A STUDY ON THE MUSCULATURE OF THE HUMAN TONGUE

Observations on transparent preparations of serial sections.

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Abstract

The musculature of the human tongue is studied and described in detail through observations of a complete, consecutive series of tongue sections (2. 5 - 3 mm in thickness) in three planes: sagittal, coronal, and transverse. The sections are put into xyrol and made quasi-transparent so that the direction of the muscle fibres is readily identifiable. The results of the observations are presented in the form of a complete series of drawings with indications of the fibres of the lingual muscles.

The present study is considered to be primarily for the benefit of those who are working in the field of speech science. It is hoped that the systematic and fairly detailed information concerning the musculature of the lingual muscles will be of help in understanding, more fully and more clearly, the role of each muscle or group(s) of muscles as they function in speech production.

Introduction

During the past ten to fifteen years there has been a renewed interest in the 'articulatory' approach to the study of speech production phenomena. It is, however, not just a simple sway back to traditional articulatory phonetics. Rather, speech scientists are now beginning to replace the subjective observations and qualitative analyses of the past with quantitative analyses based on more objective observations that are being made possible by the recent development and improvement of various experimental apparatus. Consequently, we are now faced with an urgent need for basic anatomical and neurophysiological knowledge of the speech production mechanism, for an adequate interpretation of the results of the analyses.

The present work, a study on the musculature of the human tongue, was carried out with the hope of meeting (a fraction of) such demands. It aims to provide systematic and fairly detailed information concerning the musculature of the human tongue so that it may be of help in understanding more clearly the role of each muscle, or group(s) of muscles, as they function in speech production. *

The study is considered to be primarily for the benefit of those who are working in the field of speech science, especially those who are interested in such areas as the analysis of the mechanism of speech production,

* The present paper deals exclusively with muscles and is not concerned with other aspects of the tongue, for instance, the distribution of nerves and the connective tissue framework. For such information readers may refer to the anatomical literature listed in the Selected Bibliography at the end of the paper.

computer simulation of the articulatory mechanism, speech synthesis based on articulatory (physiological) parameters, and also in such practical fields as speech therapy and foreign language teaching.

1. Material and Method

The study is based on observations of transparent preparations of serial sections of three adult human tongues assisted by ordinary dissections of two adult human tongues. The results of the dissections of the head and neck region and the observations of the transparent preparations of the tongue are given below in 2. 1. and 2. 2. respectively. The descriptions are accompanied by drawings (Fig. 1 through Fig. 5)*, all of which were made by the author during the course of these dissections and observations.

The preparations of the sections are made in the following manner:
1) Each of the three tongues, fixed in 10% formaline for a period of approximately four years is divided into exact halves, each of which is then cut either sagittally, coronally, or transversely, making different series of sections 2.5 - 3.0 mm in thickness.
2) The sections are dehydrated with alcohol, starting with a 30% solution and gradually increasing the concentration of the alcohol by 10% every 24 hours up to a 90% solution, and thereon by 5% until pure (99. 9%) alcohol is attained. The sections are kept in pure alcohol for 48 hours.
3) The sections are then put into xyrol, through which process the specimens turn brownish but the muscle fibres become transparent so that when observed with an appropriate light from below, the courses of muscle fibres are distinctly identifiable.

The observations are made essentially by eye with the help of a magnifying glass whenever necessary. The colour slides of the tongue specimens taken before dehydration are also consulted.

2. Musculature of the Tongue

The muscles that will be described in detail in this study (Section 2.2) are the three extrinsic lingual muscles, Genioglossus (GG), Hyoglossus (HG) and Styloglossus (SG), and the four intrinsic lingual muscles, Superior Longitudinalis (SL), Inferior Longitudinalis (IL), Transversus (T), and Verticalis (V). **, ***

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* All of the figures are given at the end of the paper.

** Throughout the study, both in the text and in the figures, abbreviations will be used for the identification of the muscles. The list of abbreviations is given at the end of the paper together with a list of the terms of location and orientation as used in this paper.

*** The lingual muscles are anatomically divided into two groups, the extrinsic and the intrinsic. The former group of muscles are characterized by the fact that they all originate outside the tongue mass, having attachments to the bony structures of the head. In contrast, the intrinsic muscles of the tongue have no such bony attachments, but arise from and end up within the bulk of the tongue.

For purposes of orientation, however, a brief overall description of the lingual muscles and other muscles of the head and neck region that are related to lingual articulation will be given first in 2. 1.

2. 1. Tongue in relation to other structures of the head.

This section will give an overall description of the muscles of the head and neck region based primarily on the author's observation during systematic dissections of cadavres, assisted by the information available in existing textbooks of anatomy.

Fig. 1 illustrates the position of the tongue in relation to other muscles and hard structures of the head and neck region. Shown in the figure are the seven muscles of the tongue and various other muscles that are closely related to lingual articulation. Some of the non-lingual, infra- and supra-hyoid muscles are shown in Fig. 2. The hard structures to which the above mentioned muscles attach are the mandible, the hyoid bone, the styloid processes and the mastoid processes: the areas of the muscle attachment on the mandible and the hyoid bone are illustrated in Fig. 3.

Following is a very brief description of the muscles shown in Fig. 1.

i. Genioglossus Muscle originates from the mental spine on the inner surface of the mandible, spreads out in a fan-shaped radiation in and around the median plane, and reaches the submucous tissue of the dorsum of the tongue (the medial portion) from its blade to its root. GG is not found at the tip of the tongue.

ii. Hyoglossus Muscle is a flat, quadrilateral piece of muscle that originates from the lateral portion of the anterior surface of the body of the hyoid bone and along the entire extent of its greater cornu. It spreads out laterally both in an anterior and a superior direction towards the dorsum of the tongue and inserts into the side of the tongue.

iii. Styloglossus Muscle is a pair of fairly thin muscle bundles that may be compared to a 'sling' of the tongue. They originate from the styloid processes, run down anteriorly, and insert into the sides of the tongue.

iv. Superior Longitudinalis Muscle is a layer of muscle whose fibres course longitudinally along the entire extent of the dorsum of the tongue just beneath the layer of submucous tissue. SL is noticeably thicker in the proximity of the median line.

v. Inferior Longitudinalis Muscle consists of a pair of muscle bundles that extend between the tip and the root of the tongue along the inferior surface of the tongue. Except at the tip, IL runs lateral to GG and inferior to Transversus and Verticalis Muscles. The muscle bundle becomes thicker as it runs towards the root of the tongue.

vi. Transversus Muscle constitutes a fairly thick stratum beneath the whole extent of SL, occupying a main part of the superior half and the root of the tongue. The fibres arise from the fascia in the mid-sagittal plane, and, when seen in a coronal plane, fan out a little both superiorly and inferiorly and reach the lateral margin of the tongue.

vii. Verticalis Muscle is found only in the superior half of the tongue. The fibres of this muscle arise from the dorsum and run down vertically, as in the anterior fourth, or course slightly inferio-laterally, as in the remaining part.

viii. Geniohyoid Muscle is a fairly thick muscle that originates from the

mental spine on the inner side of the mandible just below the origin of GG and inserts into the entire portion of the anterior surface of the body of the hyoid bone.

ix. Mylohyoid Muscle is a flat sheet of muscle that originates from the mylohyoidal ridge on the side of the inner surface of the mandible. The fibres originating on the posterior portion of the mylohyoidal ridge insert into the lower part of the anterior surface of the body of the hyoid and the rest of the fibres that originate on the anterior portion of the mylohyoidal ridge reach the median raphe where the fibres on both sides meet and insert into each other.

x. Stylohyoid Muscle originates on the styloid process, runs down slightly in an anterior direction, and inserts into the anteriormost portion of the greater cornu of the hyoid bone.

xi. Digastricus Muscle consists of the anterior and the posterior bellies. The former originates from the fossa digastrica, near the mental spine, on the inner surface of the mandible, while the latter originates from the mastoid process. Both bellies run toward the hyoid bone where they turn into an intermediate tendon which is strapped to the outer side of the body of the hyoid bone by a strong tendinous tissue.

xii. Sternohyoid Muscle is a long flat piece of muscle that originates mainly from the sternum and partly from the clavicle, courses vertically upwards, and inserts into the lower edge of the body of the hyoid bone.

xiii. Omohyoid Muscle is another long flat muscle that originates on the upper edge of the scapula and inserts into the lower edge of the outer surface of the hyoid bone, laterally to the insertion of SH.

xiv. Thyrohyoid Muscle originates from the oblique line of the thyroid cartilage and inserts into the lower margin of the outer side of the greater cornu of the hyoid bone. Its course is vertically upwards.

xv. Palatoglossus Muscle is a thin strip of muscle that runs between the soft palate and the side of the tongue, posteriorly. PG is sometimes considered as a muscle of the tongue and sometimes as a muscle of the soft palate. We will take the latter standpoint in this paper.

xvi. 'Glossopharyngeus' Muscle is not truly an anatomical term that refers to any specific muscle, but is commonly, though wrongly, used to denote the part of the Superior Constrictor Muscle of the pharynx that inserts into the sides of the tongue root.

2. 2. Observation of transparent specimens of the tongue.

This section will give a detailed description of the musculature of the lingual muscles based solely on the author's observation of the transparent specimens of human tongues.

The drawings of the complete serial sections of the tongues in three different planes (sagittal, coronal, and transverse) are given in Figs. 4 and 5. The sections presented in Figs. 4-ii and 4-iii are of the tongue of a 39-year-old female, the outline of which is shown in Fig. 4-i. There are 11 sagittal sections and 20 coronal sections as indicated. Fig. 5-i gives a sagittal projection of the outline of the tongue of a 29-year-old male. The left half of this tongue was cut into 18 transverse sections as presented in Fig. 5-ii. For purposes of better understanding, it would be helpful to keep referring to the figures while following the explanations in the text. The

figures that illustrate the point in the explanation best are indicated in brackets. *

2. 2. 1. Genioglossus Muscle

This muscle originates on the superior mental spine on the inner side of the mandible (Figs. 1, 2, and 3) and spreads out superiorly and posteriorly in a fan-shaped radiation: it also spreads out slightly laterally near the base of the tongue. Parasagittally, the fibres fan out towards the whole extent of the dorsum and towards the root of the tongue (S:1, 2) but laterally they spread only towards the posterior portion of the dorsum and towards the root (S:3. 4). Superiorly and posteriorly GG decussates and interdigitates with T and V, runs through the layer of SL in thin fibres and attaches to the submucous tissue of the dorsum and the root of the tongue (S:1-4).

The superior fibres** course upward towards the anterior half of the dorsum of the tongue. However, the fibres of GG are not found to curve anteriorly as is often shown in the textbooks of anatomy and are not found in the tip of the tongue (C:1-3). In the anteriormost coronal sections (excluding those of the tip) the GG fibres are hardly distinguishable from other muscle fibres such as those of IL, HG and SG. The first identifiable sign of GG anteriorly is found in C:4. The intermediate fibres course towards the posterior half of the dorsum of the tongue. The inferior fibres run towards the root of the tongue, the most inferior of them running towards the anterior surface of the hyoid bone (S:1-4, T:17, 18).

2. 2. 2. Hyoglossus Muscle

HG is a flat piece of muscle, quadrilateral in shape, which originates on the hyoid bone (Figs. 1 and 3). *** It inserts into the side of the posterior portion of the tongue and spreads anteriorly, superiorly, and also slightly posteriorly (S:7, 8, C:13-18, T:10-18).

