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# The Cortical Destruction Necessary to Produce a Transfer of a Forced Practice Function

Patricia E. Barnett

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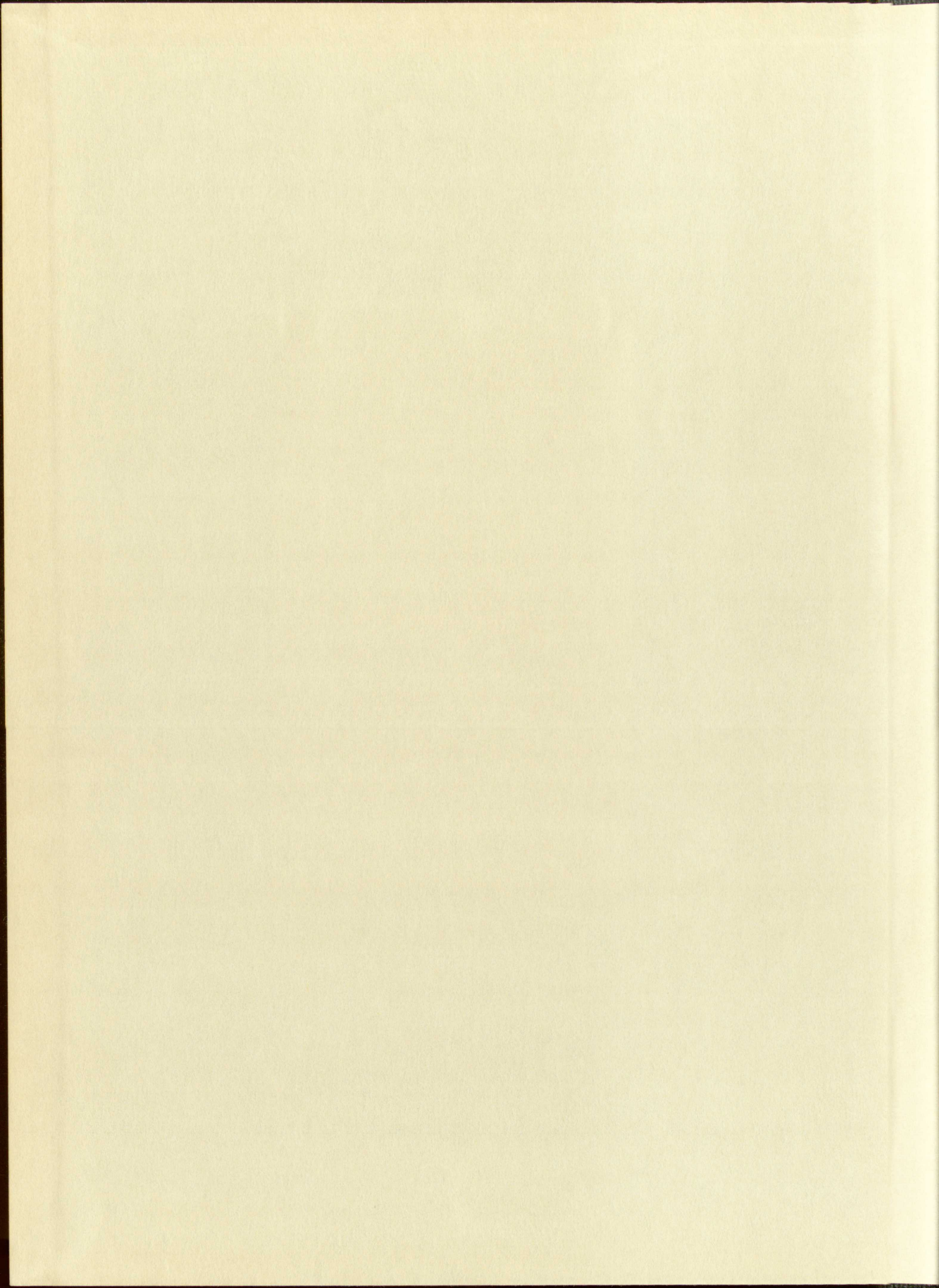
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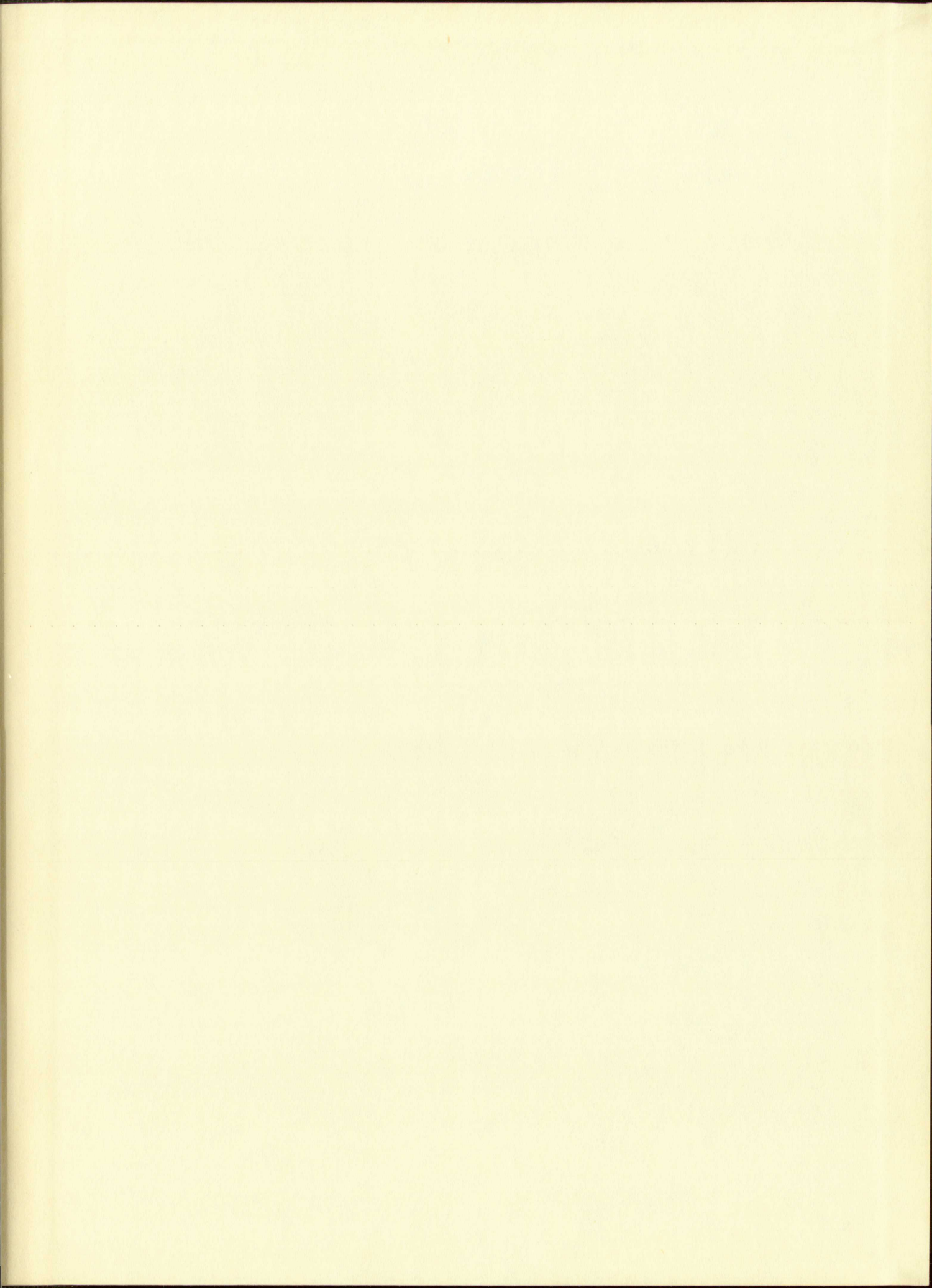
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THE CORTICAL DESTRUCTION NECESSARY TO PRODUCE A TRANSFER  
OF A FORCED PRACTICE FUNCTION

by

Patricia E. Barnett

A Thesis

Submitted in Partial Fulfillment of the  
Requirements for the Degree of Master of Science  
in Psychology

The University of New Mexico

1960



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by  
PATRICK E. BARNETT

A Thesis  
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1930



This thesis, directed and approved by the candidate's committee, has been accepted by the Graduate Committee of the University of New Mexico in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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Date

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mittee, has been accepted by the Graduate Committee of the  
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MASTER OF SCIENCE



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#### ACKNOWLEDGMENTS

The author is indebted to Dr. George M. Peterson for his continued assistance and advice during the research required for this study. I also wish to thank Donald K. Gucker for his information concerning the histological techniques, and Luther W. Rook for his continued interest in and modifications of the equipment used for the dessication operations.



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## Introduction

One of the major problems of psychology concerns the possibility of a change in the nervous system due to practice. Although investigators have postulated many different types of change, no direct evidence of its nature exists. The nervous system itself tends to compound the problem. Within the complex of central tracts and centers and peripheral nerves, where does one look for a region which consistently represents a function and which can also be altered by practice? Investigation at the level of the spinal cord has often failed when the particular function is also represented in the cortex, and vice versa. What is needed is a highly localized function which is not so complex as to be partially represented at various levels of the nervous system and yet is not so simple that it is merely reflexive in nature and cannot be modified by practice. Such a function is handedness, which is localized in the contralateral frontal cortex (Peterson, 1934).

This region can be located by making a small cortical lesion to effect a transfer in handedness preference. (In rats, the handedness preference is defined by the number of times an animal completes hand to mouth feeding with a particular hand, either right or left.) The volume of a destruction necessary to produce such a transfer may be as little as 1.3 cubic millimeters (Peterson and Gucker, 1959).

The evidence indicates that the depth locus of the handedness function is probably in the fifth and sixth cortical layers (Peterson



## Introduction

One of the major problems of psychology concerns the possibility-

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and Farcarol, 1938). This conclusion, however, needs verification. The common areas in terms of the medial or frontal plane are not so finely delineated as the depth area, but effective lesions are known to cluster about the head of the caudate nucleus. Extensive lesions outside this area fail to produce transfer.

A method other than extirpation has also been used to localize the handedness function, in an attempt to leave the area functionally intact. Electrical stimulation is applied to the cortex to produce a movement of the contralateral arm. The stimuable area for arm movements is in the frontal cortex (Woolsey, 1958). This method provides information about the locus of the function without destroying tissue or producing transfer. Small destructions made in the electrical stimulation area, however, do not always produce transfers, indicating that the method is not very precise (Peterson and Gucker, 1959).

Because the fundamental problem under investigation concerns a change in cortical tissue as a function of practice, a method (such as electrical stimulation) which delineates without destroying should add a good deal of information. One factor operating against such a method is the spread of current over a field. Thus, stimulation at the dura may not follow a straight line to the fifth cortical layer. This would interfere with accurate determination by electrical stimulation. Obviously, the difficulty with the destruction method is that the tissue cannot be observed postoperationally.

If one wishes to study the neural equivalent of practice (in the handedness area) then one must change the animal's behavior by



and Warrick, 1938). This conclusion, however, must be qualified. The common areas in terms of the medial or frontal lobe are finely delineated as the depth areas, but effective lesions are known to cluster about the head of the caudate nucleus. Consequently, lesions outside this area fail to produce tremor.

