorized into any of the four customarily recognized modalities of cutaneous sensation, i.e., touch, warmth, cold and pricking pain. These spots are named “specific” sensory spots. Sensory experiences of these spots are expressed as “itch”, “itchy pain”, “penetrating pain”, “burning pain”, etc., and are accompanied with unpleasant affects, and when these responses are strong, reflex withdrawal, cold sweat or shudder are observed. These unpleasant affects and concomitant reflex phenomena are encountered even with relatively weak stimuli at which the ordinary pricking pain spots give never such phenomena. The “specific” sensory spots also tended to show marked after-sensation and radiation of sensation. These spots give no tactile or pricking pain responses, but only “specific” sensory responses to any strength of stimulus above the
threshold, as shown in Fig. 12. This fact suggests that these “specific” sensations are not induced by overstimulation of tactile mechanism, nor by subliminal stimulation of pain mechanism, and seem to have “elementary” characteristics like touch and pain.

Density of “specific” sensory points on different regions of the body, measured by means of “grid method”, are very varied. On the forehead, the palmar surface of the distal phalanx and the sole no “specific” sensory response is obtained despite many repeated trials. The popliteal region is very characteristic, since, as shown in Fig. 13, almost all points respond with “specific” sensations; and in this region itch and itchy pain sensations are especially remarkable. On the forearm a few “specific” sensory points are encountered. Although in the case shown in Fig. 13 no “specific” sensory point was found on 36 points explored, repeated examinations in many subjects revealed that incidence of “specific” sensory points was about 2% of points examined. In this region the difference of pricking pain and “specific” sensory response is distinct, and penetrating pain and burning pain sensations are marked. In the other regions tested, i.e., the back, the cheek, and the thigh, the situation is slightly different. Namely, among non-tactile responses on these regions there are transitional or intermediate qualities of sensations, which have more or less “specific” sensory-like characteristics, between distinct pricking pain and typical “specific” sensory responses, and clear-cut distinction between these sensations, as on the forearm, is difficult. However, sensory experiences of one and the same point are almost of the same quality unrelated to the quantity of stimuli.

Taking the above-described characteristics of the “specific” sensory spots into consideration, the relationship of the “specific” sensation to “second” or “delayed” pain should be investigated. The “second” pain has been said to have slower onset, burning quality, and disagreeable affect and a tendency to after-sensation. In these respects “specific” sensory responses might be similar to those of “second” pain.

Double pain responses to single stimulation were to my knowledge first described by Gad and Goldscheider (1892). Alrutz (1901) postulated two kinds of fibers for explanation of these double pain responses. The first association of C fiber pain with the “second” pain was made by Zotterman (1933). "Second" or “delayed” pain unassociated by “first” pain has been observed both under experimental conditions and clinically. Prolonged asphyxia of the arm with sphygmomanometer cuff (Zotterman, 1933; Lewis and Pochin, 1938) provides the necessary experimental conditions; while clinically it has been observed that in certain cases of tabes dorsalis the only pain which can be evoked from the limb by pain-producing stimuli is that mediated by the slow impulses (Pochin, 1938). On the other hand Lewis (1938) has stated that pain of only one quality can be provoked from skin and the difference between “pricking” and “burning” pain is not one of quality or tone, but purely one of duration of sensation, a prolonged stimulus giving rise to pain described as “burning”. Woollard, Weddell and Harpman (1940) have shown that, when a fine, sharp needle is inserted into the skin, two types of pain can be aroused,
the first being abrupt in onset, hurting little, and lasting for a period corresponding to that during which the stimulus is being applied; the second is delayed in onset, rises gradually in intensity, gives the impression of a small stinging area and disappears slowly. Both types of cutaneous pain may occur independently or successively during the course of a single penetration, and the first or superficial pain is aroused at a level 0.25-0.5 mm below the skin surface and the second or deep pain at a level of 1.0 mm (average). On the basis of the physiological and histological investigations, they concluded that “several varieties of cutaneous pain can be aroused by a single stimulus, depending upon the nature of the stimulus and the region of the body stimulated” and “all varieties of cutaneous pain are subserved by the same nerve apparatus.” Weddell, Sinclair and Feindel (1948) found that, where pain of an unpleasant quality could be aroused, the nerve nets and terminals subserving the sensation of pain in the skin (Woollard, Weddell and Harpman, 1940) were isolated from their neighbors instead of interweaving with them as they do in normal skin (Weddell, 1941a, 1941b) and further suggested that pain of an unpleasant quality obtained during the compression experiments on the normal area was caused by “functional isolation” accompanied by decreased number of effectively conducting pain fibers and terminals; and objected to the view that the second pain was mediated by C-fibers.