The anterior portion of HG extends anteriorly along the inferior surface of the tongue lateral to IL. It merges with IL and SG towards the tip of the tongue but its fibres near the tip are difficult to identify in the coronal sections. **** The intermediate fibres of HG run vertically upward in a slightly anterior direction and are easily distinguished from other muscles in the tongue mass (C:13-16, T:10-18). The posterior fibres course

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* Any specific drawing of a tongue section will be referred to by a capital letter denoting the type of the section, e. g. S for 'sagittal, ' followed by a number of that section, e. g. S:1, S:2, S:3-5.

** In speaking of GG, I shall use the terms 'superior, ' 'intermediate, ' and 'inferior, ' depending on the relative position of the bony attachments of the fibres on the mandible. That is, the fibres having a superior attachment will be referred to as the 'superior' fibres of GG.

*** HG is often described as being made up of two parts, but it was difficult to identify them accurately in the present samples.

**** They can, however, be traced down — with some difficulty — towards the tongue tip in an ordinary dissection of the tongue.

posteriorly upward towards the posteriormost part of the dorsum of the tongue (C:17, 18).

2. 2. 3. Styloglossus Muscle

SG is a pair of muscles originating from the styloid processes (Fig. 1) and inserting into the sides of the tongue mass (S:5-11, C:9-19, T:13-16). Once within the tongue mass, the fibres course anteriorly towards the tip of the tongue. The posterior third of SG within the tongue mass, lying lateral to HG, is flat mediolaterally (C:14-18), whereas the middle third is flat superio-inferiorly and lies inferior to IL (C:9-13). This is due to a twist of the fibre bundles which can be seen when we compare C:13 and 14. The anterior portion of SG runs along with IL towards the tip, some of the fibres merging with those of IL and HG (C:4-8, T:11).

2. 2. 4. Superior Longitudinalis Muscle

SL is a layer of muscle whose fibres run longitudinally along the entire superior surface of the tongue, just beneath the layer of submucous tissue, from the tip to the very root of the tongue in the proximity of the hyoid bone (S:1-7, C:1-19, T:1-16). SL also runs longitudinally along the lateral border of the tongue (S:8, 9, C:4-15, T:5-6). At the root of the tongue the fibres run vertically, ending in the fibrous tissue near the attachment of the tongue to the hyoid bone (S:1-7, C:17-19). In the middle two fourths of the tongue mass, SL is noticeably thicker near the midline than elsewhere (C:6-15). The layer becomes thinner laterally and posteriorly (S:7, 8, C:16-17). SL interdigitates with GG and V dorsally and posteriorly, and with T laterally.

2. 2. 5. Inferior Longitudinalis Muscle

IL is a pair of muscle bundles extending in an anterior-posterior direction on the inferior side of the tongue from the tip to the root. It lies inferior to all other intrinsic muscles except, of course, where SL runs vertically at the root of the tongue (S:1-7, C:1-19, T:10-15). The fibres spread out in a conical form as they approach the root of the tongue.

In the anterior third it is a flat layer of muscle fibres lying beneath T and V (C:1-6). Elsewhere, except at the posteriormost end of the tongue mass, IL is environed superiorly by T and V, medially by GG and laterally by HG (C:12-16). Posteriorly, it seems to run through T and interdigitate with SL running vertically (S:5, 6, T:12-16).

2. 2. 6. Transversus Muscle

T forms a fairly thick stratum beneath the whole extent of SL, constituting a main part of the dorsal half of the tongue together with V (C:2-18). The fibres attach to the median septum in the middle of the tongue mass, or to the fibres of the same muscle on the other side, e. g. at the tip of the tongue. The fibres, when seen in a coronal section, fan out a little both superiorly and inferiorly, and attach to the sides of the tongue. At the tip, it is found decussating with fibres of V and interdigi-

tating with fibres of SL, IL and those of SG and HG that reach the tip (C:2-4). In about the middle two fourths of the tongue, antero-posteriorly, T lies superior to IL and the borderline between the two groups of muscles is quite distinct (C:7-16). In the posterior one fourth, as is seen in the sagittal sections (S:1, 2), the layer of T extends inferiorly, the stratum now lying anterior to the layer of SL. This is clearly indicated by comparing T:8 and T:9, or C:15 and C:16. In this part the fibres of T interdigitate with those of V (C:17, 18) and are hard to distinguish from those of IL in the coronal sections.

2.2.7. Verticalis Muscle

This muscle is found only in the superior half of the tongue (C:2-18). When seen on the coronal plane the fibres of this muscle, symmetric on either side of the midline, extend either vertically downwards, as in the anterior fourth (C:2-5), or inferio-laterally, as in the remaining portion (C:6-18). For the most part the fibres are found to interdigitate with IL and end there before reaching the inferior surface of the tongue or other muscle fibres. In the posteriormost part of the tongue where SL runs vertically, V decussates with it but the fibres are less in quantity there than in the main part of the stratum.

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The tongue, in spite of being always recognized as the primary -- and absolutely indispensable -- organ for the articulation of speech sounds, seems to be somewhat left behind in the study of speech. One of the reasons for this may be that the anatomical structure of the tongue is far from simple and that the dynamics of the lingual movement are as complex as the tongue itself.

It is hoped that the present study will serve as a stepping stone for future research on the tongue and its dynamics in the production of speech.

Acknowledgments

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List of Abbreviations

Muscles:
GG: Genioglossus (muscle)
HG: Hyoglossus (")
SG: Styloglossus (")
SL: Superior Longitudinalis (")
IL: Inferior Longitudinalis (")
T: Transversus (")
V: Verticalis (")
GH: Geniohyoid (")
MH: Mylohyoid (")
SH: Stylohyoid (")
Dig. ant., post.: Digastricus (")
(anterior belly and posterior belly)
SH: Sternohyoid (muscle)
OH: Omohyoid (")
ThH: Thyrohyoid (")
PG: Palatoglossus (")
[GPh: Glossopharyngeus (")]

Types of Sections:
S: Sagittal (sections)
C: Coronal (")
T: Transverse (")

List of Terms of Location and Orientation As Used in this Paper (See Fig. A)

1. Anterior
2. Posterior
3. Superior
4. Inferior
5. Medial
6. Lateral
7. Sagittal
8. Coronal
9. Transverse

Selected Bibliography

1. Abd-el-Malek, S., 'Observations of the Morphology of the Human Tongue,' Journal of Anatomy 73, 201-210 (1938/39).

This is a comprehensive study of the morphology of the human tongue. The descriptions are detailed and seem to be based on sound observations. Described here are: 1) connective tissue framework of the tongue, e. g. lamina propria and various septa, 2) musculature of the tongue --- Genioglossus, Hyoglossus, Styloglossus, Superior and Inferior Longitudinals, Transversus and Verticalis, and 3) Hypoglossal nerve and lingual artery. There

are seven good microphotographs of selected sections of the tongue at the end of the paper.

2. Hill, K. C., 'The Musculature of the Tongue,' Working Papers in Phonetics, UCLA Vol. 1, 22 (1964)

   This article gives a simple overall description of 1) the suprahyoid muscles (Stylohyoid, Digastric, Mylohyoid, and Geniohyoid), 2) the intrinsic lingual muscles (Superior and Inferior Longitudinals, Transversus, and Verticalis), 3) the extrinsic muscles (Genioglossus, Hyoglossus, Styloglossus, Palatoglossus and Glossopharyngeus --- the last two muscles are included in the extrinsic lingual muscles according to this author), and 4) the connective tissue framework of the tongue. There are 14 illustrations to assit the explanations in the text which are, though very rough, helpful in grasping the overall make-up of the tongue and the surrounding structures. The descriptions are simple but intelligible.

3. Lanz, T. von, and Wachsmuth, W., Praktische Anatomie: I/2 Hals Springer-Verlag, Berlin (1955).

   Pages 63 through 122 contain many illustrations and descriptions of supra- and infra-hyoid muscles including the muscles of the tongue. The drawings are very neat and clear.

4. Pernkopf, E., Atlas of Topographical and Applied Human Anatomy. Vol. One. Head and Neck. Edited by H. Ferner and translated by H. Monsen. W. B. Saunders Company, Philadelphia (1963).

   This book is extremely helpful in that it provides an abundant collection of drawings. They are mostly in colour and are both detailed and clear. The illustrations of the lingual muscles and the related muscles are found mainly on pp. 111-150 and pp. 195-230.

5. Strong, H., and Gold, E. M., 'Force components of the tongue musculature, with emphasis on the intrinsic fibres, especially those used in speech.' Anatomical Record 106, 252 (1950) Abstract.

   This abstract of only twenty lines or so gives, in the authors' words, 'Functionally significant findings hitherto not recorded. . . .' Their account, principally on Genioglossus, Verticalis, and Transversus, is short but accurate

6. Zemlin, W. R., Speech and Hearing Science, Prentice Hall, Englewood Cliffs, N. J., (1968)

   This book, nearly 600 pages in all, gives a comprehensive description (although the author says he will have to write several volumes to make it 'comprehensive') of the speech and hearing mechanisms and their functions together with numerous illustrations and photographs. It is a very useful book both for introductory purposes and for later reference. Pages 277 through 290 are concerned specifically with 'tongue', i. e. its anatomy and dynamics in articulation. The figures include several schematic drawings, some good photographs of the sections of the tongue, and traditional palatograms of selected speech sounds.

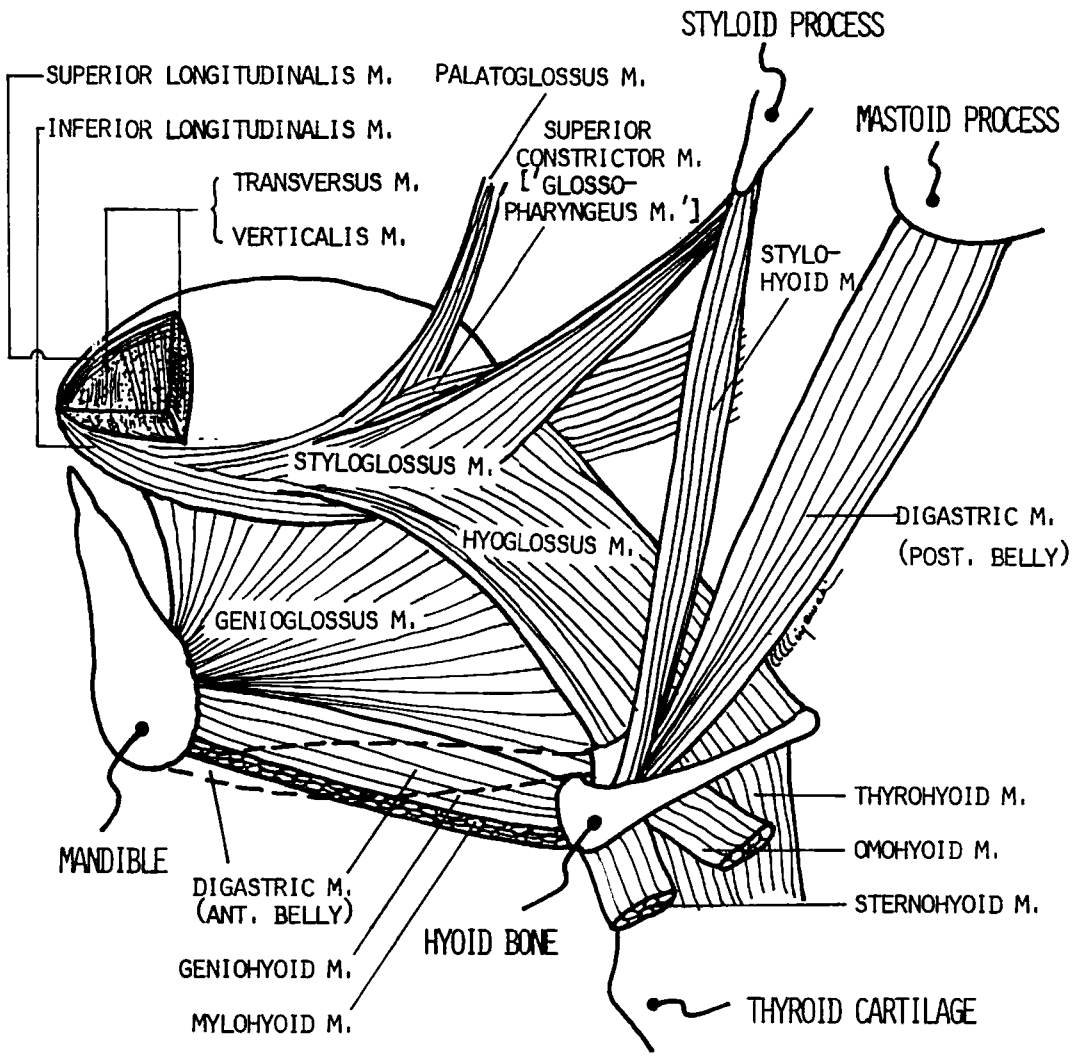


FIG. I THE MUSCLES OF THE TONGUE AND OTHER MUSCLES RELATED TO LINGUAL ARTICULATION. THE ANTERIOR PORTION OF THE LEFT HALF OF THE TONGUE IS CUT OFF TO SHOW THE INTRINSIC LINGUAL MUSCLES.