A method other than excitation has also been used to study the handness function, in an attempt to leave the area functionally intact. Electrical stimulation is applied to the motor cortex to produce a movement of the contralateral arm. The stimulus is applied for a movement is in the frontal cortex (Woolsey, 1953). These methods provide information about the focus of the function without destroying tissue or producing tremor. Small destructions, resulting in the cal stimulation area, however, do not always produce tremor, indicating that the method is not very precise (Woolsey and Mount, 1955). Because the fundamental problem under investigation concerns change in cortical tissue as a function of practice, it is desirable to add a good deal of information. One factor operating against this method is the spread of current over a field. Thus, when the current is applied, it may not follow a straight line to the focal area. This would interfere with accurate determination of the focal area. Obviously, the difficulty with the destruction method is that the tissue cannot be observed postoperatively. If one wishes to study the neural equivalent of the handness area (then one must change the animal's behavior by



means of practice. The method for achieving this is to force practice with the non-preferred hand. One way of doing the latter is to use an offset feeding dish, placed so that the rat can make complete reaches only with the non-preferred hand (Peterson, 1951). Unfortunately this method does not often produce transfer if the animal is given many pre-test reaches to establish handedness preference. Moreover, if the animal is given only a few test trials with the non-biased dish, the assertion that it is single-handed is less reliable.

Peterson (1951) however, reported another method which is superior to that of using the offset feeding dish. This involved binding the preferred arm so that it was held against the trunk of the animal. Thus, the animal could continue to feed from a non-biased dish, yet was forced to use the non-preferred hand for reaching. After a number of forced trials, the animals were unbound and observed for transfer. This method was highly efficient in producing transfers, but has been criticized as being injurious to the bound limb so that the resulting transfers might be due to injury. However, control animals which were bound but given no practice did not transfer, indicating that it was the forced practice which effected the change. It may be presumed that such practice produces a change somewhere in the rat.

The question now arises as to where the changes occur. A reasonable place to look for such changes would be the contralateral frontal cortex, if forced practice handedness is localized in the same way as natural handedness. If small destructions in this region



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The question now arises as to where the changes occur. A reasonable place to look for such changes would be the contralateral frontal cortex, if forced practice handness is localized in the same way as natural handness. If small lesions in this region



produce a retransfer to the originally preferred hand, and large destructions outside the area fail to be effective, then the question of the locus would be answered affirmatively. Thus, the present study is aimed at mapping the cortical region which controls forced practice of the handedness function, in the hope that such delineation may provide a specific region for the study of the neural equivalent of practice.



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destructions outside the area fail to be effective. Then the question  
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is aimed at mapping the cortical region which controls learned practices  
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vide a specific region for the study of the manual equivalent of

practices.



## Method

### General:

This study is based on the results of tests on forty-one animals from two laboratory strains (albino and hooded) which met the criterion of 90 or more single-handed reaches out of 100 trials in the Peterson (1931) food reaching situation.

These experimental animals had their preferred arms bound with adhesive tape. With the originally preferred hand thus immobilized, the animals were forced to reach with the non-preferred hand. Forced reaching continued until a transfer of preference occurred. The number of forced reaching trials to achieve transfer criterion varied from 600 to 1300 for different animals (see Table I). Transfer was checked by unbinding the originally preferred arm and observing the animals in a reaching situation. Those which transferred (90% single-handed reaches) were subjected to brain operation under ether anesthesia.

A 3/16 inch trephine was used to expose the frontal cortex at the angle of the midline and parietal sutures. This opening was contralateral to the hand preferred after forced reaching.

The cortical area to be altered operationally was located by electrical stimulation, resulting in a flexion of the contralateral arm. Following localization, an electrode was inserted in the cortex to produce a destruction of tissue.

Postoperatively, animals were given 100 reaches (in blocks of fifty) to check for Retransfer to the originally preferred hand.



## Method

## General:

This study is based on the results of tests on forty-one animals from two laboratory strains (albino and hooded) which was the criterion of 50 or more single-handed reaches out of 100 trials in the Peterson (1931) food reaching situation.

These experimental animals had their preferred arm bound with adhesive tape. With the originally preferred hand thus immobilized, the animals were forced to reach with the non-preferred hand. Forced reaching continued until a transfer of preference occurred. The number of forced reaching trials to achieve transfer varied from 600 to 1500 for different animals (see Table I). Transfer was checked by unbinding the originally preferred arm and observing the animals in a reaching situation. Those which transferred (50% single-handed reaches) were subjected to brain operation under ether anesthesia.

A 3/16 inch trephine was used to expose the frontal cortex at

the angle of the altiline and parietal sutures. This opening was

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The cortical area to be altered operationally was located by

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arm. Following localization, an electrode was inserted in the cortex

to produce a destruction of tissue.

Postoperatively, animals were given 100 reaches (in blocks

of fifty) to check for transfer to the originally preferred hand.



### Apparatus:

During the operation, animals were held by a modified stereotaxic instrument with two base plates. The uppermost of these plates had a raised V-block for holding the rat's head and a wire clamp for the animal's upper incisors. The lower of the two base plates had a steel arm which could be moved vertically so that the stimulating and destruction electrodes could be raised and lowered. In order to stimulate different areas of the cortex, the upper plate could be moved across the lower in a horizontal plane.

Electrical stimulation to produce an arm movement was performed with interrupted direct current at a 200 cps rate with a pulse duration of 0.5 milliseconds. The stimulation waveform was displayed on a Tektronix oscilloscope. Stimulation voltage was applied between a search electrode (0.6 millimeters in diameter) and a grounding electrode inserted at the region of the soft pad in the homolateral hind leg.

A thermocautery was used to make the larger destructions, while a unipolar electrode of approximately 100 microns in diameter and insulated to within 150 microns of the tip was used to produce smaller destructions. The insertion depth of the small electrode was measured by a GE depth gauge, reading in tenths of millimeters.

### Procedure:

In fifteen animals, the transfer trials were followed by electrical stimulation and thermocauterization. A single-wire cautery, less than 1 millimeter in diameter (Peterson and Gucker, 1959) was used to produce destructions. The destructions varied in size from



## Apparatus:

During the operation, animals were held by an assistant. The animal was held in a special instrument with two base plates. The apparatus of these plates had a raised U-block for holding the rat's head and a wire clamp for the animal's upper jaw. The lower of the two base plates had a steel arm which could be moved vertically so that the stimulation and destruction electrodes could be raised and lowered. In order to stimulate different areas of the cortex, the upper plate could be moved across the lower in a horizontal plane.

Electrical stimulation to produce an epileptic seizure was given with interrupted direct current at a 200 cps rate with a pulse duration of 0.5 milliseconds. The stimulation waveform was displayed on a Tektronix oscilloscope. Stimulation voltage was applied between a search electrode (0.5 millimeter in diameter) and a grounding electrode inserted at the region of the scalp and in the underlying tissue.

A chronostimulus was used to make the timing of stimulation, while a unipolar electrode of approximately 100 microns in diameter and insulated to within 100 microns of the tip was used to produce electrical destruction. The insertion depth of the search electrode was measured by a CE depth gauge, reading in tenths of millimeters.

## Procedure:

In fifteen animals, the transverse sulcus was followed by electrical stimulation and destruction. The search electrode was less than 1 millimeter in diameter (Borison and Ruchman, 1953) and used to produce destruction. The destructions were made in the



3.6 to 18.8 mm<sup>3</sup>. The brains for these cases were prepared for histologic analysis by freezing, sectioning at 30 microns, and staining with thionin. Every other section through the damaged region was mounted and stained. Destruction areas were measured microscopically by a grid with minimum divisions of 210 microns on the side.

In twenty-one animals, electrical stimulation was followed by dessication with a Hyfrecator and a 100 micron electrode. The Hyfrecator setting for these destructions was 75 and the variac reading 100. Time was set at minimum, which was approximately 0.2 seconds duration. These settings were chosen because they produce a very small destruction.

Since it was difficult to see when the brain contact was made with this electrode, an auditory signal was used to indicate contact. This was triggered by an abrupt change in conductivity between the electrode and the dura. At the signal, the depth recorder was engaged and the electrode pierced the cortex to a predetermined level. Depth for these destructions was varied from 1.5 to 2.5 millimeters to provide destruction in different cortical layers.

Cases 16 through 32 had one electrode insertion to provide destruction. Rats 35 and 36 had two electrode insertions displaced approximately 1.5 millimeters in the area of the arm movement response. Rats 33 and 34 had three electrode insertions triangulated about the site of the positive stimulation area, and displaced from each other about 1.5 millimeters.

The brains from cases 17 through 32 were frozen, sectioned at



3.6 to 13.8 mm<sup>2</sup>. The brains for these cases were prepared for histo-  
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with thionin. Every other section through the damaged region was  
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Cases 16 through 22 had one electrode insertion to provide  
destruction. Cases 23 and 24 had two electrode insertions displaced  
approximately 1.5 millimeters in the area of the arm movement response.  
Cases 23 and 24 had three electrode insertions triangulated about the  
site of the positive extinction area, and displaced from each other  
about 1.5 millimeters.  
The brains from cases 17 through 22 were frozen, sectioned at



30 microns, and stained with thionin. Rats 33 through 36 has a brownish colored circle on the cortex which disintegrated when sliced. Since no prediction could be made for these animals unless the discolored area could be microscopically observed, cases 35 and 36 were not prepared by the freezing method, but were encased in thick celloidin. Slices were taken at 50 microns, and every fifth section through the damage region was kept for mounting and staining with thionin.

Five animals had trephine openings in the occipital area contralateral to the preferred hand. This opening was enlarged in a dorso-lateral direction by means of bone forceps. No electrical stimulation was applied. Destructions were made with a looped wire thermocautery, heated to a cherry red glow. The areas destroyed by this procedure ranged from 33% to 50% of one hemisphere.



30 microns, and stained with thionin. Brain 33 through 36 has a brownish colored circle on the cortex which demonstrated when sliced. Since no prediction could be made for these animals unless the dorsal-ventral area could be microscopically observed, cases 35 and 36 were not prepared by the freezing method, but were embedded in thick collodion. Slices were taken at 50 microns, and every fifth section through the damage region was kept for mounting and staining with thionin.

Five animals had trephine openings in the occipital area contralateral to the preferred hand. This opening was enlarged in a dorso-lateral direction by means of bone forceps. No electrical stimulation was applied. Restrictions were made with a looped wire thermocautery, heated to a cherry red glow. The areas destroyed by this procedure ranged from 12% to 50% of one hemisphere.



### Results

The results for all animals are summarized in Table I. Seven animals, with thermocautery destructions ranging from 10.3 to 18.8 mm<sup>3</sup>, retransferred to the originally preferred hand. One animal who failed to transfer (see No. 12) after 1300 forced reaches, was operated on the side contralateral to the originally preferred hand. 100% transfer resulted from a 12.6 mm<sup>3</sup> destruction for this animal.

Four animals with thermocautery destructions of from 5.1 to 9.8 mm<sup>3</sup> showed partial retransfer following the operation. The magnitude of this retransfer ranged from 15% to 83%.

Three animals, with thermocautery destructions, failed to retransfer. The destruction volumes for these animals were 3.6, 5.6, and 10.7 mm<sup>3</sup>.

In order to determine if a common area existed for the retransfer cases, tissue sections which represented the site of greatest damage were selected for each animal. Cases which had destruction in the left hemisphere were transposed for ease of examination. Figure 1 shows the superimposed damage areas for retransfer cases. Cases were studied for common depth locus without regard for frontal dispersion, since previous studies established such variability as to cause a common area to vanish.