In the present series the “specific” sensation and pricking pain do not occur successively to single stimulus but they occur independently. Further, the stimulations for both pricking pain and “specific” sensation are the same and not different in duration as in the case of Lewis' study (1938). Size of fibers subserving “specific” sensation will be discussed below in relation to differential nerve block experiments.

A reversible dissociation of the various modalities of cutaneous sensation has been produced by the application of cold (Weber, 1847), pressure (Bastien and Vulpian, 1855), or local anesthetics to a nerve trunk. Donaldson (1885) observed that cocaine instilled into the eye led to a dissociated anesthesia, and Goldscheider (1886) noted a similar phenomena when cocaine was injected round the trunks of the median ulnar nerves. Later, Bier (1899) studied sensory dissociation by spinal anesthesia with cocaine. The general results of all these experiments have since been ample confirmed. Since Gasser and Erlanger (1929) showed that the elevations in the electroneurograms of isolated frog and mammalian nerves exposed to the action of procaine disappeared in a characteristic order, the studies on differential nerve block have become an important method in the field of physiology of cutaneous sensations.

In the present study, during and after differential nerve block by means of compression with a pressure above the systolic blood pressure and with a pressure intermediate between the systolic and diastolic pressures induced by the sphygmomanometer cuff, of perineural infiltration of procaine and of cold anesthesia by local ethyl chloride spray, time-threshold relations of “specific” sensory, tactile and pain points were observed.

As concerns differential block with cuff compression, regarding touch and pain, Boeri and di Silvestro (1899), Fabritius and Bermann (1913), Lewis,
Pickering and Rothschild (1931), Zotterman (1933), Clark, Hughes and Gasser (1935), Lewis and Pochin (1938), Wortis, Stein and Jolliffe (1942), Weddell, Sinclair and Feindel (1948), Merrington and Nathan (1949), all have shown that touch is eliminated before pain. Sinclair and Hinshaw (1950b), considering compression block critically, have stated that, though in many cases touch is eliminated before pain, the order of sensory loss may become varied by modifying the conditions of the experiments. In these types of experiment in the past the "end point" of sensory elimination was determined rather roughly, at best, as the point at which the responses to stimuli of a given strength are eliminated. Furthermore, in many cases tactile and pain stimuli employed were different in character. These facts are decisive faults in discussion of order of sensory loss. It is clearly shown in Fig. 14, which shows the temporal variations in threshold of various kinds of points in the compression block experiment, that the time taken to reach the "end point" is a function of the intensity of the stimulus. Furthermore, if tactile and pain stimuli are different in quality, investigation of order of elimination of touch and pain sensations may be almost insignificant. In the compression experiments with the pressure above the systolic blood pressure (Fig. 14) and with intermediate pressure (Fig. 15) the threshold of tactile point does not change practically until 20 minutes after the start of compression, when it rises abruptly and markedly, while the threshold of pain point shows gradual and slight elevation relatively early in the course of compression. Consequently, nerve fibers subserving these two sensations are not blocked simultaneously. If, in this case, non-quantitative rough methods were used for determining "end point", the results would be that "touch was eliminated 20 minutes after the start of compression, while the pain was hardly eliminated". Pattern of the threshold variation in the compression experiment with the pressure intermediate between the systolic and the diastolic blood pressures (Fig. 15) is essentially identical with that in the experiment with the pressure above the systolic blood pressure, except that the threshold variation of the "specific" sensory and the pain points tend to be more marked in the former experiment than in the latter.

During the compression block experiment development of spontaneous dysesthesia is most marked, when the pressure is maintained intermediate between the systolic and the diastolic blood pressures (Sobue, 1957), so it is interesting whether the "specific" sensory point behaves in this condition differently from that in the over-systolic-pressure experiment. In both conditions, however, the threshold variations of the "specific" sensory points are similar to those of the pain points, and there are materially no differences between threshold variations in both experiments. This fact may suggest that there is no relationship between spontaneous dysesthesia during compression and the "specific" sensory points.

Concerning differential nerve block with anesthetics, Goldscheider (with cocaine, 1886) stated that pain and touch were eliminated almost simultaneously, but pain recovered before touch; and Endres (with Novocaine, 1929) showed that pain and touch were lost at the same time. Heinbecker, Bishop and O'Leary (1934), Dawkins (1945) and Merrington and Nathan (1949), using
procaine as an anesthetic, stated that pain was eliminated before touch. Sinclair and Hinshaw (1950a) stated, studying on procaine nerve block, that, in general, pain was blocked first and touch lost later but the order of sensory loss could be influenced by changing the various condition of experiments. In the quantitative experiment of the present study (Fig. 16) touch threshold was entirely unchanged and tactile impressions remained very clear, while threshold of pain point showed definite elevation and the threshold of the "specific" sensory point a more marked elevation.