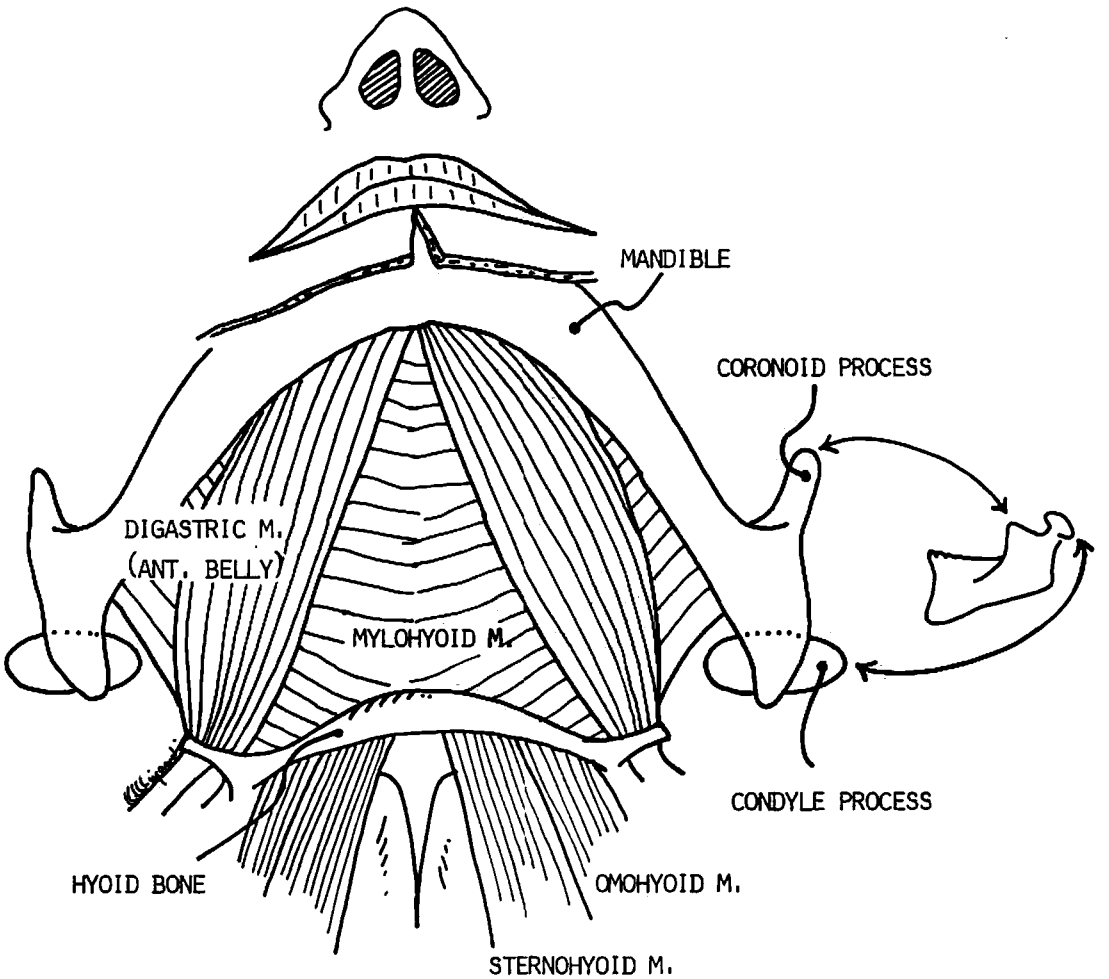


FIG. 2 SOME OF THE SUPRA- AND INFRA-HYOID MUSCLES AS VIEWED FROM BELOW.

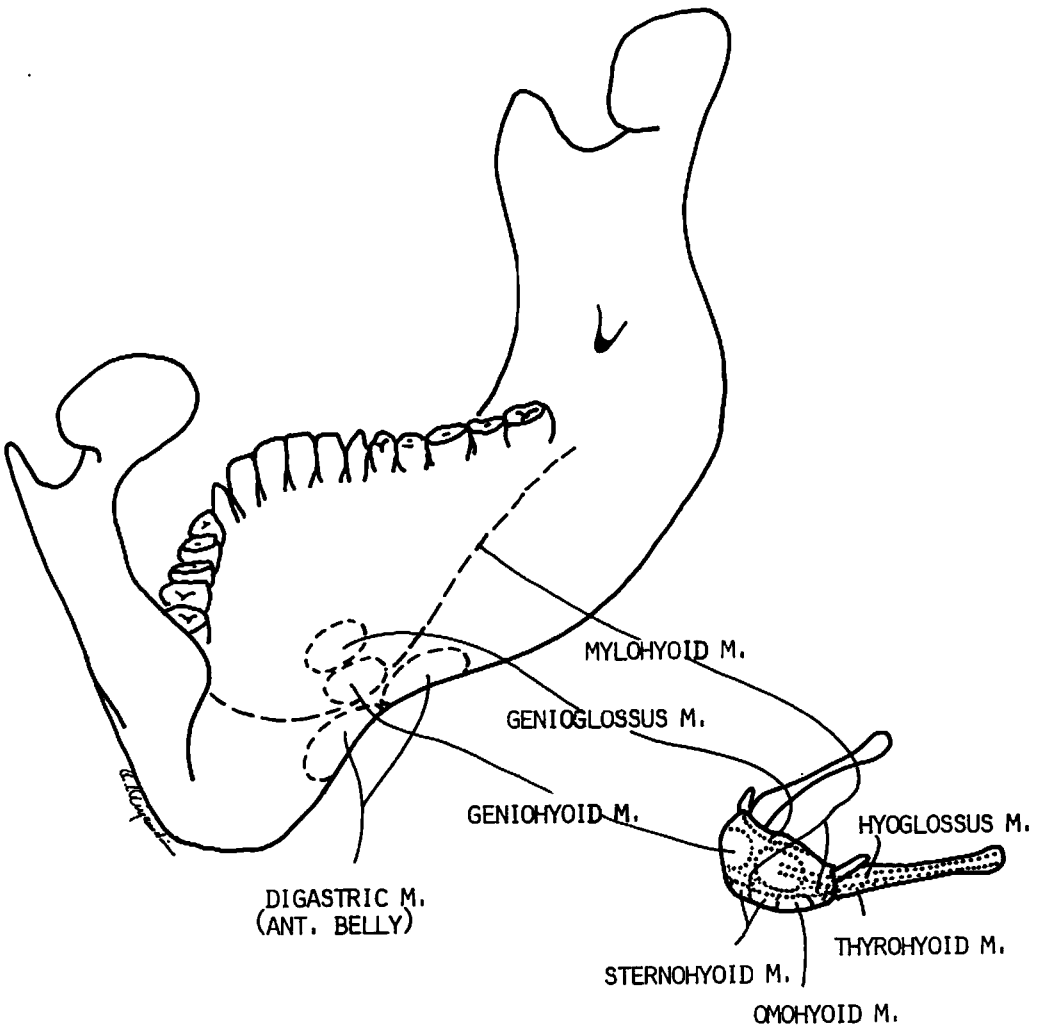
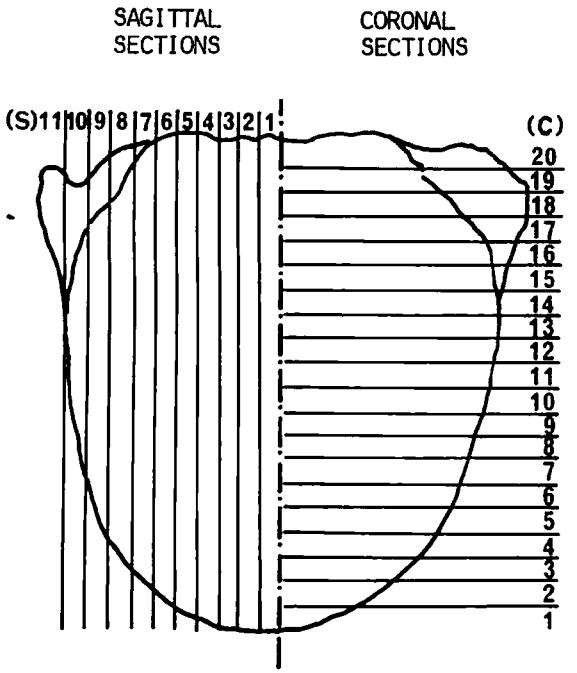


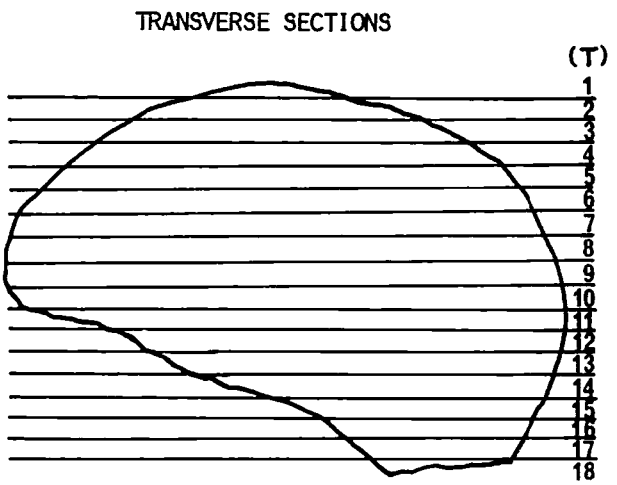
FIG. 3 THE AREAS OF MUSCLE ATTACHMENT ON THE MANDIBLE AND THE HYOID BONE.



Tongue # 25926 ♀39

FIG. 4-i

THE OUTLINE OF A TONGUE -- VIEWED FROM ABOVE -- FROM WHICH SAGITTAL AND CORONAL SECTIONS, PRESENTED IN FIG. 4-ii AND 4-iii RESPECTIVELY, WERE MADE. THE SECTIONS WERE CUT IN THE MANNER INDICATED BY THE SETS OF PARALLEL LINES.



Tongue # 25986 ♂ 29

FIG. 5-i

THE OUTLINE OF A TONGUE -- VIEWED FROM THE SIDE -- FROM WHICH TRANSVERSE SECTIONS SHOWN IN FIG. 5-ii WERE MADE AS INDICATED BY THE SET OF PARALLEL LINES.