Figure 2 displays the superimposed areas of greatest damage for partial and non-retransferring cases.

Figure 3 was derived from an overlay of Figure 1 on Figure 2, and is that area in which at least part of each transfer case



## Results

The results for all animals are summarized in Table I. The animals, with the exception of the two animals which were sacrificed to the originally preferred basal level, were operated on after 12) after 1500 forced respiration, was operated on the side contralateral to the originally preferred basal level. The results from a 12) description for this animal.

Four animals with the originally preferred basal level of 12) showed partial respiration following the operation. The magnitude of this respiration ranged from 12) to 12).

Three animals, with the originally preferred basal level of 12), showed partial respiration. The description values for these animals were 12), 12), and 12).

In order to determine if a common area existed for the various for cases, tissue sections which represented the area of respiration damage were selected for each animal. Cases which had respiration damage on the left hemisphere were transposed for each of the animals. Figure 1 shows the superimposed damage areas for retinal damage. These were studied for common depth focus without regard for retinal damage. Since previous studies established such variability as to be common areas to various.

Figure 2 displays the superimposed areas of retinal damage for partial and non-retinalizing cases. Figure 3 was derived from an overlay of Figure 1 and Figure 2 and is that area in which at least part of each hemisphere was



destruction appears, and in which no partial or non-retransferring case is represented. This region is approximately 3 millimeters wide, and 2 millimeters deep at the points of greatest width and depth and does not involve cortical layers 1, 2, and 3.

Using the head of the caudate nucleus as a landmark for determining destruction spread along a frontal plane, it was found that no common area existed for the fifteen thermocautery animals. However, the limits for effective destruction were from one millimeter rostral to somewhat more than 2.3 millimeters caudal of the landmark.

Of the 21 animals with tissue destruction produced by dessication, eight retransferred following operational procedures. Four of these animals had dessication destructions varying in volume from 0.7 to 3.4 mm<sup>3</sup>.

The other four who retransferred had both dessication destructions and thermocoagulated tissue, resulting from trephine heat. The volumes for these destructions ranged from 18.6 to 27.1 mm<sup>3</sup>. It is immediately apparent that these destructions are of a magnitude and nature that adds no knowledge to the question under investigation. Therefore, no further analysis of these cases was made.

Animals 18, 22, 27, and 31 exhibited partial retransfer following dessication of cortical tissue. Percent retransfer for these animals ranged from 28 to 75% and the volumes of tissue damage from 0.6 to 1.0 mm<sup>3</sup>. Nine animals failed to retransfer following dessication. Damage volumes for this group ranged from 0.1 to 2.1 mm<sup>3</sup>.

Figure 4 was obtained by superimposing the individual areas



destruction appears, and in which no partial or non-retaining case is represented. This region is approximately 2 millimeters wide, and 2 millimeters deep at the points of greatest width and depth and does not involve cortical layers I, II, and III.

Using the head of the mandible as a landmark for determining destruction spread along a horizontal plane, it was found that no common area existed for the fifteen experimental animals. However, the limits for extensive destruction were from one millimeter anterior to somewhat more than 2.5 millimeters posterior of the landmark.

Of the 31 animals with known destruction produced by dental action, eight represented following experimental procedures. Four of these animals had destructions varying in volume from 0.7 to 2.4 mm<sup>3</sup>.

The other four who represented both destruction destructions and chronic inflammation, resulting from chronic heat.

The volumes for these destructions varied from 18.6 to 27.1 mm<sup>3</sup>. It is immediately apparent that these destructions are of a magnitude and nature that adds no knowledge to the question under investigation. Therefore, no further analysis of these cases was made.

Animals 18, 22, 25, and 31 exhibited partial retention following destruction of cortical tissue. Permanent retention for these animals ranged from 28 to 73% and the volume of tissue damage from 0.6 to 1.0 mm<sup>3</sup>. These animals failed to retain after following dental action. Damage volume for this group ranged from 0.1 to 2.1 mm<sup>3</sup>. Figure 4 was obtained by superimposing the individual areas



of destruction for animals who retransferred following dessication of cortical tissue. This figure is a spatial overlay of the lateral and depth planes. To determine the correspondence between the area defined by the thermocautery cases, Figure 4 was placed on Figure 3 and the region common to both figures presented in Figure 5. Thus Figure 5 represents the area common to all retransferring animals regardless of type of destruction. Figure 5 is somewhat smaller than Figure 3 in a lateral direction. (2.3 millimeters as compared to 3.1 millimeters in Figure 3.)

The dorso-ventral spread of the dessication destructions shows that no retransfer animal had a destruction nasal to the head of the caudate nucleus, and the caudal-most destruction is only 1.7 millimeters behind the caudate nucleus.

Of the five animals which had occipital destructions varying in size from 33% to 50% of one hemisphere, only one showed a minor (18%) retransfer. The destruction area for that animal (no.39) is shown in Figure 7. It is doubtful that this is a bona fide retransfer case, especially in the light of the other four occipital-temporal cases who failed to be influenced despite extensive injuries.

Damage areas for animals 37, 38, 40, and 41 are superimposed on figure 6. All these animals failed to retransfer. Thus, extensive lesions outside the critical area (as defined by these data) fail to produce a change in the handedness function.

Examination of the damage areas for all retransfer cases, despite operating method, shows that the cortical care which represents



of destruction for animals who underwent following destruction of cortical tissue. This figure is a spatial overlay of the lateral and depth planes. To determine the correspondence between the area defined by the thymectomy cases, Figure 4 was placed on Figure 3 and the region common to both figures presented as Figure 5. Thus Figure 5 represents the area common to all representative animals regardless of type of destruction. Figure 5 is somewhat smaller than Figure 3 in a lateral direction. (2.5 millimeters as compared to 3.1 millimeters in Figure 3.)

The dorso-ventral spread of the destruction destructions show that no representative animal had a destruction medial to the head of the caudate nucleus, and the caudal-most destruction is only 1.7 millimeters behind the caudate nucleus.

Of the five animals which had occipital destructions varying in size from 33% to 50% of area hemisphere, only one showed a minor (13%) reticular. The destruction area for these animals (no. 33) is shown in Figure 7. It is doubtful that this is a bona fide reticular case, especially in the light of the other four occipital-temporal cases who failed to be influenced despite extensive lesions. Damage areas for animals 37, 38, 40, and 41 are superimposed on Figure 8. All these animals failed to extricate. Thus, extensive lesions outside the critical area (as defined by these data) fail to produce a change in the hand-dominant function. Examination of the damage areas for all representative cases, despite operating method, shows that the cortical area which represents



forced practice is approximately the same as the cortical area which represents "natural" handedness (see Figure 5).



forward practice is approximately the same as the forward pass.

regression "natural" handedness (see Figure 1).

X



### Discussion

In an effort to localize the region representing forced practice, both the volume and location of effective destructions were critically analyzed.

It was found that a volume of  $0.7 \text{ mm}^3$  representing approximately 1000 cells (Tower, 1952) effected a retransfer in one case. This volume is smaller by  $0.6 \text{ mm}^3$  than the least effective volume reported by Peterson and Gucker (1959) for ambidextrous animals.

It might be hypothesized that "forced practice" animals are more like ambidexters than single-handed animals, since both hemispheres have regions representing the handedness function. This hypothesis is supported by the fact that the least effective volumes reported for single-handed animals was  $1.3 \text{ mm}^3$ .

On the other hand, it may be that the limiting factor is not in the size of the destruction, but in the ability of the equipment accurately to place the electrode. If this is the case, then ambidexters and single-handers may not be so divided as it now appears.

Certainly the size of the destruction alone does not account for transfer or retransfer. Excluding those cases with trephine injury, and focusing on cases with frontal damage alone, it may be seen that a great deal of size overlap occurs. Table II shows the volumes of destructions for these animals, dividing the cases into retransferring, partial retransferring and non-retransferring categories. The volumes are reported in increasing magnitudes from the smallest to the largest. The area of overlap is enclosed by horizontal



## Discussion

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lines. Inspection of this table supports the postulate that volume cannot be the critical variable in producing retransfers.

From Figure 5, showing the effective region common to all retransferring cases, the limits in the lateral plane are well defined. The problem, then, is to assure that a lesion will occur within the limits set by the data. This involves the equipment to be used.

Part of the problem lies in the stereotaxic instrument. If the two base plates of this equipment were marked off in 0.01 millimeter divisions, and a vernier control for the two transverse directions in the horizontal plane was attached, then post-stimulation operating would be more precise.

Of course there is always the problem of subdural spread of impulses when electrical stimulation is used to identify a region. At the surface of the tissue point X might be stimulated to produce a response. However, by the time the impulse reaches layer 5, the spread might be such that a circular area, say four times the diameter of the stimulating electrode might be involved. If only one peripheral arc of this circle really represented handedness, and if the destruction electrode was consistently inserted at the point on the dura where stimulation produced a response, then a change in handedness preference could not always be predicted for such a destruction. What is called for to correct for sub-dural or intra-cortical spread is a method of asserting just what this spread will be.

If one had the precise stereotaxic instrument indicated previously, it would be possible to maximize the choice of destruction region by



In the case of this electrode, the position of the electrode cannot be the critical variable in producing the response. From Figure 5, showing the effective region common to all remaining cases, the limits in the lateral plane are well defined. The problem, then, is to assume that a lesion will occur within the limits set by the data. This involves the assumption to be made. Part of the problem lies in the electrode's position. If the two base plates of this electrode were spaced 0.01 millimeter apart, and a vertical control for the two transverse directions in the horizontal plane was attached, then post-stimulation operating would be more precise. Of course, there is always the problem of lateral spread of impulses when electrical stimulation is used to identify a region. At the surface of the tissue point X, a sharp electrode is produced a response. However, by the time the impulse reaches layer 5, the spread might be such that a circular area, say four times the diameter of the stimulating electrode might be involved. If only one peripheral any of this circle really represented the response, and if the stimulation electrode was consistently inserted at the point on the data where stimulation produced a response, then a change in response near persistence could not always be predicted for such a stimulation. What is called for is a control for and-during on intra-cortical spread. As a method of assessing just what this spread will be. If one had the precise stereotaxic instrument indicated previously, it would be possible to maximize the choice of electrode region by



plotting stimulation responses as a function of two mutually orthogonal directions.

However, even if the region was so minutely defined at the surface, other problems arise. There are two major problems in trying to isolate the destruction to a very restricted area at a sub-dural level. One is the incompatibility of the strength of materials, with the desirability of producing as small a destruction as possible in the layers lying above the fifth and sixth layers. The other is the restriction of the destruction zone in a longitudinal direction (along the axis of the electrode at the fifth and sixth layers). A possibility that may be examined comes from recent developments in the field of metallurgy and the marriage of metallurgy and ceramics. Single crystalline iron with approximately ten times the strength of normal iron has been grown in the laboratory. One of these small "whisker" crystals with a thin plating of fused quartz as an insulator should allow a reduction of a full order of magnitude in the diameter of the destruction electrode. In turn, this would allow for the control of the longitudinal length of the destruction within a tolerance of 0.04 millimeters.

Thus, by the development of precision equipment it may be possible to localize the region of forced practice in handedness to within far smaller limits than were achieved in this study.



giving stimulation responses as a function of the externally applied  
direction.