In this experiment, when the thresholds of the "specific" sensory and the pain points rise markedly, the "specific" sensory points behave as "tactile point" and some pain point as "point of the second type response". This fact is explained by the dissociated "shift" of the curved surface of threshold for touch and pain (cf. Fig. 21). When, under the action of procaine, the curved surface of threshold for pain rises dissociatedly and comes into contact with that for touch hitherto "covered" by that for pain, the pain point changes into "point of the second type response", and when the curved surface of threshold for pain further rises above that for touch, it changes into a "tactile point". This fact may confirm the validity of the schematic representation of the curved surface of thresholds for various sensations (Fig. 21).

In the refrigeration anesthesia induced by local ethyl chloride spray, Franz and Ruediger (1910) reported that the process of anesthetization was too rapid for stating a definite order of sensory loss, but pain recovered after touch. Hacker (1914) stated that pain was eliminated before touch. In the present series the beginning of sensory loss was so rapid that the temporal variation of threshold was not traceable. In the course of recovery, however, distinct dissociation appeared, tactile threshold returning rapidly to normal, pain and "specific"-sensory thresholds returning slowly.

In the above-described quantitative study of differential blocks with compression, anesthetic and cold anesthesia, it was shown that there is a clear dissociation between touch and pain or "specific" sensation. Pain and "specific" sensations behave similarly under the influence of compression and cold anesthesia, so that it is difficult to distinguish pain and "specific" sensation in this respect. The "specific" sensation seems to be more sensitive to procaine block than pain.

Comparison of differential sensory block in human experiments and differential elimination of the elevations in the electroneurogram in animal experiments have yielded important informations in the field of cutaneous esthesiology. Gasser and his co-workers stated that, when a nerve was asphyxiated in an experimental animal, the first fibers to be blocked were small myelinated fibers; then as the asphyxia progressed, the larger myelinated fibers were included. After all the myelinated fibers were blocked, the unmyelinated C fibers were still functioning. Cocaine, on the contrary, blocked the C fibers very early, and then proceeded to block the myelinated fibers in the same way as asphyxia (Gasser and Erlanger, 1929; Clark, Hughes and Gasser, 1935; Gasser, 1935 and 1943). Comparing the results described above with the order of elimination of sensory modalities, they concluded that the tactile sensation was con-
ducted by the large myelinated (A-beta and -gamma) fibers and the pain sensation by the unmyelinated C fibers. On repeating the experiments of Gasser and Erlanger with cocaine, but with substitution of procaine, Heinbecker, Bishop and O'Leary (1934) confirmed their findings that fibers were blocked in the order of size, the smallest fibers first. Zotterman (1939) confirmed the association of C fibers with pain and showed that fine myelinated fibers of A-delta group also conducted pain impulses. In these studies, however, the determination of the end-point of sensory elimination was non-quantitative and rather arbitrary, so that the correlation of sensory elimination with elimination of elevations in the electroneurogram was not completely convincing.

When the threshold changes are followed quantitatively, it was clearly shown that, in compression block (Figs. 14 and 15) touch is suddenly and relatively completely blocked at a given point of time, whereas the thresholds of pain and “specific” sensory points begin to rise gradually early in the course of compression, and the grade of threshold elevation not so marked; and that, in procaine block (Fig. 16) touch threshold is not changed, while the thresholds of pain and “specific” sensory points show gradual elevation. These facts suggest, in connection with the electroneurographic findings, that fibers subserving touch are myelinated fibers, large and relatively uniform in size, and those subserving pain and “specific” sensation are unmyelinated and small myelinated fibers, the size of which is distributed over a relatively wide range. It is suggested from the experiment shown in Fig. 16 that the fibers subserving the “specific” sensation may be smaller than those subserving pain but they may be largely overlapping in size spectrum.

Many “specific” sensory points were found in the skin area adjacent to a scar where the wound showed slightly irregular healing (Fig. 18, case 1). This fact can not easily be explained but histological rarefaction of multiple innervation in the vicinity of the scar suggested by Weddell, Sinclair and Feindel (1948) may be responsible. In the cuff compression experiment in the present series responses of pain point were not changed into, or tinged with, responses of “second” pain or of “specific” sensation, though spontaneous dysesthesia were felt on the region below the site of compression. Namely, the “functional isolation” of pain apparatus reported by Weddell et al. was not observed.

The fact that in the compression experiment the time-threshold curve of touch points observed in the area neighboring the scar behaved differently from those in the normal skin area (Fig. 19) is not easy elucidated, but the following explanation may be presented; that, to the histological rarefaction of multiple innervation in the area adjacent to the scar is added functional rarefaction induced by compression, which in itself is not manifested without histological rarefaction, and ultimate “isolation” of peripheral touch apparatus is aggravated, so that, as shown in §6, the touch responses are occasionally accompanied by unpleasant effect and touch threshold is elevated in contrast to stability of threshold of the touch points in normal skin areas.