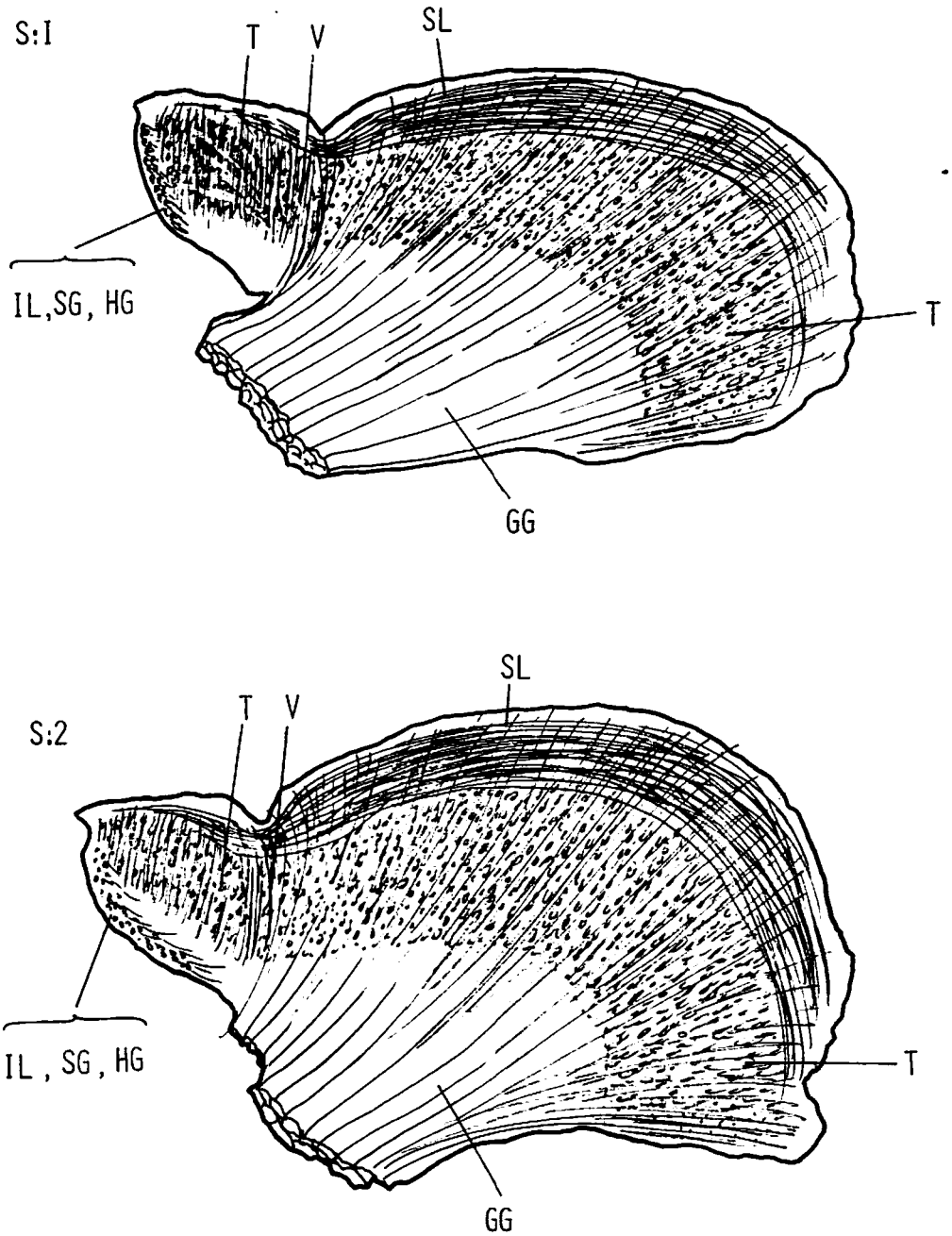


FIG. 4-ii THE SAGITTAL SECTIONS OF THE RIGHT HALF OF A TONGUE WHOSE ORIGINAL SHAPE IS SHOWN IN FIG. 4-i.

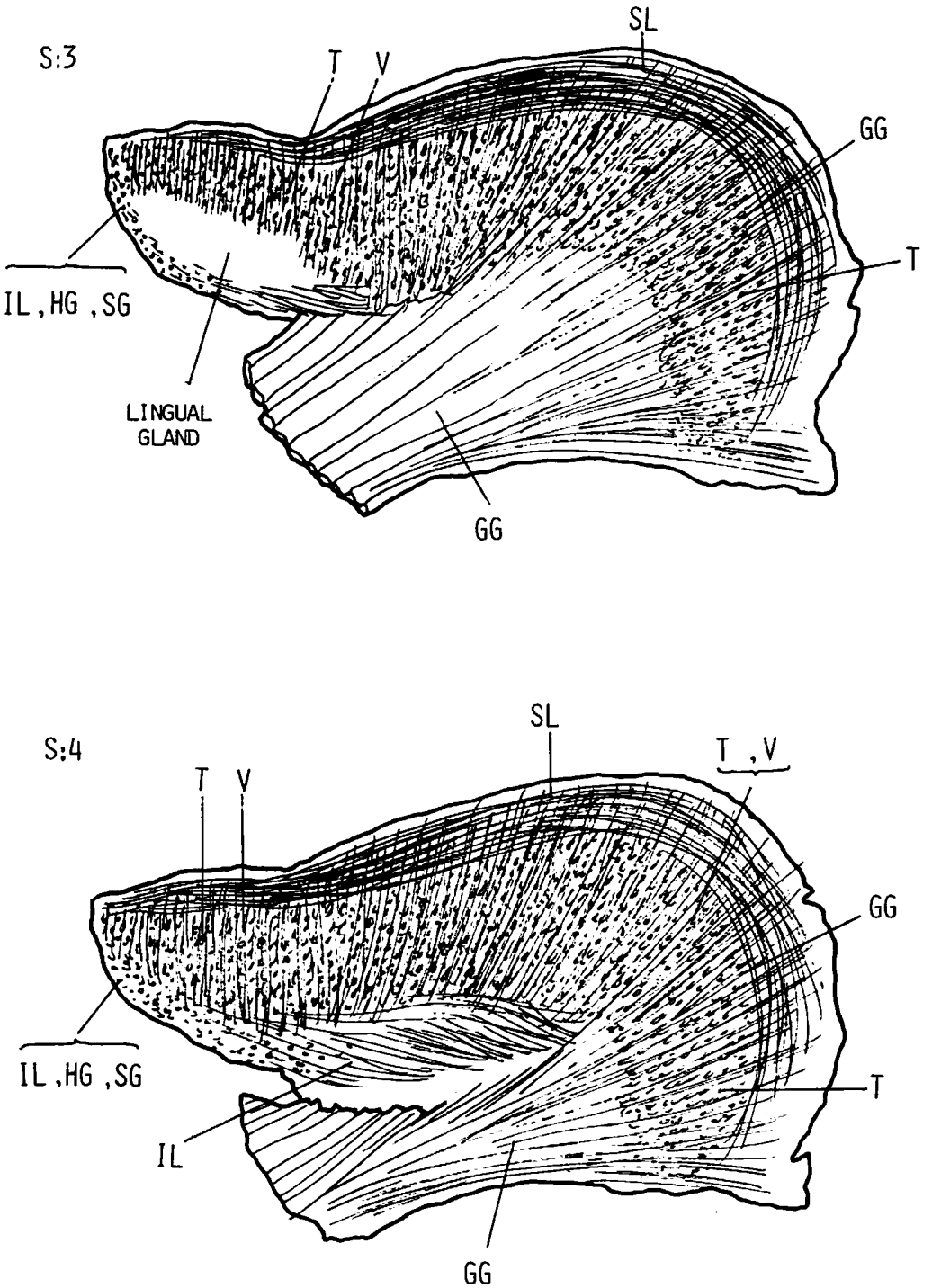
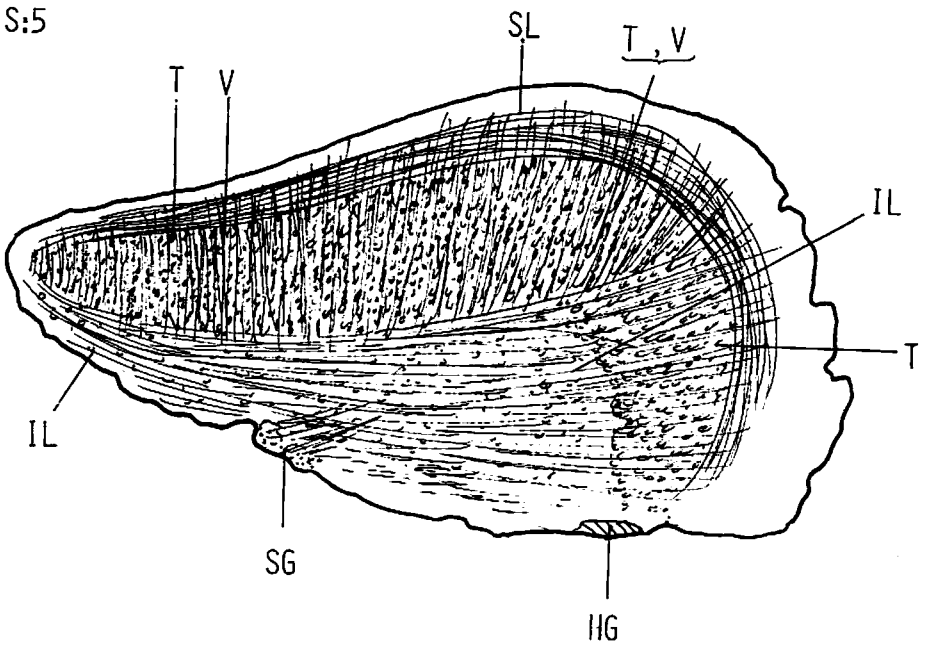


FIG. 4-ii (CONTINUED)



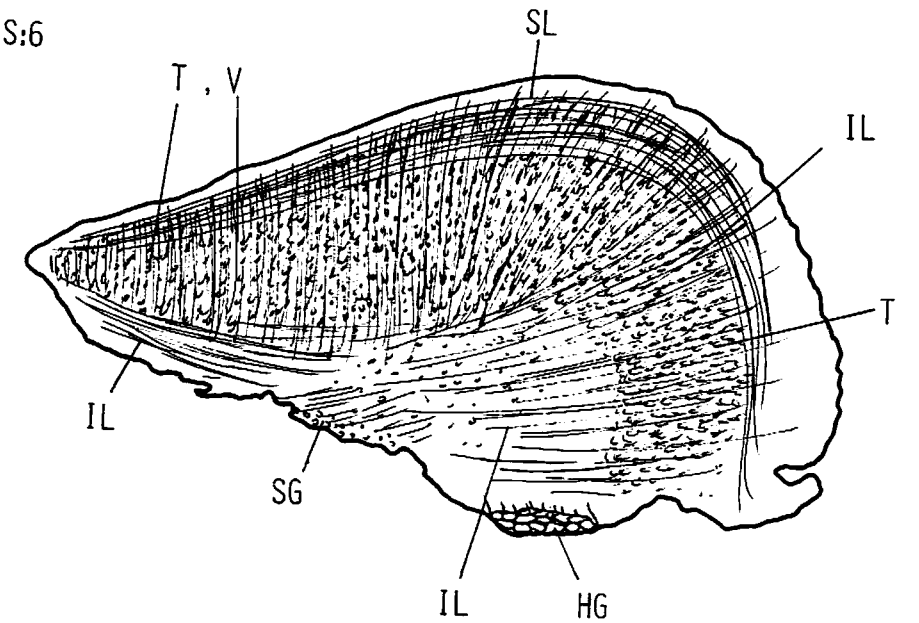


FIG. 4-ii (CONTINUED)