However, even if the region was successfully defined at the  
surface, other problems arise. There are two major problems in trying  
to isolate the destruction to a very restricted area of a sub-surface  
level. One is the localization of the intensity of stimulation,  
with the possibility of producing as much a sensation as possible  
in the layers lying above the fifth and sixth layers. The other is  
the restriction of the destruction zone to a longitudinal direction  
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normal iron has been given in the laboratory. One of these small  
"whisker" crystals with a thin plating of fused quartz as an insula-  
tor should allow a reduction of a full order of magnitude in the diam-  
eter of the destruction electrode. In turn, this would allow for  
the control of the longitudinal length of the destruction within a  
tolerance of 0.05 millimeters.

Thus, by the development of precision equipment it may be  
possible to localize the region of forced reaction in handbooks  
to within ten-thousandths inch than were achieved in this study.



### Summary and Conclusions

If one wishes to study the neural equivalent of learning as a function of practice, then one must locate a particular neural region which consistently represents a function and which may also be altered by practice. The handedness area of the frontal cortex has been located for a "natural" handedness preference, an area which also fulfills the second requirement. This study was done to ascertain whether or not this region could be so located and so altered when it represents a forced practice handedness function.

Forty-one rats were forced to reach with an originally non-preferred hand until this forcing resulted in a transfer of handedness preference.

Animals were then operated on and cortical lesions produced. If the animals demonstrated a retransfer to the originally preferred hand following the operation, the area of lesion would represent the forced handedness function. The brains of all animals were examined histologically and the destruction areas for non-retransferring cases subtracted from the areas for retransferring cases to delimit the critical area.

As hypothesized, the resulting area was in the same region as that which had been found to represent a "natural" handedness function in the rat. Thus, a particularized region for the study of the neural equivalent of learning as a function of practice is available for further investigation.

Within the limits of the data for this study, the volume of the



## Summary and Conclusions

In an attempt to study the neural equivalent of learning as a function of practice, three rats learned a hand preference for a particular neutral region which consistently represented a function and which may also be altered by practice. The hand preference area of the frontal cortex has been located for a "natural" hand preference preference, an area which also facilitates the second requirement. This study was done to determine whether or not this region could be so located and so altered when it represents a forced practice hand preference function.

Four rats were forced to learn which hand to use originally for a preferred hand until this forcing resulted in a reversal of hand preference.

Animals were then operated on and cortical lesions produced. If the animals demonstrated a reversal to the originally preferred hand following the operation, the area of lesion would represent the forced hand preference function. The brains of all animals were examined histologically and the destruction areas for non-reversing cases subtracted from the areas for reversing cases to define the critical area.

As hypothesized, the resulting area was in the same region as that which had been found to represent a "natural" hand preference function in the rat. Thus, a particularized region for the study of the neural equivalent of learning as a function of practice is available for further investigation.

Within the limits of the data for this study, the volume of the



lesion was not as critical to retransferring as was the position of the lesion. Since one retransfer was effected by a lesion of  $0.7 \text{ mm}^3$ , it may be inferred that, with finely controlled equipment, the region may be accurately predicted within the confines of some 1000 cells.



factor was not as critical to reestablishing as was the position of the lesion. Since one reestablishment was followed by a lesion of 0.7 mm, it may be inferred that, when fully controlled experiment, the region may be accurately predicted within the confines of some 1000 cells.



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APPENDIX







TABLE I  
Summary of Reaching Records and Results  
According to Various Methods

Rat No.	Pref. Hand	Forced	Number of Reaches				Destruction in min <sup>3</sup>
			Pre-op		Post-op		
			R	L	R	L	
1	R	1000	1	99	98	2	12.3
2	L	1000	100	0	0	100	16.4
3	R	1000	0	100	42	58	8.8
4	L	1000	96	4	3	97	12.8
5	L	1000	96	4	0	100	11.2
6	R	1000	0	100	81	19	10.0
7	L	1000	100	0	98	2	10.7
8	L	800	93	7	6	94	10.3
9	L	1000	96	4	0	100	13.6
10	L	1000	100	0	100	0	3.6
11	L	1200	93	7	7	93	18.8
12	R	1300	69	31	0	100	12.6
13	L	1000	99	1	17	83	7.6
14	L	1000	92	8	85	15	5.1
15	L	1000	90	10	100	0	5.6

Dessicator

16	R	800	3	98	100	0	0.7
17	L	900	90	10	97	3	0.2
18	R	700	6	94	75	25	0.5



TABLE I  
Summary of Reading Records and Weights  
According to Various Methods

Ref. No.	Pref. Hand	Forced	Number of Branches		Post-up L	Post-up R	Distinction in sec.
			P	L			
1	R	1000	1	99	98	98	12.3
2	L	1000	100	0	0	100	18.4
3	R	1000	0	100	42	28	3.8
4	L	1000	96	4	2	97	12.8
5	L	1000	96	4	0	100	11.2
6	R	1000	0	100	81	19	10.0
7	L	1000	100	0	98	2	10.7
8	L	800	93	7	0	94	10.3
9	L	1000	96	4	9	100	13.6
10	L	1000	100	0	100	0	3.6
11	L	1000	93	7	7	93	18.6
12	R	1000	80	20	0	100	12.6
13	L	1000	99	1	17	83	7.6
14	L	1000	93	8	82	13	2.1
15	L	1000	90	10	100	0	2.6
Distinction							
16	R	800	2	98	100	0	0.7
17	L	900	90	10	97	3	0.2
18	R	700	0	94	72	22	0.2



TABLE I (cont'd)  
Summary of Reaching Records and Results  
According to Various Methods

Rat No.	Pref. Hand	Forced	Number of Reaches				Destruction in mm <sup>3</sup>
			Pre-op		Post-op		
			R	L	R	L	
19	L	900	99	1	91	9	2.0
20	R	600	0	100	1	99	0.5
21	R	900	0	100	50	50	0.6
22	R	700	1	99	94	6	3.4
23	R	700	0	100	100	0	2.8
24	L	900	99	1	100	0	0.6
25	R	900	100	0	99	9	2.1
26	R	900	7	93	28	72	0.4
27	R	1000	0	100	96	4	1.1
28	L	1000	100	0	100	0	0.4
29	L	900	99	1	91	9	0.3
30	L	600	98	2	97	3	0.1
31	R	1000	0	100	69	31	0.9
32	L	600	98	2	97	3	0.2

Dessicator-Trephine Damage

33	R	800	0	100	100	0	18.6
34	R	800	6	94	100	0	22.4
35	L	800	100	0	0	100	27.1
36	R	800	10	90	91	9	19.8



TABLE I (cont'd)  
Summary of Sealing Records and Results  
According to Various Methods

Rec. No.	Trsf. Hand	Forced	Number of Seams		Distortion in mm.
			Pre-up	Post-up	
			R	R	
19	L	300	99	91	2.0
20	R	600	0 100	1	0.2
21	R	300	0 100	20	0.2
22	R	700	1 99	94	3.4
23	R	700	0 100	100	2.8
24	L	200	99	100	0.6
25	R	900	100 0	99	2.1
26	R	300	7 93	23	0.4
27	R	1200	0 100	96	1.1
28	L	1000	100 0	100	0.4
29	L	700	99	91	0.3
30	L	600	98	97	0.1
31	R	1000	0 100	99	0.9
32	L	600	98	97	0.2
Demarcator-Torching Damage					
33	R	800	0 100	100	18.6
34	R	800	6 94	100	22.4
35	L	800	100 0	100	17.1
36	R	800	10 90	91	19.8



TABLE I (cont'd)  
Summary of Reaching Records and Results  
According to Various Methods

Rat No.	Pref. Hand	Forced	Number of Reaches				Percent Hemisphere Destroyed
			Pre-op		Post-op		
			R	L	R	L	
37	L	600	92	8	100	0	36
38	L	1000	100	0	100	0	33
39	L	700	95	5	82	18	41
40	L	700	100	0	97	3	50
41	R	800	0	100	0	100	36



TABLE I (cont'd)  
Summary of Hearing Records and Results  
According to Various Methods

Ear No.	Freq. Hertz	Number of Reactions				Percent Hearing Preserved
		Forward	Fit-up	Post-up	Post-up	
		L	R	L	R	
37	1	100	92	8	100	36
38	1	100	100	0	100	33
39	1	70	92	2	82	41
40	1	100	100	0	97	30
41	1	100	0 100	0	100	36
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TABLE II  
 Volumes of Destruction for All Cases  
 (Excepting occipital and trephine damage)

Rat No.	Retransferring	Rat No.	Partial Retransferring	Rat No.	non- Retransferring
				30	0.1
				32	0.2
				17	0.2
				29	0.3
		26	0.4	28	0.4
		18	0.5	20	0.5
		21	0.6	24	0.6
16	0.7	31	0.9	19	2.0
27	1.1	14	5.1	25	2.0
23	2.8	13	7.6	10	3.6
22	3.4	3	8.8	15	5.6
8	10.3	6	10.0	7	10.7
5	11.2				
1	12.3				
12	12.6				
4	12.8				
9	13.6				
2	16.4				
11	18.8				



TABLE III  
 Volume of Production per Acre  
 (Excluding marginal and special crops)

Year	Normalizing	Year	Partial	Year	Normalizing
No.	No.	No.	No.	No.	No.
1	11.2	2	10.3	3	8.4
2	12.3	4	12.8	5	12.6
3	12.6	6	12.8	7	12.6
4	12.8	8	12.8	9	12.6
5	12.8	10	12.8	11	12.6
6	12.8	12	12.8	13	12.6
7	12.6	14	12.8	15	12.6
8	12.6	16	12.8	17	12.6
9	12.6	18	12.8	19	12.6
10	12.6	20	12.8	21	12.6
11	12.6	22	12.8	23	12.6
12	12.6	24	12.8	25	12.6
13	12.6	26	12.8	27	12.6
14	12.6	28	12.8	29	12.6
15	12.6	30	12.8	31	12.6
16	12.6	32	12.8	33	12.6
17	12.6	34	12.8	35	12.6
18	12.6	36	12.8	37	12.6
19	12.6	38	12.8	39	12.6
20	12.6	40	12.8	41	12.6
21	12.6	42	12.8	43	12.6
22	12.6	44	12.8	45	12.6
23	12.6	46	12.8	47	12.6
24	12.6	48	12.8	49	12.6
25	12.6	50	12.8	51	12.6
26	12.6	52	12.8	53	12.6
27	12.6	54	12.8	55	12.6
28	12.6	56	12.8	57	12.6
29	12.6	58	12.8	59	12.6
30	12.6	60	12.8	61	12.6
31	12.6	62	12.8	63	12.6
32	12.6	64	12.8	65	12.6
33	12.6	66	12.8	67	12.6
34	12.6	68	12.8	69	12.6
35	12.6	70	12.8	71	12.6
36	12.6	72	12.8	73	12.6
37	12.6	74	12.8	75	12.6
38	12.6	76	12.8	77	12.6
39	12.6	78	12.8	79	12.6
40	12.6	80	12.8	81	12.6
41	12.6	82	12.8	83	12.6
42	12.6	84	12.8	85	12.6
43	12.6	86	12.8	87	12.6
44	12.6	88	12.8	89	12.6
45	12.6	90	12.8	91	12.6
46	12.6	92	12.8	93	12.6
47	12.6	94	12.8	95	12.6
48	12.6	96	12.8	97	12.6
49	12.6	98	12.8	99	12.6
50	12.6	100	12.8	101	12.6
51	12.6	102	12.8	103	12.6
52	12.6	104	12.8	105	12.6
53	12.6	106	12.8	107	12.6
54	12.6	108	12.8	109	12.6
55	12.6	110	12.8	111	12.6
56	12.6	112	12.8	113	12.6
57	12.6	114	12.8	115	12.6
58	12.6	116	12.8	117	12.6
59	12.6	118	12.8	119	12.6
60	12.6	120	12.8	121	12.6
61	12.6	122	12.8	123	12.6
62	12.6	124	12.8	125	12.6
63	12.6	126	12.8	127	12.6
64	12.6	128	12.8	129	12.6
65	12.6	130	12.8	131	12.6
66	12.6	132	12.8	133	12.6
67	12.6	134	12.8	135	12.6
68	12.6	136	12.8	137	12.6
69	12.6	138	12.8	139	12.6
70	12.6	140	12.8	141	12.6
71	12.6	142	12.8	143	12.6
72	12.6	144	12.8	145	12.6
73	12.6	146	12.8	147	12.6
74	12.6	148	12.8	149	12.6
75	12.6	150	12.8	151	12.6
76	12.6	152	12.8	153	12.6
77	12.6	154	12.8	155	12.6
78	12.6	156	12.8	157	12.6
79	12.6	158	12.8	159	12.6
80	12.6	160	12.8	161	12.6
81	12.6	162	12.8	163	12.6
82	12.6	164	12.8	165	12.6
83	12.6	166	12.8	167	12.6
84	12.6	168	12.8	169	12.6
85	12.6	170	12.8	171	12.6
86	12.6	172	12.8	173	12.6
87	12.6	174	12.8	175	12.6
88	12.6	176	12.8	177	12.6
89	12.6	178	12.8	179	12.6
90	12.6	180	12.8	181	12.6
91	12.6	182	12.8	183	12.6
92	12.6	184	12.8	185	12.6
93	12.6	186	12.8	187	12.6
94	12.6	188	12.8	189	12.6
95	12.6	190	12.8	191	12.6
96	12.6	192	12.8	193	12.6
97	12.6	194	12.8	195	12.6
98	12.6	196	12.8	197	12.6
99	12.6	198	12.8	199	12.6
100	12.6	200	12.8	201	12.6



