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THE BRAIN AND THE VOICE IN SPEECH AND SONG

BY

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1910

PREFACE

The contents of this little book formed the subject of three lectures

delivered at the Royal Institution "On the Mechanism of the Human Voice"

and three London University lectures at King's College on "The Brain in

relation to Speech and Song." I have endeavoured to place this subject

before my readers in as simple language as scientific accuracy and

requirements permit. Where I have been obliged to use technical anatomical

and physiological terms I have either explained their meaning in the text,

aided by diagrams and figures, or I have given in brackets the English

equivalents of the terms used.

I trust my attempt to give a sketch of the mechanism of the human voice,

and how it is produced in speech and song, may prove of interest to the

general public, and I even hope that teachers of voice production may find

some of the pages dealing with the brain mechanism not unworthy of their

attention.

F.W. MOTT

LONDON

\_July, 1910\_

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THE BRAIN AND THE VOICE IN SPEECH AND SONG

In the following pages on the Relation of the Brain to the mechanism of the

Voice in Speech and Song, I intend, as far as possible, to explain the

mechanism of the instrument, and what I know regarding the cerebral

mechanism by which the instrument is played upon in the production of the

singing voice and articulate speech. Before, however, passing to consider

in detail the instrument, I will briefly direct your attention to some

facts and theories regarding the origin of speech.

THEORIES ON THE ORIGIN OF SPEECH

The evolutionary theory is thus propounded by Romanes in his "Mental

Evolution in Man," pp. 377-399: "Starting from the highly intelligent and

social species of anthropoid ape as pictured by Darwin, we can imagine that

this animal was accustomed to use its voice freely for the expression of

the emotions, uttering danger signals, and singing. Possibly it may also

have been sufficiently intelligent to use a few imitative sounds; and

certainly sooner or later the receptual life of this social animal must

have advanced far enough to have become comparable with that of an infant

of about two years of age. That is to say, this animal, although not yet

having begun to use articulate signs, must have advanced far enough in the

conventional use of natural signs (a sign with a natural origin in tone and

gesture, whether spontaneously or intentionally imitative) to have admitted

of a totally free exchange of receptual ideas, such as would be concerned

in animal wants and even, perhaps, in the simplest forms of co-operative

action. Next I think it probable that the advance of receptual intelligence

which would have been occasioned by this advance in sign-making would in

turn have led to a development of the latter--the two thus acting and

reacting on each other until the language of tone and gesture became

gradually raised to the level of imperfect pantomime, as in children before

they begin to use words. At this stage, however, or even before it, I think

very probably vowel sounds must have been employed in tone language, if not

also a few consonants. Eventually the action and reaction of receptual

intelligence and conventional sign-making must have ended in so far

developing the former as to have admitted of the breaking up (or

articulation) of vocal sounds, as the only direction in which any

improvement in vocal sign-making was possible." Romanes continues his

sketch by referring to the probability that this important stage in the

development of speech was greatly assisted by the already existing habit of

articulating musical notes, supposing our progenitors to have resembled the

gibbons or the chimpanzees in this respect. Darwin in his great work on the

"Expression of the Emotions" points to the fact that the gibbon, the most

erect and active of the anthropoid apes, is able to sing an octave in

half-tones, and it is interesting to note that Dubois considers his

Pithecanthropus Erectus is on the same stem as the gibbon. But it has

lately been shown that some animals much lower in the scale than monkeys,

namely, rodents, are able to produce correct musical tones. Therefore the

argument loses force that the progenitors of man probably uttered musical

sounds before they had acquired the power of articulate speech, and that

consequently, when the voice is used under any strong emotion, it tends to

assume through the principle of association a musical character. The work

of anthropologists and linguists, especially the former, supports the

progressive-evolution theory, which, briefly stated, is--that articulate

language is the result of an elaboration in the long procession of ages in

which there occurred three stages--the cry, vocalisation, and articulation.

The cry is the primordial, pure animal language; it is a simple vocal

aspiration without articulation; it is either a reflex expressing needs and

emotions, or at a higher stage intentional (to call, warn, menace, etc.).

Vocalisation (emission of vowels) is a natural production of the vocal

instrument, and does not in itself contain the essential elements of

speech. Many animals are capable of vocalisation, and in the child the

utterance of vowel sounds is the next stage after the cry.

The conditions necessary to the existence of speech arose with

articulation, and it is intelligence that has converted the vocal

instrument into the speaking instrument. For whereas correct intonation

depends upon the innate musical ear, which is able to control and regulate

the tensions of the minute muscles acting upon the vocal cords, it is

intelligence which alters and changes the form of the resonator by means of

movement of the lips, tongue, and jaw in the production of articulate

speech. The simple musical instrument in the production of phonation is

bilaterally represented in the brain, but as a speaking instrument it is

unilaterally represented in right-handed individuals in the left hemisphere

and in left-handed individuals in the right hemisphere. The reason for this

we shall consider later; but the fact supports Darwin's hypothesis.