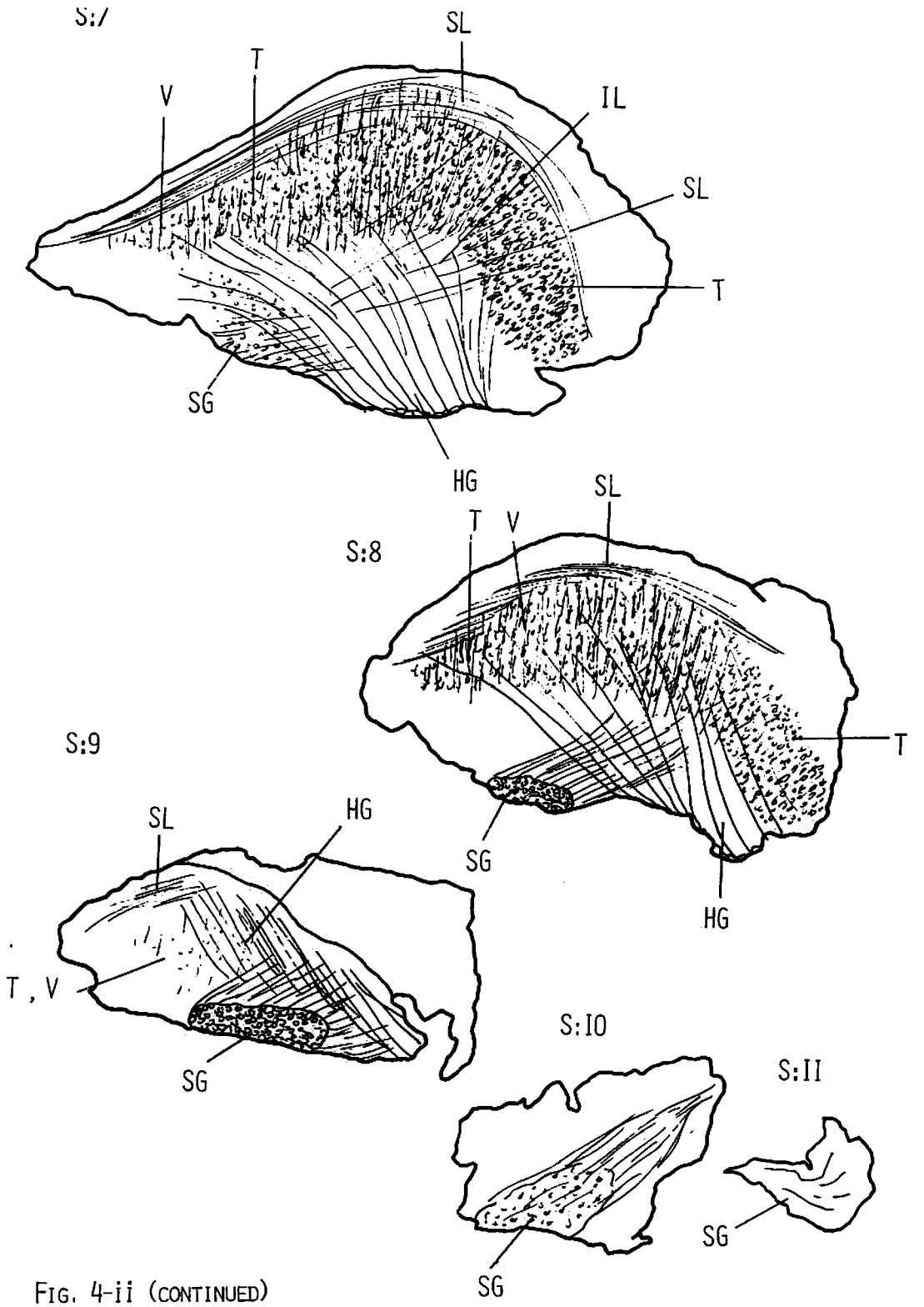


FIG. 4-ii (CONTINUED)

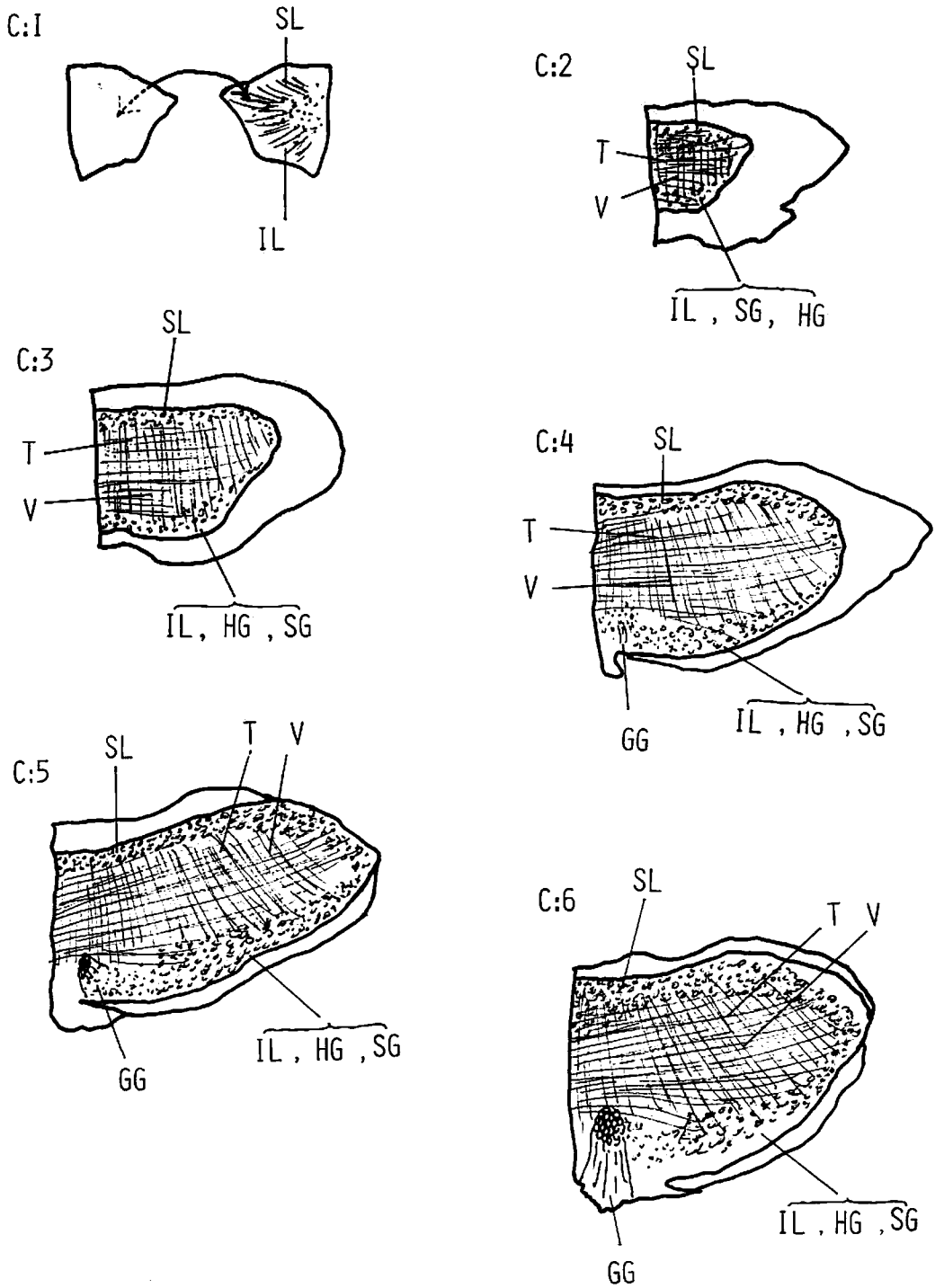


FIG. 4-iii THE CORONAL SECTIONS OF THE LEFT HALF OF A TONGUE WHOSE ORIGINAL SHAPE IS SHOWN IN FIG. 4-i.

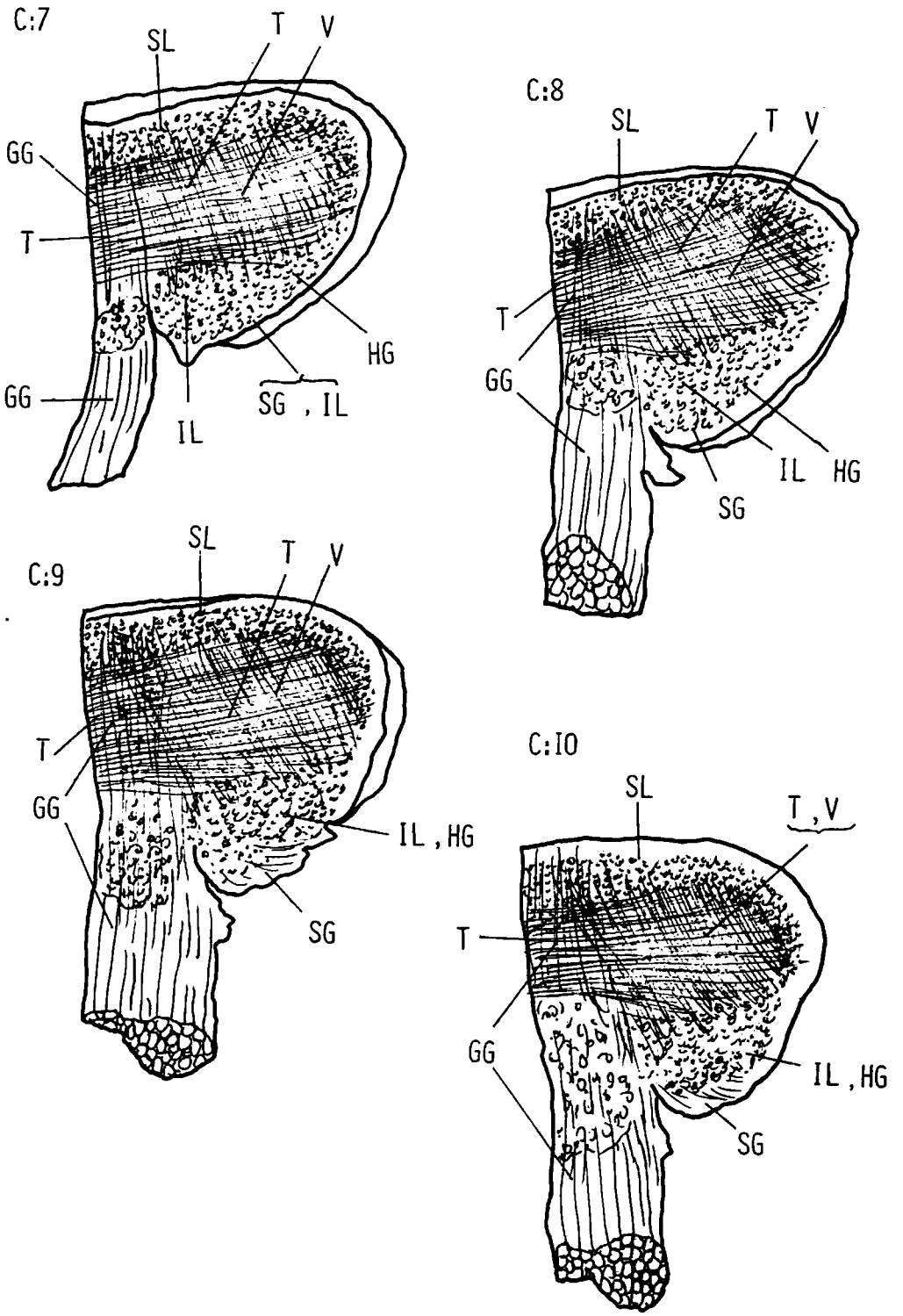


FIG. 4-iii (CONTINUED)