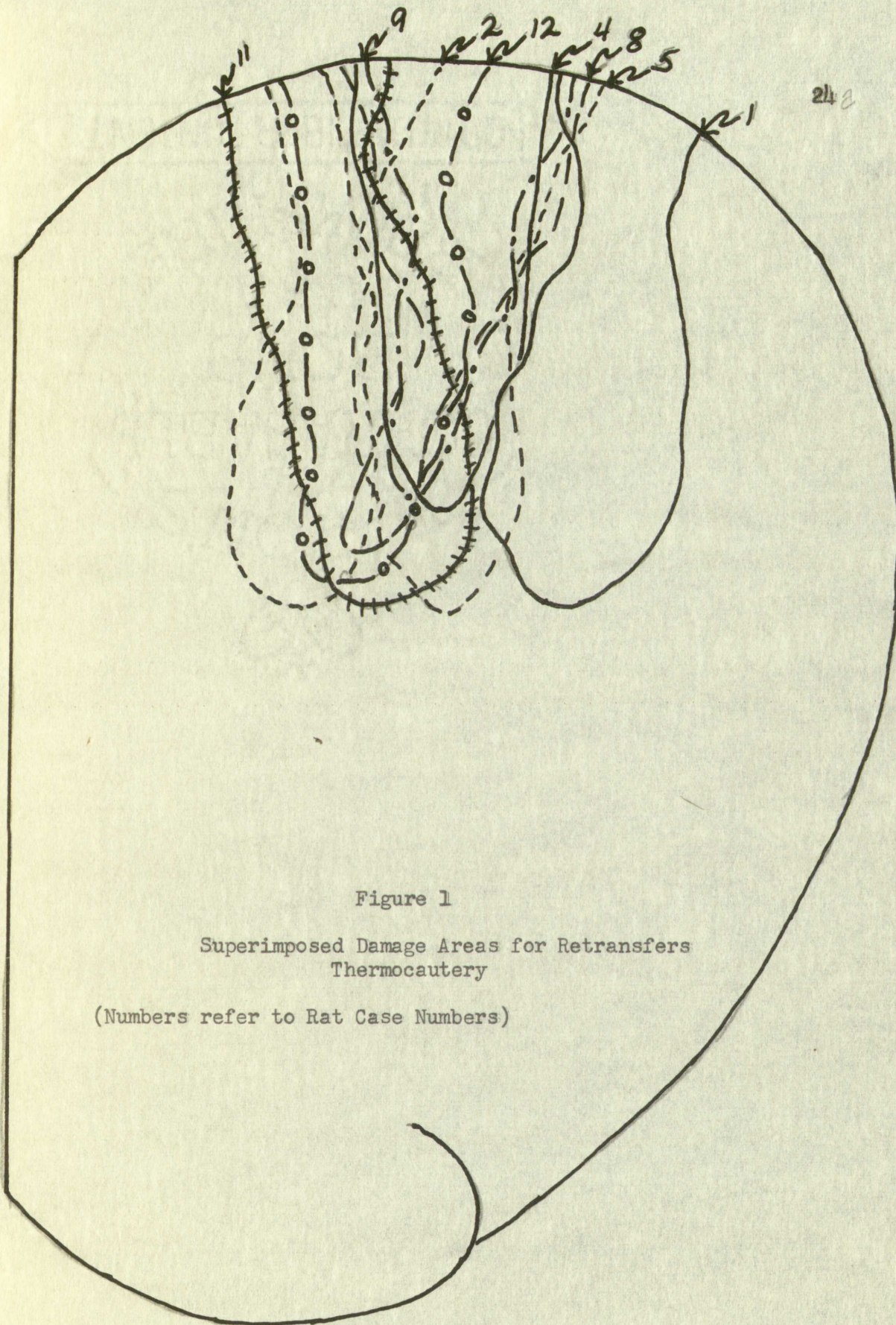


Figure 1

Superimposed Damage Areas for Retransfers  
Thermocautery

(Numbers refer to Rat Case Numbers)



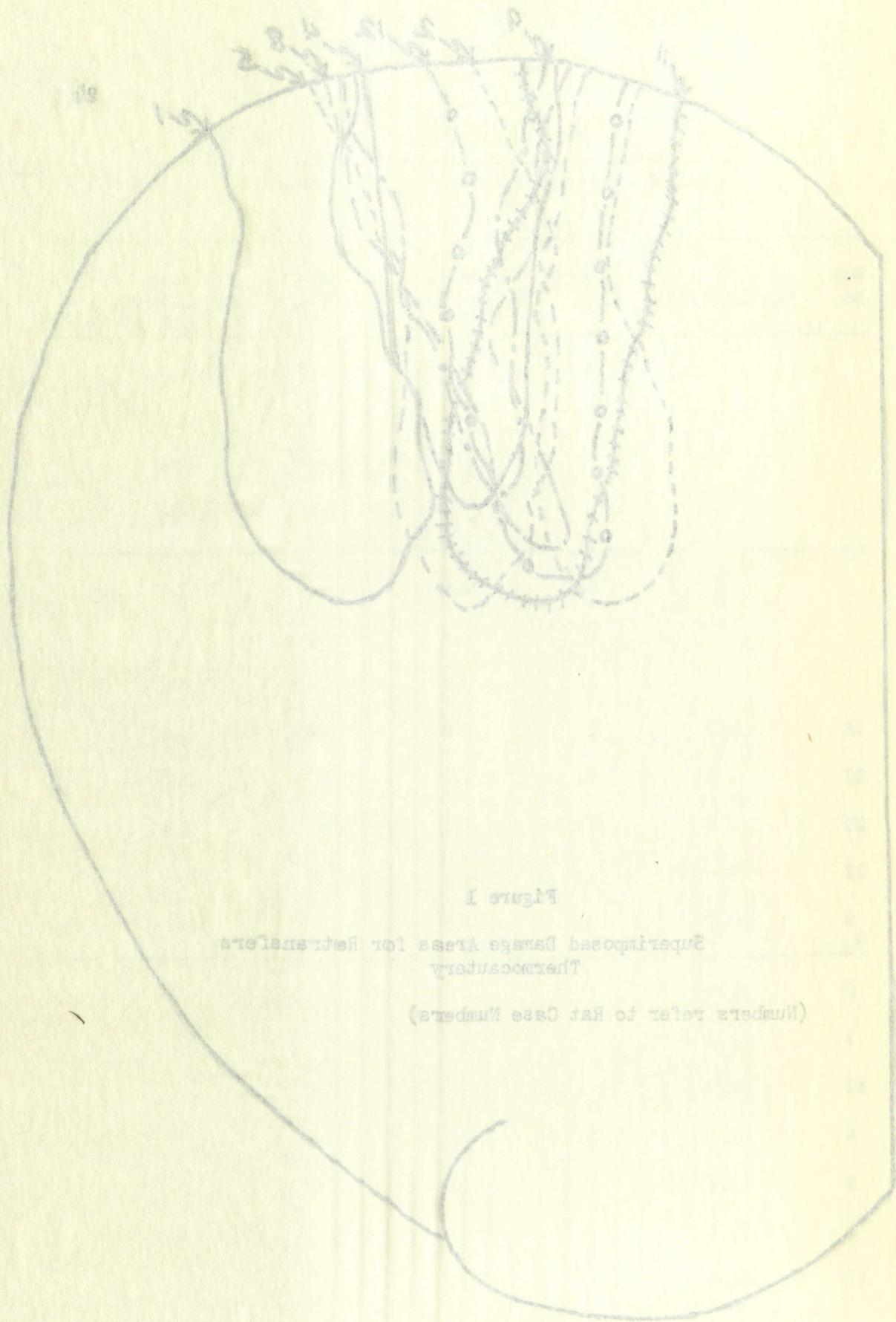


Figure 1  
 Superimposed Damage Areas for Retransfers  
 Thermocautery  
 (Numbers refer to Rat Case Numbers)