Histological study of the “specific” sensory spots with Nonidez' staining revealed a bundle of several nerve fibers in the dermis. Most former descriptions have stated that nerve fibers run singly under the epidermis and are
interlocked with each other in terminals, and fibers which run in a bundle to the very proximity of the epidermis do not seem to have attracted attention.

**SUMMARY**

In this paper cutaneous sensation to mechanical stimulation was studied in human subjects. The newly devised Abe's esthesio-algesiometer was used which enabled us to perform fine, quantitative needle stimulations of the same quality for both touch and pain sensations, permitting detailed quantitative and comparative examinations of these sensations. The results obtained are as follows:

1) Single cutaneous points were classified into four types according to their response types to needle stimulation by Abe's esthesio algesiometer; i.e., tactile point, pain point, point of the second type response and "specific" sensory point. "Tactile point", to stimuli progressively increasing in strength, gives rise first to tactile responses and, as the strength of stimuli is increased further, to pain responses. "Pain point" is that with no tactile responses but only pain responses are obtained. "Point of the second type response" stimulated with stimuli progressively increasing in strength gives rise to both pain and touch responses at a given strength of stimuli, and with slightly stronger stimuli, the pain threshold is determined.

"Specific sensory point" is defined as such cutaneous point that, stimulated with needle stimuli, gives rise to sensations of peculiar qualities which cannot be classified into any one of the customarily recognized modalities of cutaneous sensation, such as touch, warmth, cold and pricking pain. Sensory experiences aroused from this point are expressed as itch, itchy pain, penetrating pain, burning pain, etc., and accompanied by unpleasant affective component and reflex phenomena, such as withdrawal response, cold sweat or shudder. The "specific" sensory point does not give rise to touch or pricking pain sensation to any strength of stimulus, suggesting elementary characteristics of the "specific" sensation.

2) The thresholds for touch and pain sensations are distributed independently over the skin and may be graphically represented as independently undulating three-dimensional surfaces. Pain threshold surface is continuous except at the site of the "specific" sensory spot, while tactile threshold surface is penetrated at several regions by pain threshold surface, where the responses of "pain point" are obtained, and by threshold surface for "specific" sensation. "Point of the second type response" may be found in such a region where both tactile and pain threshold surfaces come into contact.

The relation between touch and pain thresholds of a given point is not constant but varies upon the sharpness of point of the stimulating needle. The tactile thresholds to a duller needle (60 micra in radius of curvature) are equal to, or slightly lower, than those to the standard needle (10 micra in radius of curvature). On the contrary, pain thresholds to the duller needle are considerably higher than those to the standard one. Consequently, changes in response types of the cutaneous point, such as, from the pain point in the
case of the standard needle to the touch point in the case of the duller needle or from the point of the second type response in the former to the tactile point in the latter, are observed. The dissociated change in the thresholds for touch and pain and consequent change in response types of cutaneous point are also observed in procaine nerve block experiments.

3) Comparison of the cutaneous sensory pattern of different regions of the body, such as the forehead, cheek, forearm (volar), finger tip, back, thigh (anterior), popliteal fossa, sole and glans penis, was made in regard to the sensitivity and relative distribution of various response types of the cutaneous points. The sensory patterns have regional characteristics. Touch thresholds are low on the finger tip, cheek, and then on the forehead. On these three regions and on the sole all the points examined are tactile, and the two-point thresholds are lower than those on the other regions examined. The pain thresholds are highest on the finger-tip and sole, and then on the forehead and glans penis. On the popliteal region almost all the points examined are the "specific" sensory points. Various factors, central and peripheral, influencing the regional differences in the sensory pattern were discussed.

4) Differential nerve block experiments were performed by means of a sphygmomanometer cuff with the pressure above the systolic blood pressure and with that intermediate between the systolic and the diastolic blood pressure, of perineural procaine infiltration and of refrigeration anesthesia by local ethyl chloride spray. Analyses of the time-threshold curves of various cutaneous points under these experimental conditions suggest that fibers subserving touch sensation are myelinated fibers, large and relatively uniform in size, and those subserving pain sensation are unmyelinated and small myelinated fibers, the size of which is distributed over a relatively wide range. Fibers subserving "specific" sensation may be slightly smaller than those subserving pain but they are largely overlapping in size spectrum.

5) Histological sections of the "specific" sensory spots revealed no encapsulated or organized ending but several nerve fibers gathered in a bundle in the dermis close beneath the tattoo mark which indicate the position of the "specific" sensory spot.

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Fig. 20. Underlying histology of the "specific" sensory spot. Nonidez' stain.