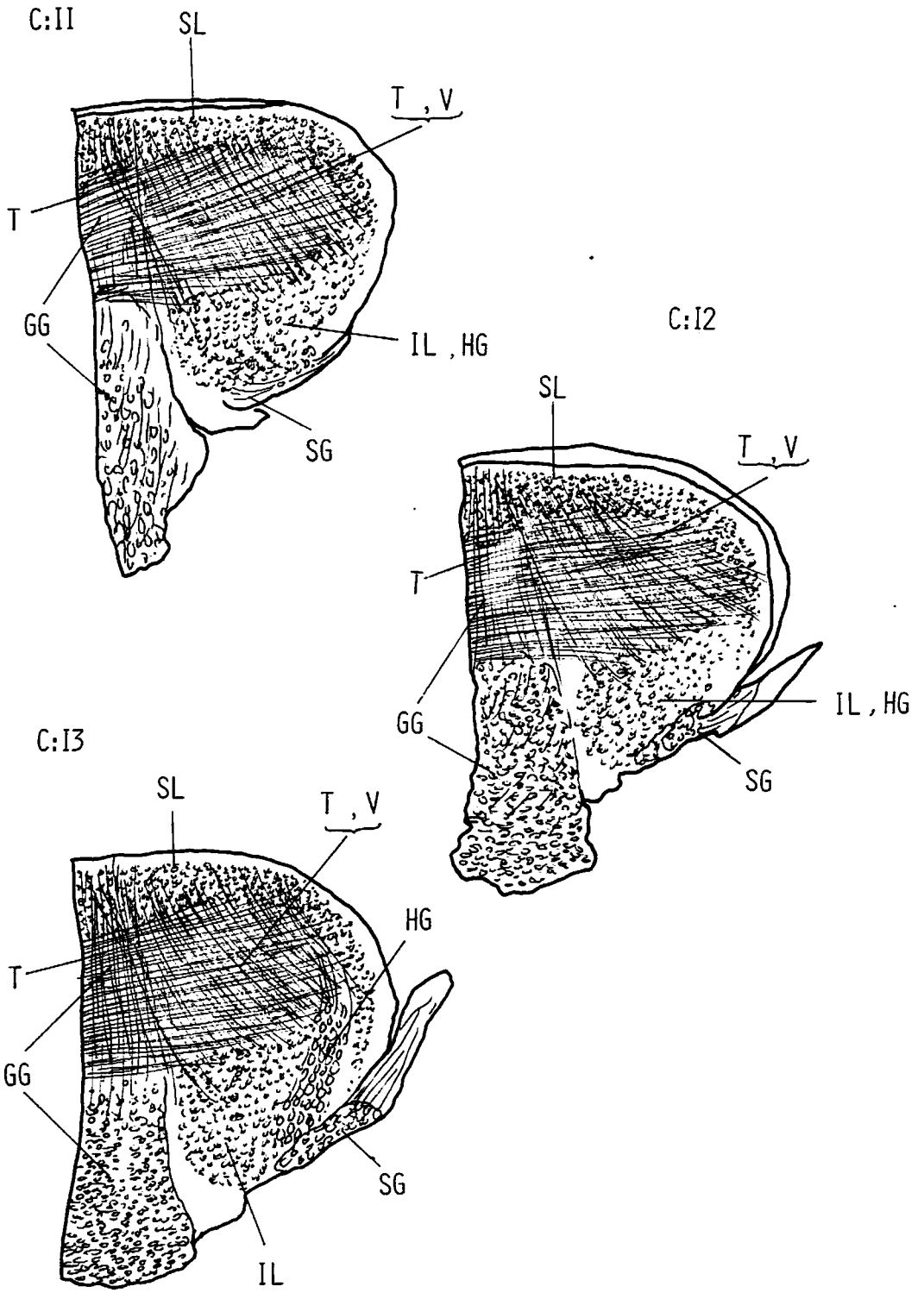


FIG. 4-iii (CONTINUED)

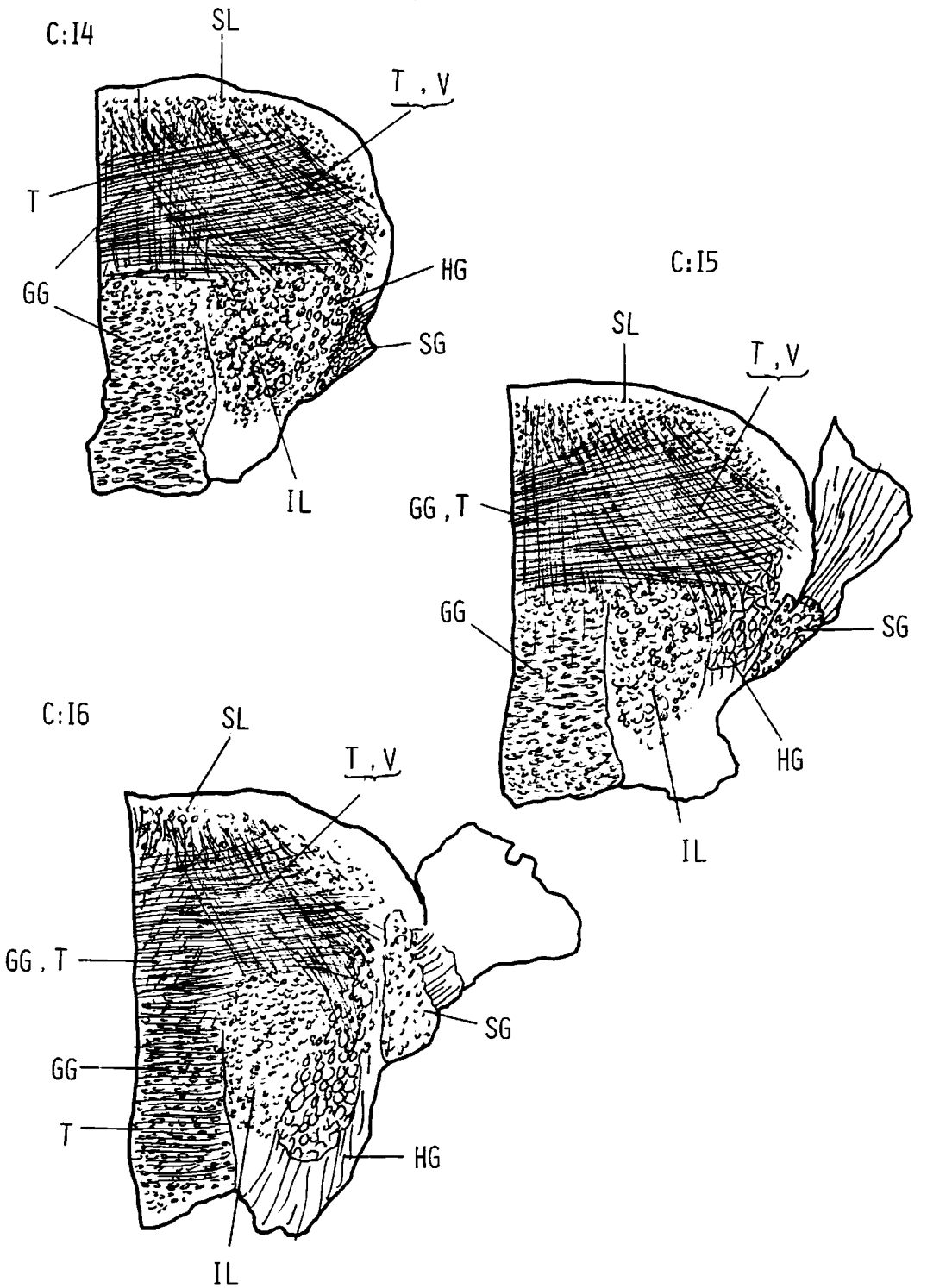


FIG. 4-iii (CONTINUED)

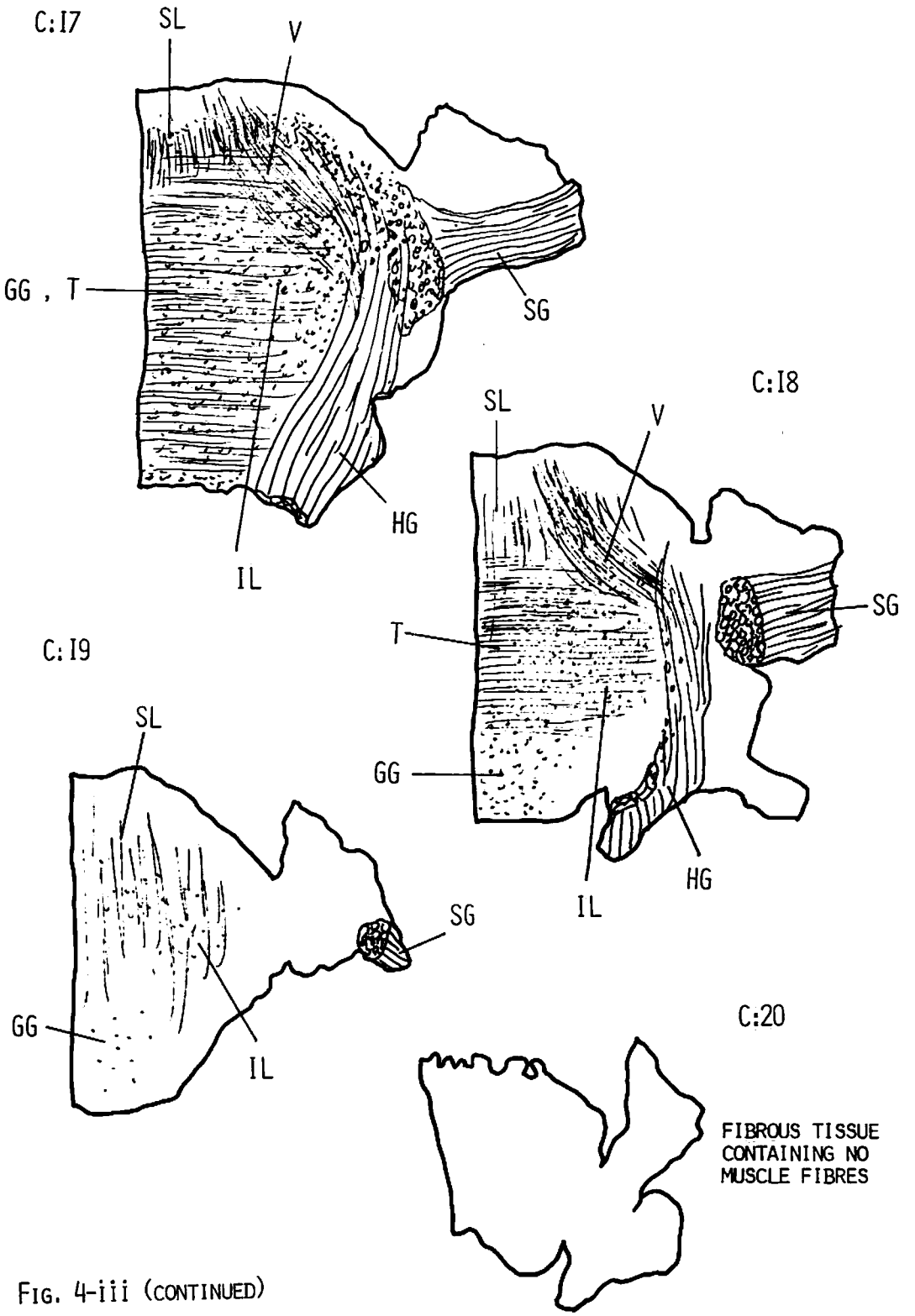


FIG. 4-iii (CONTINUED)