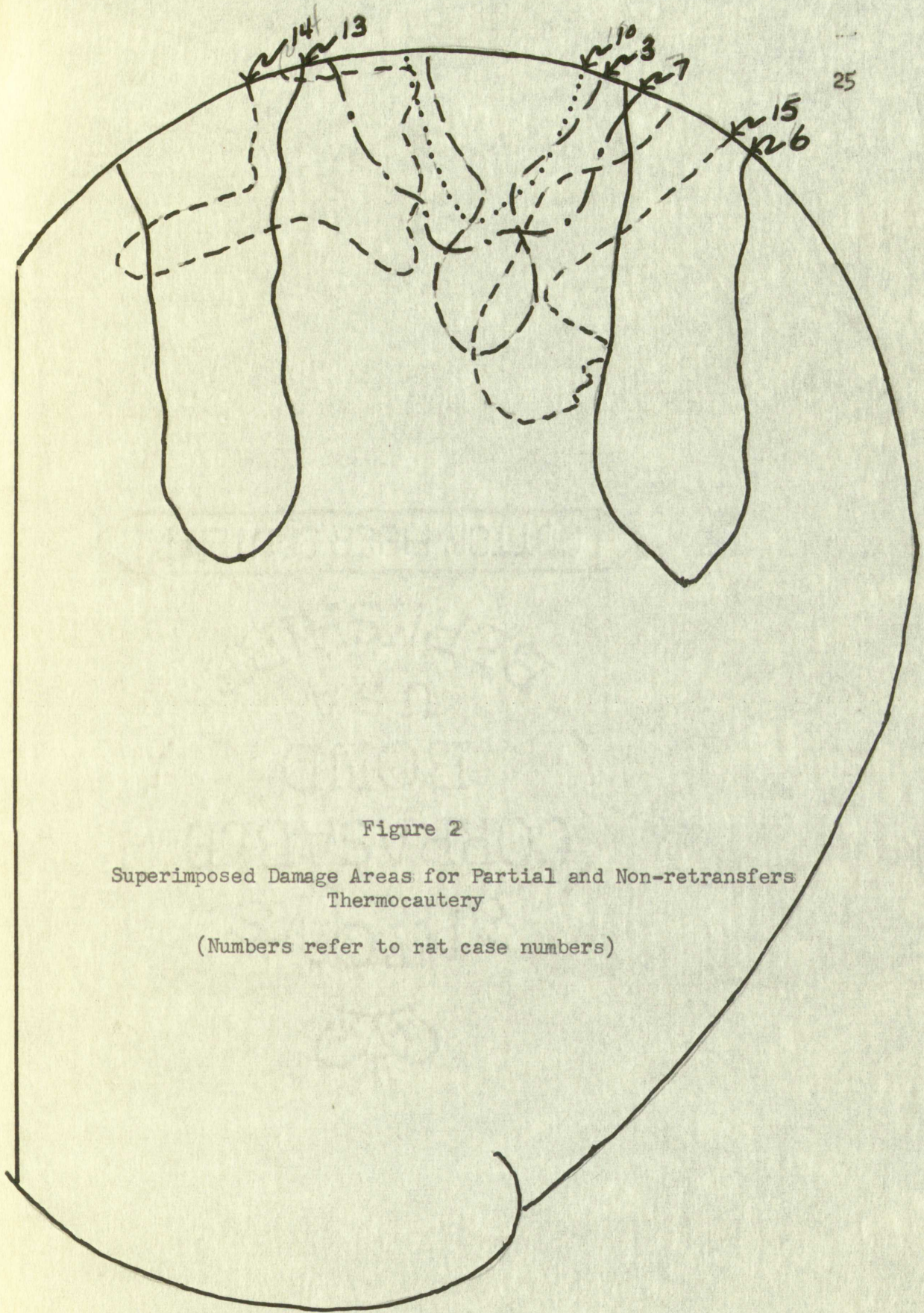


Figure 2

Superimposed Damage Areas for Partial and Non-retransfers  
Thermocautery

(Numbers refer to rat case numbers)



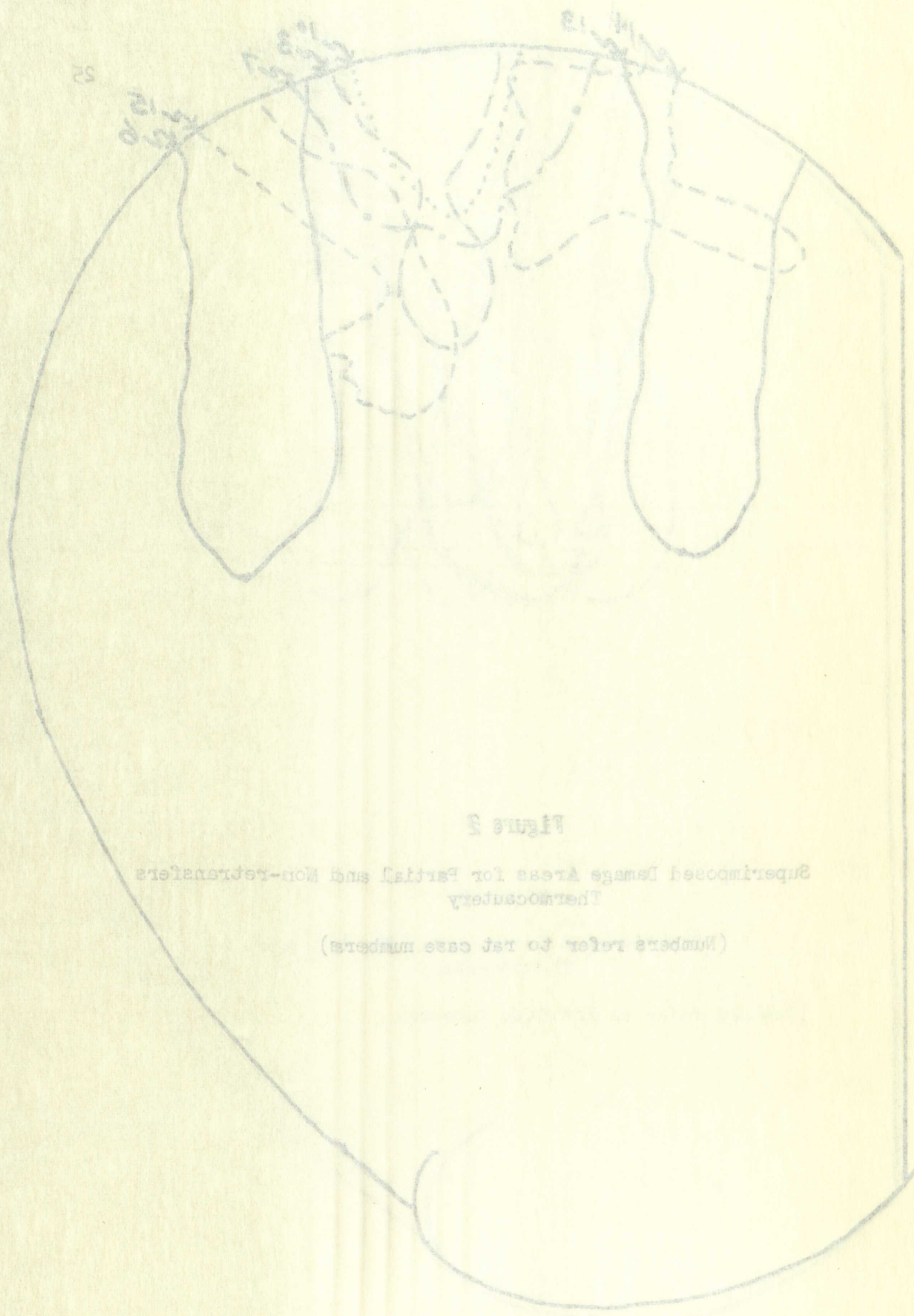


Figure 2

Superimposed Damage Areas for Partial and Non-retractors  
Thermocautery

(Numbers refer to rat case numbers)



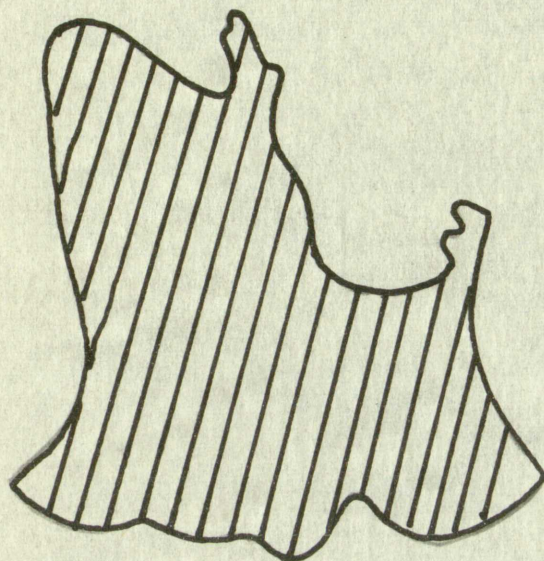


Figure 3

Critical Area for Retransferring Cases  
Thermocautery

(Figure 1 minus Figure 2)



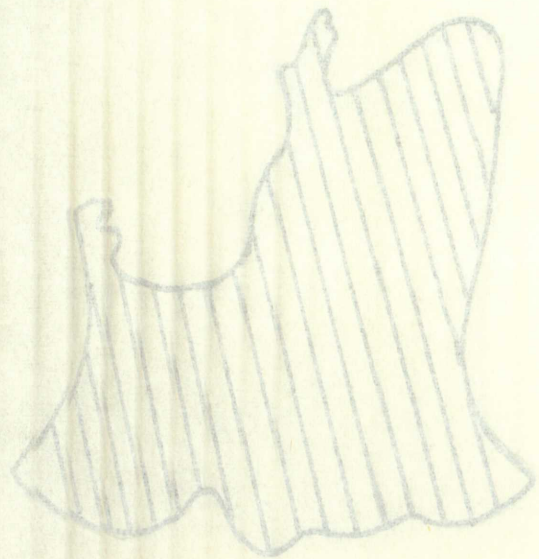


Figure 3  
Critical Area for Retransferring Cases  
Thermocautery  
(Figure 1 minus Figure 2)



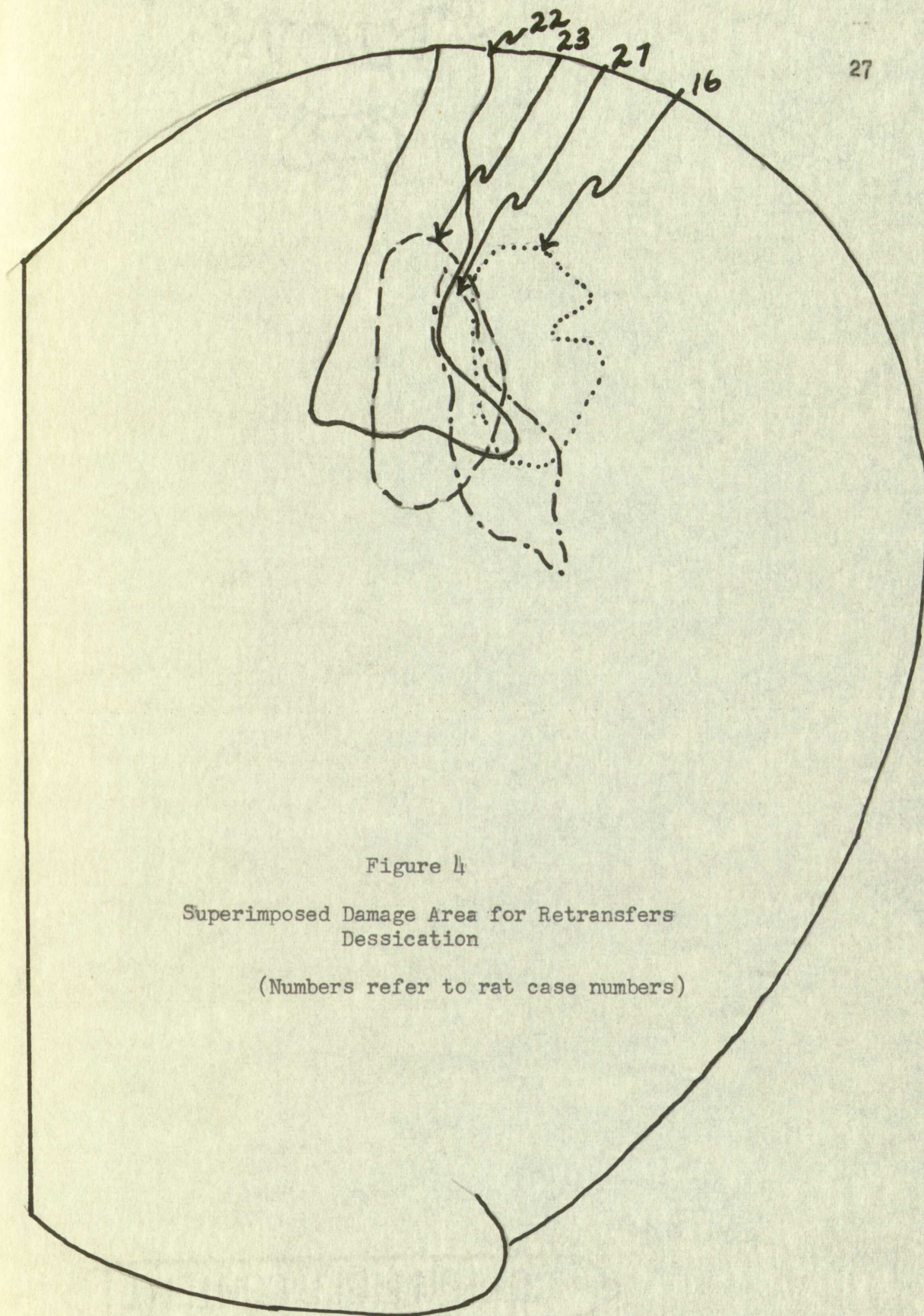


Figure 4

Superimposed Damage Area for Retransfers  
Dessication

(Numbers refer to rat case numbers)