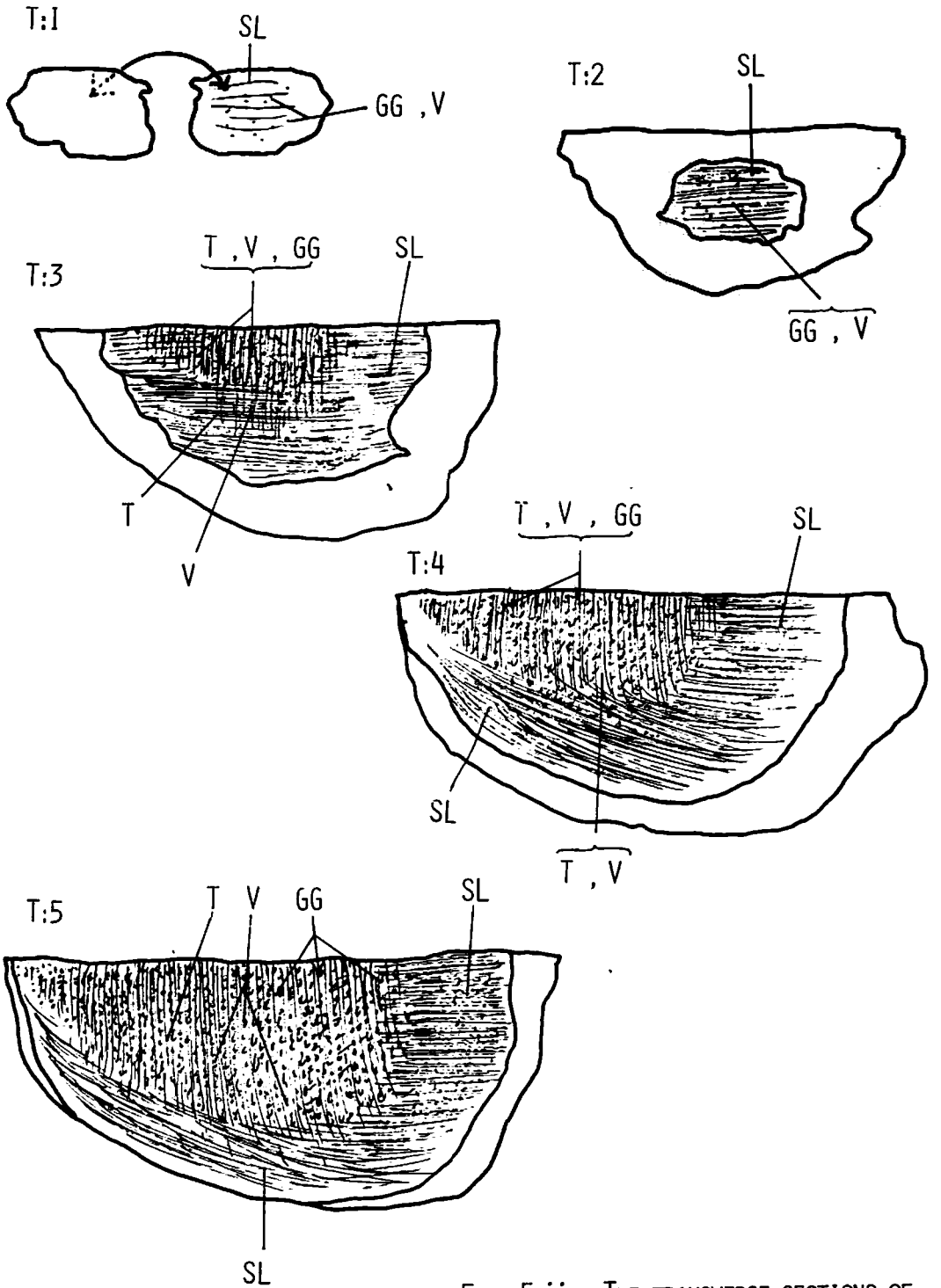


FIG. 5-ii THE TRANSVERSE SECTIONS OF THE LEFT HALF OF A TONGUE WHOSE ORIGINAL SHAPE IS SHOWN IN FIG. 5-i.

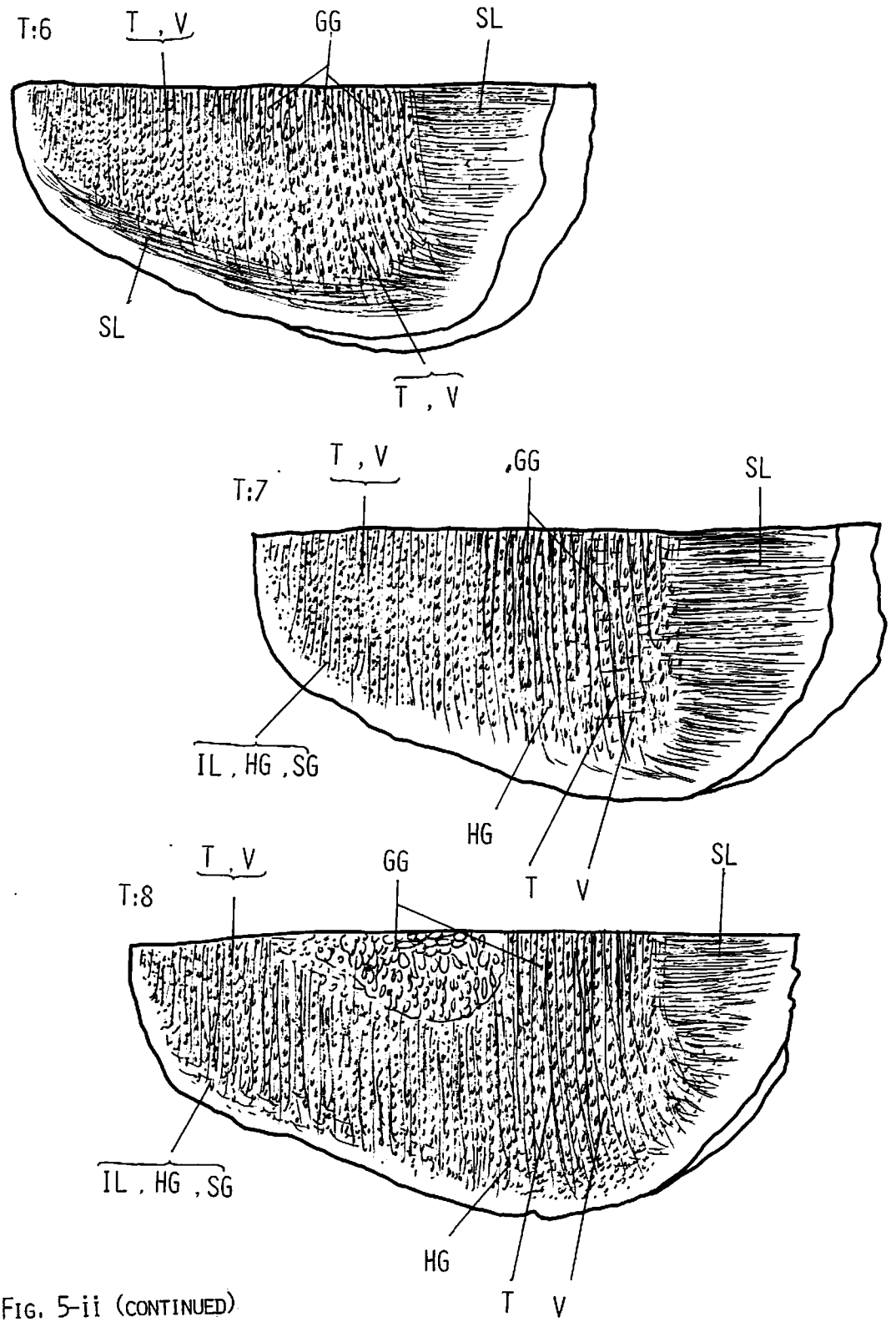


FIG. 5-ii (CONTINUED)

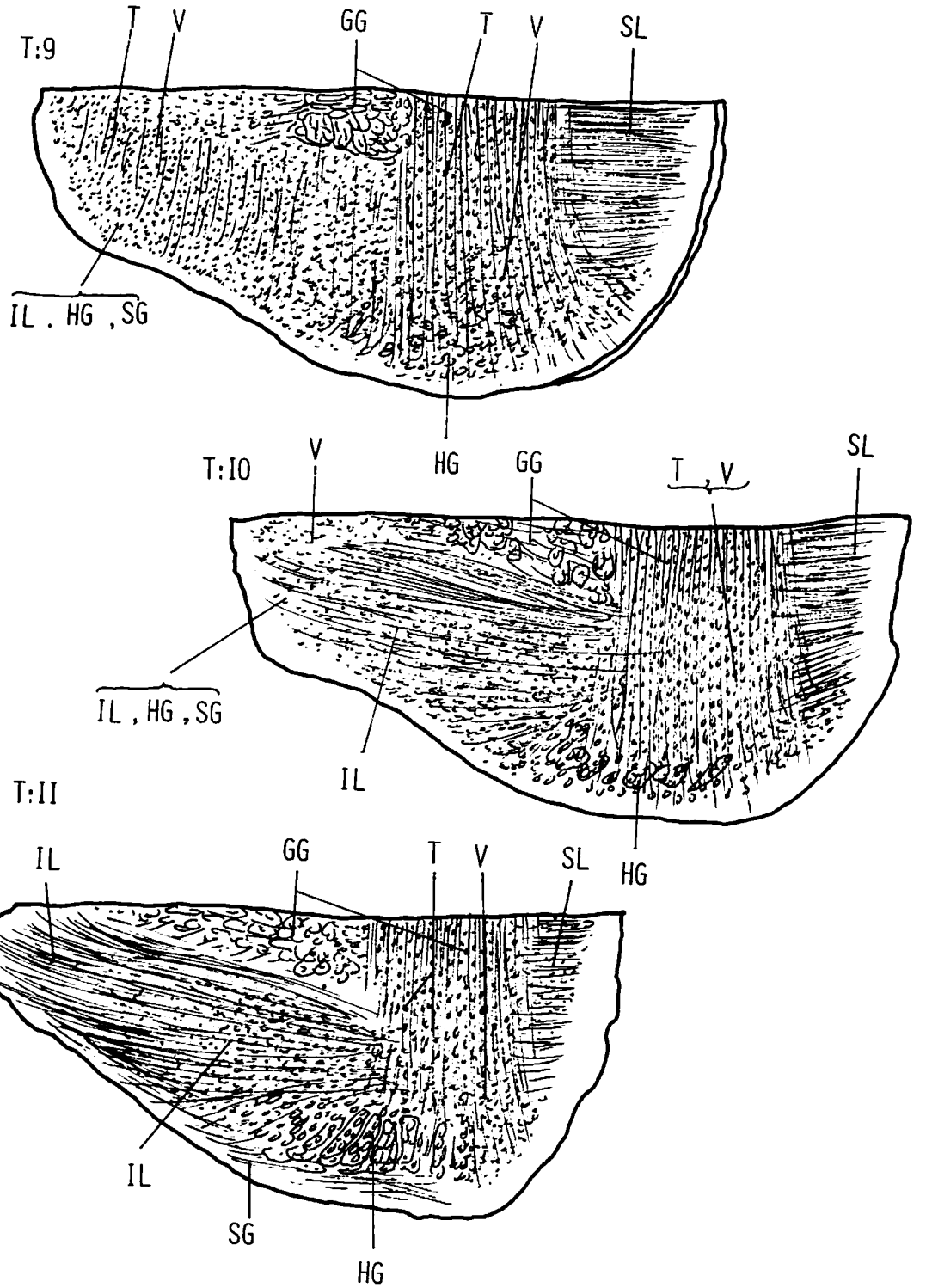


FIG. 5-ii (CONTINUED)