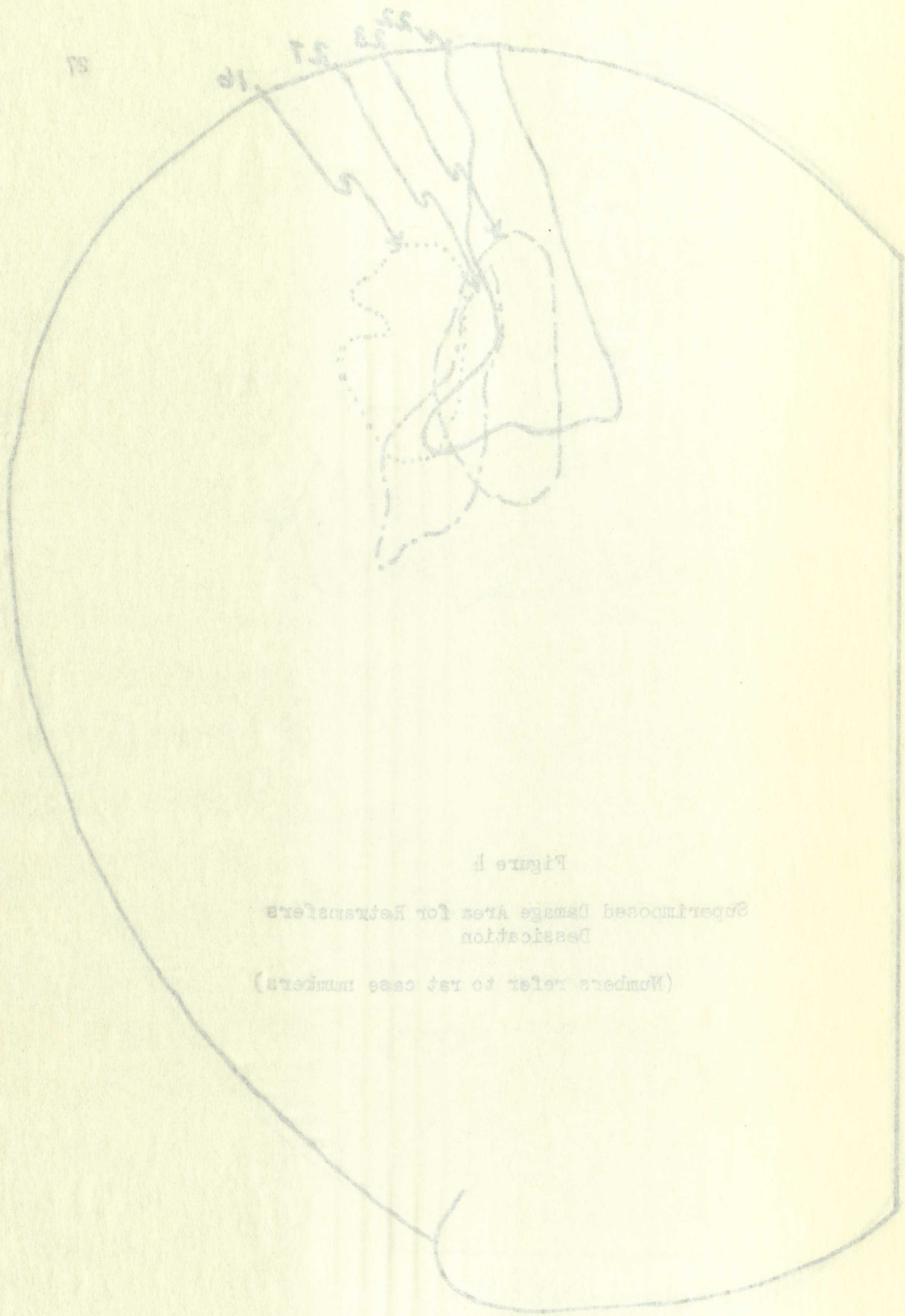


Figure 1  
Superimposed Damage Area for Refrangers  
Destination  
(Numbers refer to ref case numbers)



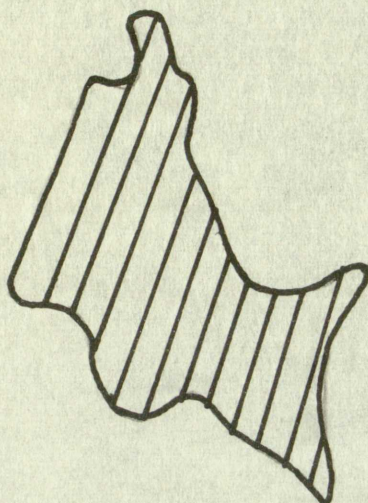


Figure 5

Critical Area for All Retransferring Cases



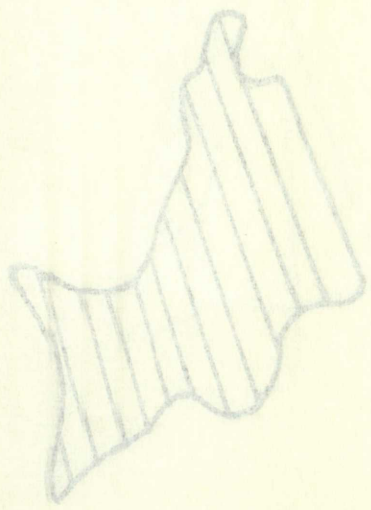


Figure 5  
Critical Area for All Retransferring Cases



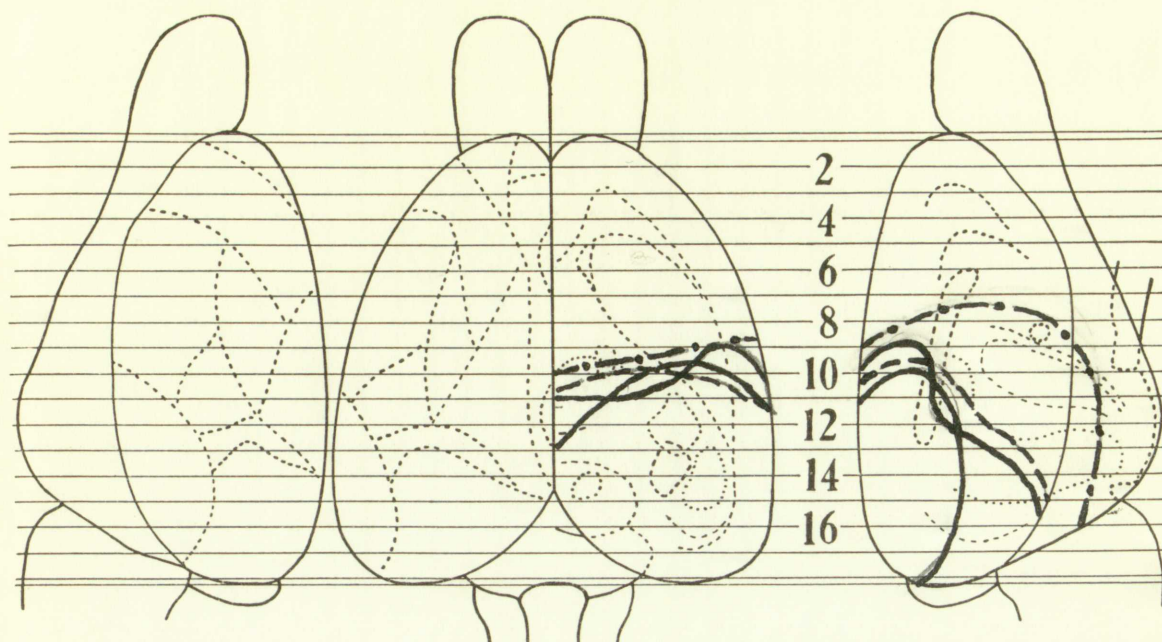


Figure 6. Destruction for Occipital Cases 37,38, 40 and 41

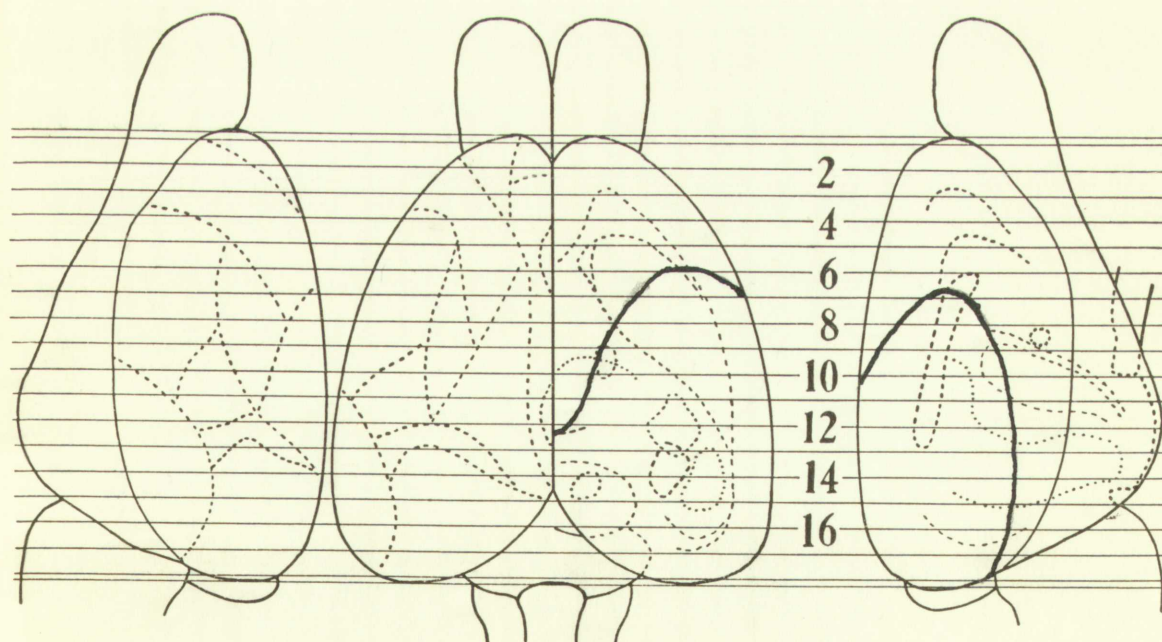


Figure 7. Destruction for Occipital Case 39





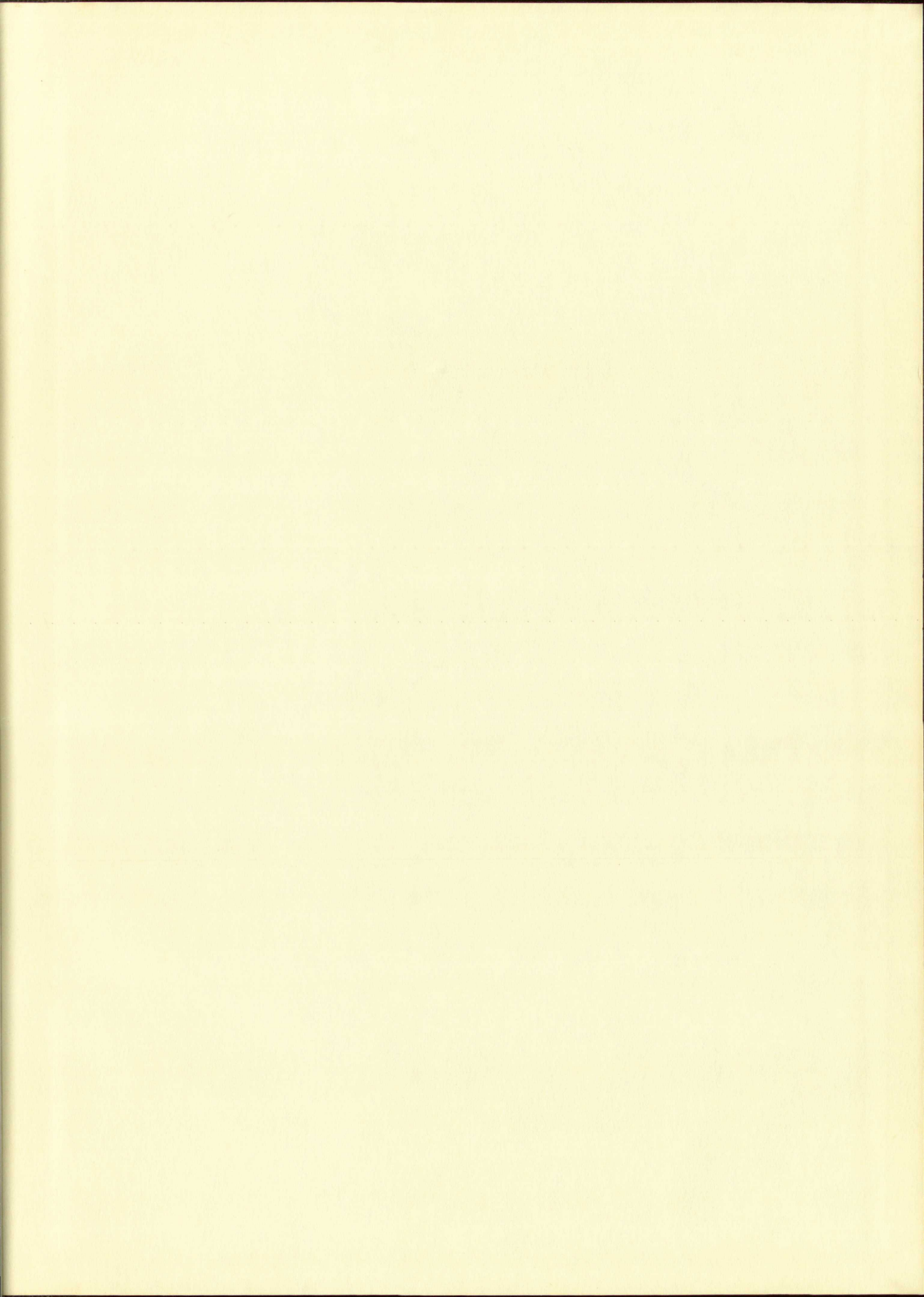




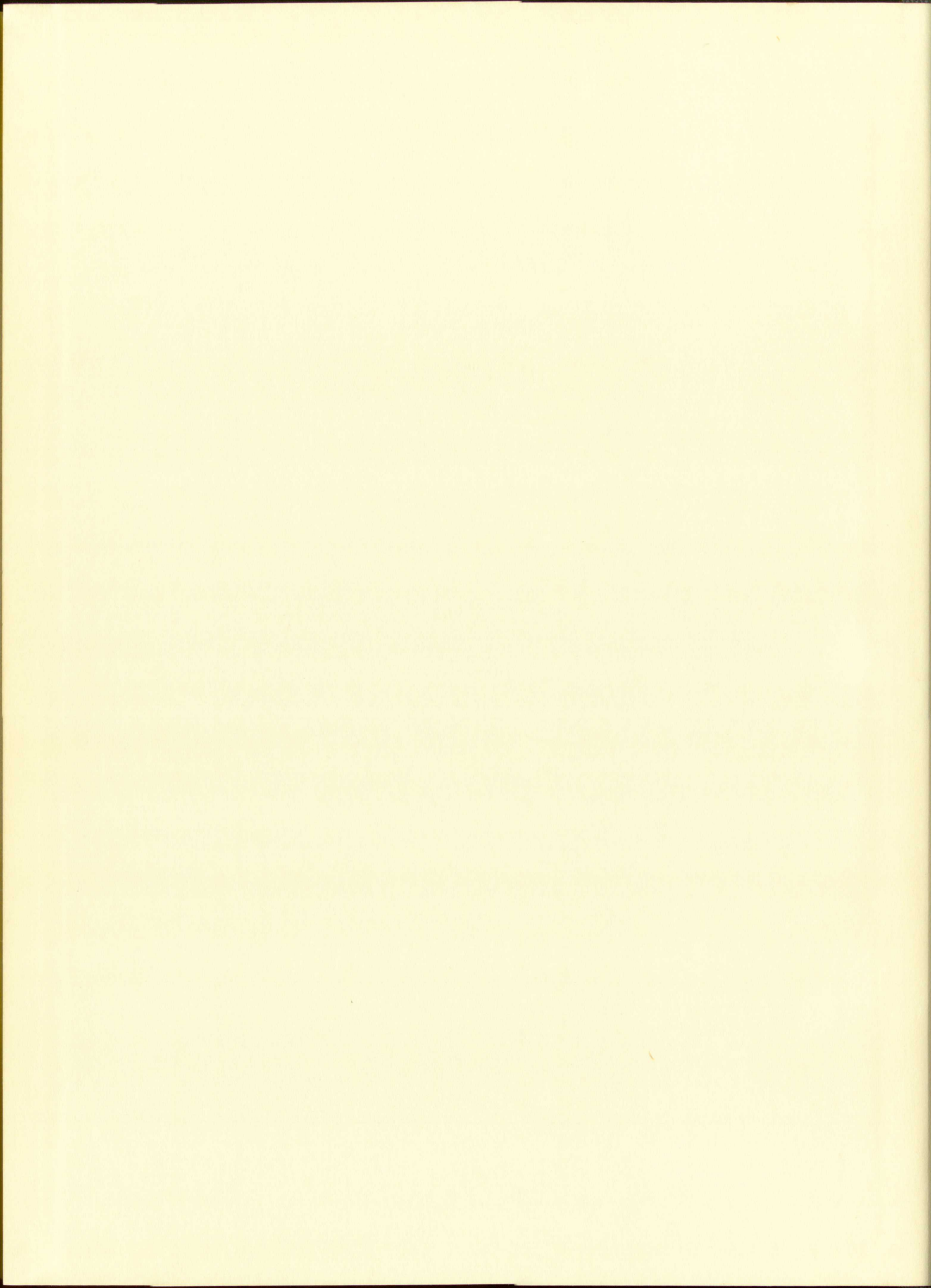


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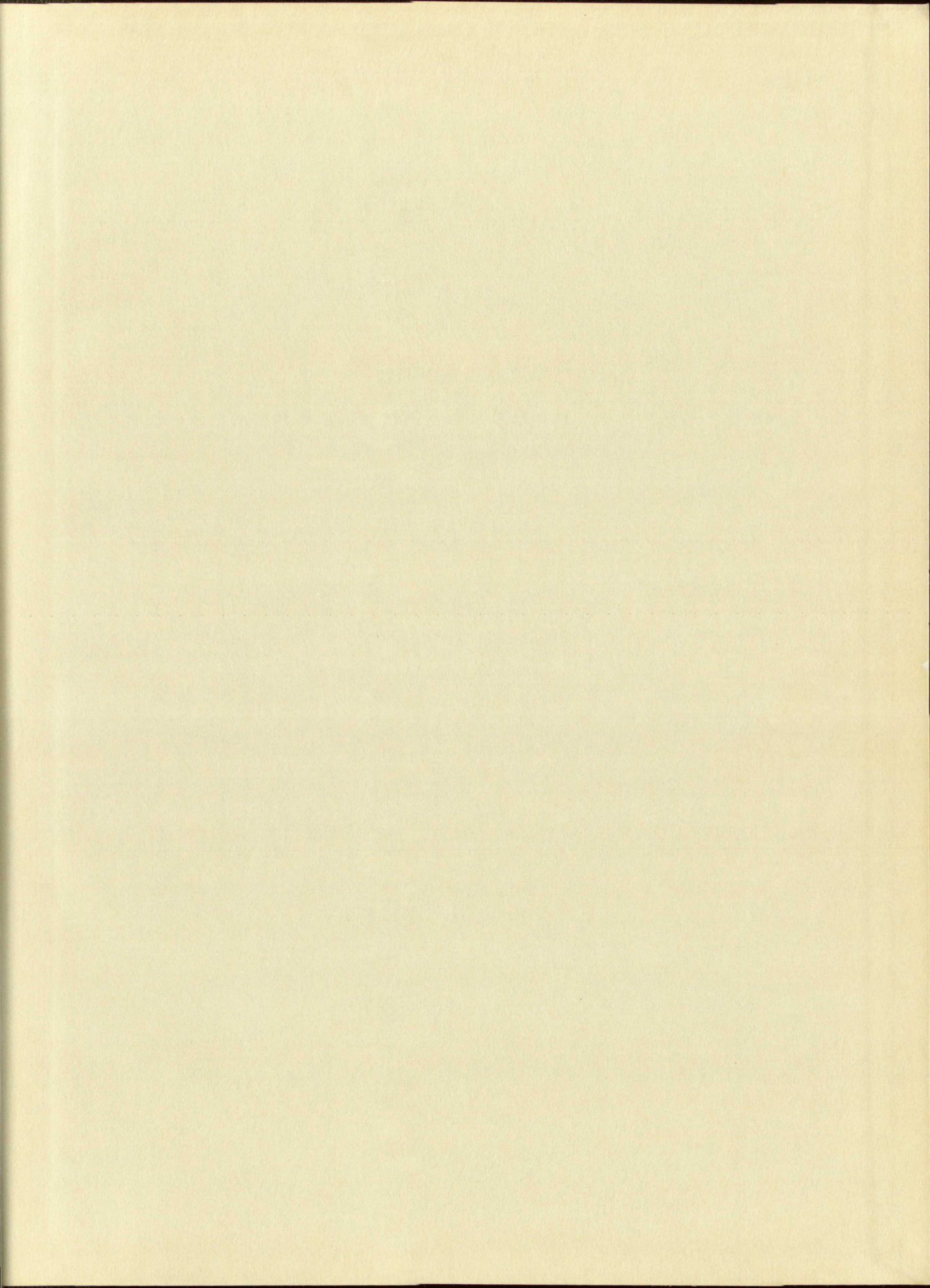














## **IMPORTANT!**

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