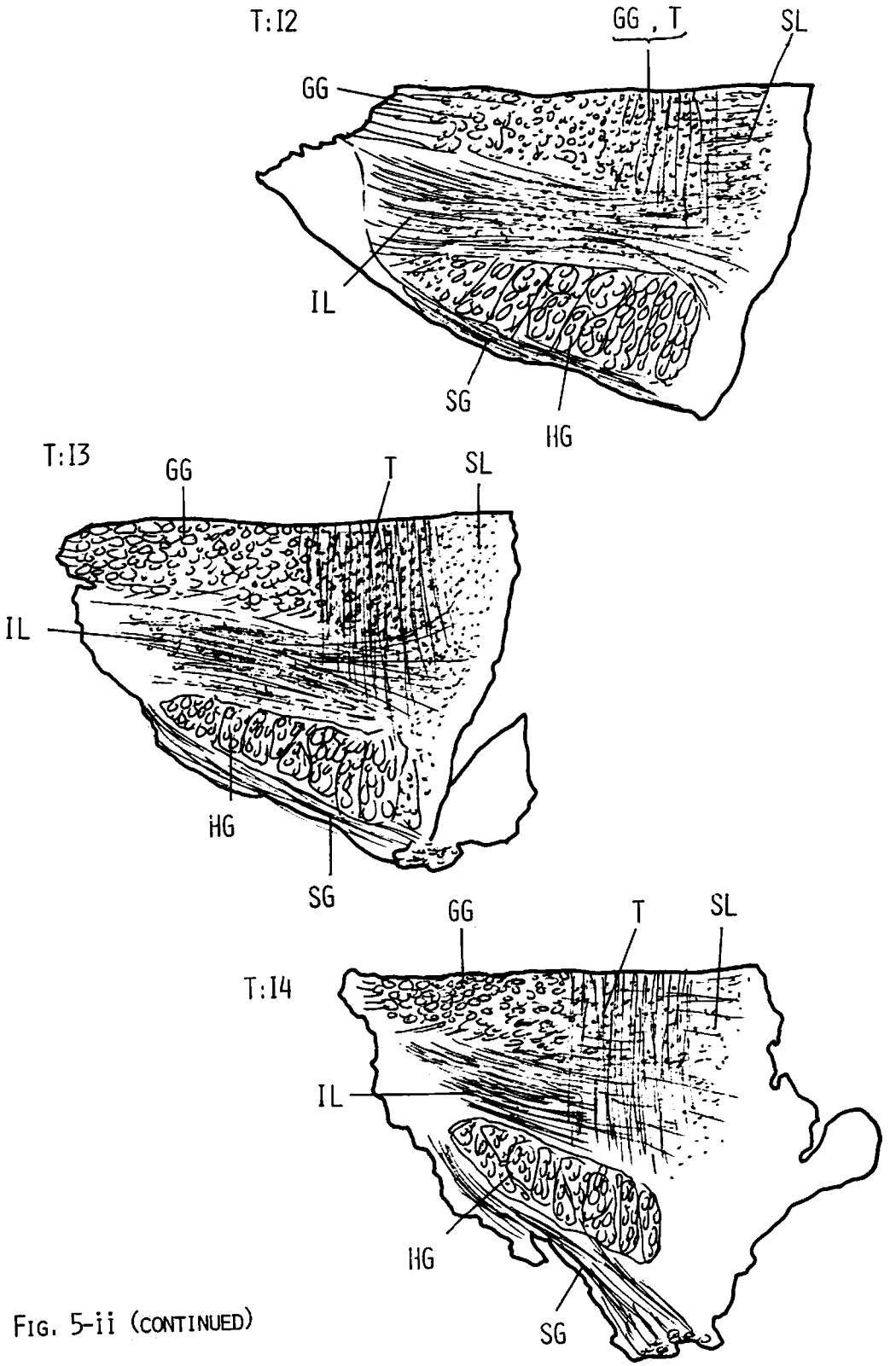


FIG. 5-ii (CONTINUED)

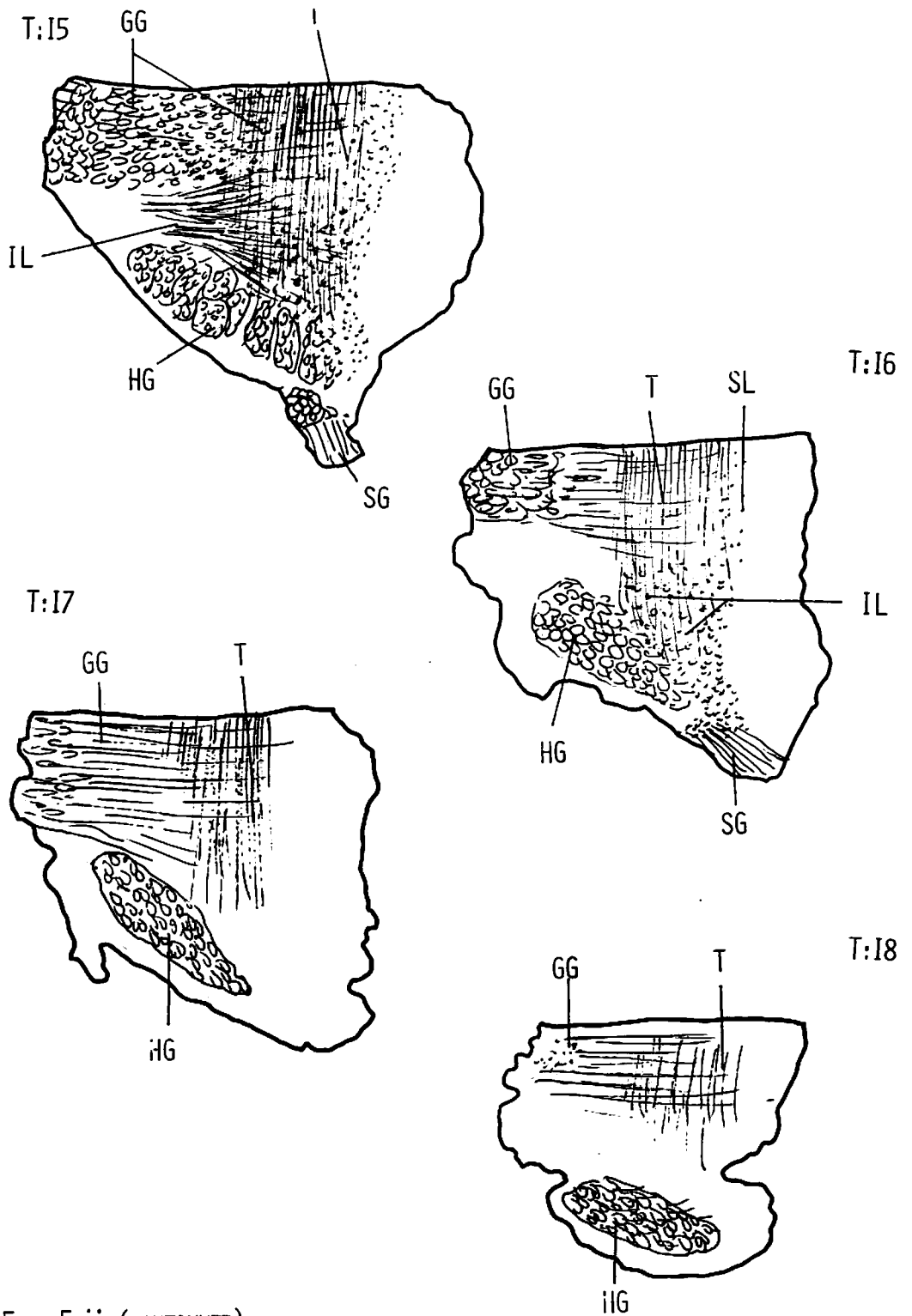


FIG. 5-ii (CONTINUED)

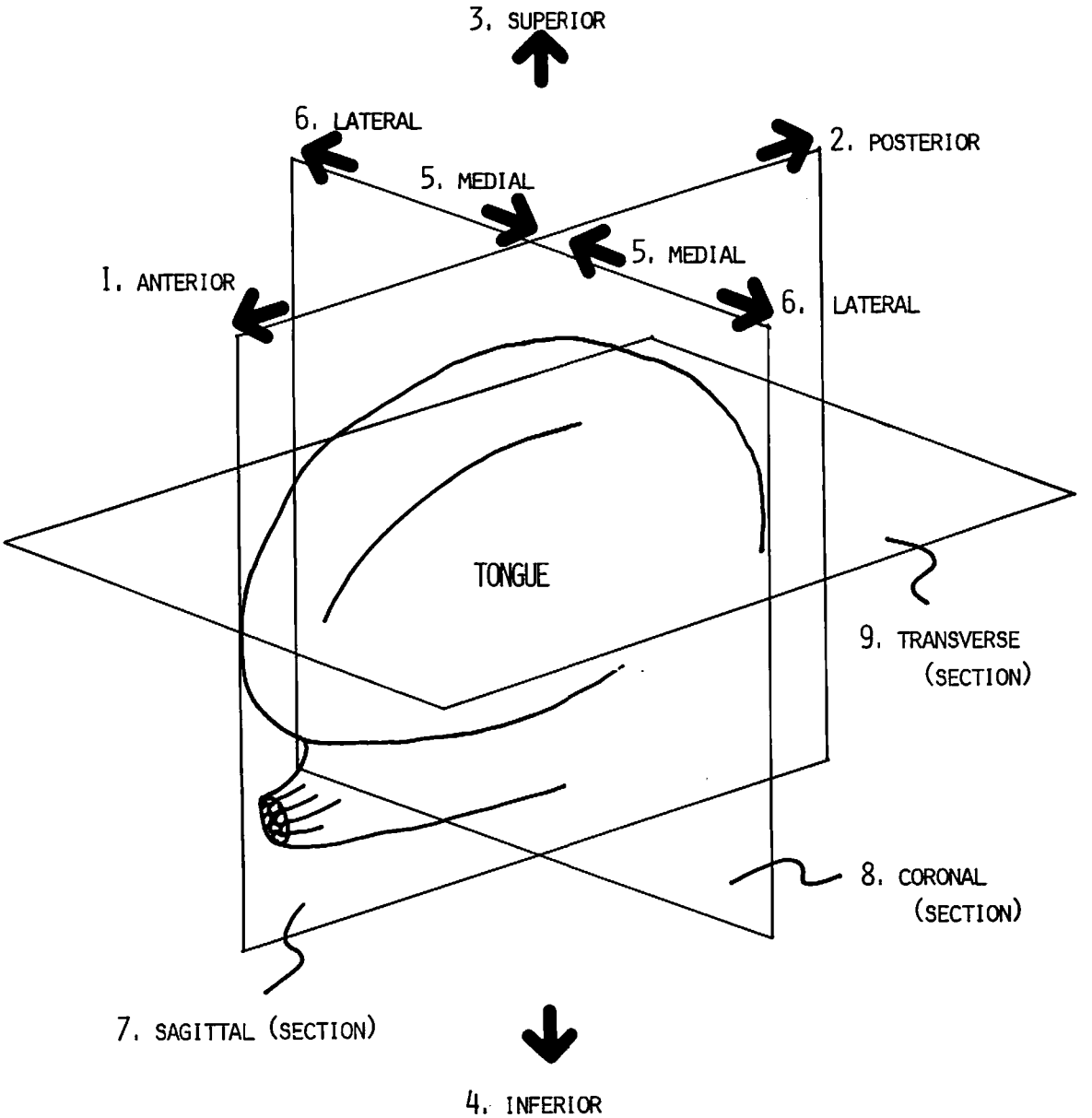


FIG. A TERMS OF LOCATION AND ORIENTATION AS USED IN THIS PAPER.