Another hypothesis which was brought forward by Grieger and supported by

some authors is summarised by Ribot as follows: "Words are an imitation of

the movements of the mouth. The predominant sense in man is that of sight;

man is pre-eminently visual. Prior to the acquisition of speech he

communicated with his fellows by the aid of gestures and movement of the

mouth and face; he appealed to their eyes. Their facial 'grimaces,'

fulfilled and elucidated by gesture, became signs for others; they fixed

their attention upon them. When articulate sounds came into being, these

lent themselves to a more or less conventional language by reason of their

acquired importance." For support of this hypothesis the case of

non-educated deaf-mutes is cited. They invent articulate sounds which they

cannot hear and use them to designate certain things. Moreover, they employ

gesture language--a language which is universally understood.

Another theory of the origin of the speaking voice is that speech is an

instinct not evolved, but breaking forth spontaneously in man; but even if

this be so, it was originally so inadequate and weak that it required

support from the gesture language to become intelligible. This mixed

language still survives among some of the inferior races of men. Miss

Kingsley and Tylor have pointed out that tribes in Africa have to gather

round the camp fires at night in order to converse, because their

vocabulary is so incomplete that without being reinforced by gesture and

pantomime they would be unable to communicate with one another. Gesture is

indispensable for giving precision to vocal sounds in many languages, e.g.

those of the Tasmanians, Greenlanders, savage tribes of Brazil, and Grebos

of Western Africa. In other cases speech is associated with inarticulate

sounds. These sounds have been compared to clicking and clapping, and

according to Sayce, these clickings and clappings survive as though to show

us how man when deprived of speech can fix and transmit his thoughts by

certain sounds. These mixed states represent articulate speech in its

primordial state; they represent the stage of transition from pure

pantomime to articulate speech.

It seems, then, that originally man had two languages at his disposal which

he used simultaneously or interchangeably. They supported each other in the

intercommunication of ideas, but speech has triumphed because of its

greater practical utility. The language of gesture is disadvantageous for

the following reasons: (1) it monopolises the use of the hands; (2) it has

the disadvantage that it does not carry any distance; (3) it is useless in

the dark; (4) it is vague in character; (5) it is imitative in nature and

permits only of the intercommunication of ideas based upon concrete images.

Speech, on the other hand, is transmitted in the dark and with objects

intervening; moreover, distance affects its transmission much less. The

images of auditory and visual symbols in the growth of speech replace in

our minds concrete images and they permit of abstract thought. It is

dependent primarily upon the ear, an organ of exquisite feeling, whose

sensations are infinite in number and in kind. This sensory receptor with

its cerebral perceptor has in the long process of time, aided by vision,

under the influence of natural laws of the survival of the fittest,

educated and developed an instrument of simple construction (primarily

adapted only for the vegetative functions of life and simple vocalisation)

into that wonderful instrument the human voice; but by that development,

borrowing the words of Huxley, "man has slowly accumulated and organised

the experience which is almost wholly lost with the cessation of every

individual life in other animals; so that now he stands raised as upon a

mountain-top, far above the level of his humble fellows, and transfigured

from his grosser nature by reflecting here and there a ray from the

infinite source of truth." Thought in all the higher mental processes could

not be carried on at all without the aid of language.

Written language probably originated in an analytical process analogous to

the language of gesture. Like that, it: (1) isolates terms; (2) arranges

them in a certain order; (3) translates thoughts in a crude and somewhat

vague form. A curious example of this may be found in Max Müller's "Chips

from a German Workshop," XIV.: "The aborigines of the Caroline Islands sent

a letter to a Spanish captain as follows: A man with extended arms, sign of

greeting; below to the left, the objects they have to barter--five big

shells, seven little ones, three others of different forms; to the right,

drawing of the objects they wanted in exchange--three large fish-hooks,

four small ones, two axes, two pieces of iron."

Language of graphic signs and spoken language have progressed together, and

simultaneously supported each other in the development of the higher mental

faculties that differentiate the savage from the brute and the civilised

human being from the savage. In spoken language, at any rate, it is not the

vocal instrument that has been changed, but the organ of mind with its

innate and invisible molecular potentialities, the result of racial and

ancestral experiences in past ages. Completely developed languages when

studied from the point of view of their evolution are stamped with the

print of an unconscious labour that has been fashioning them for centuries.

A little consideration and reflection upon words which have been coined in

our own time shows that language offers an abstract and brief chronicle of

social psychology.

Articulate language has converted the vocal instrument into the chief agent

of the will, but the brain in the process of time has developed by the

movements of the lips, tongue, jaw, and soft palate a kinæsthetic[A] sense

of articulate speech, which has been integrated and associated in the mind

with rhythmical modulated sounds conveyed to the brain by the auditory

nerves. There has thus been a reciprocal simultaneity in the development of

these two senses by which the mental ideas of spoken words are memorised

and recalled. Had man been limited to articulate speech he could not have

made the immense progress he has made in the development of complex mental

processes, for language, by using written verbal symbols, has allowed, not

merely the transmission of thought from one individual to another, but the

thoughts of the world, past and present, are in a certain measure at the

disposal of every individual. With this introduction to the subject I will

pass on to give a detailed description of the instrument of the voice.

[Footnote A: Sense of movement.]

THE VOCAL INSTRUMENT

A distinction is generally made in physics between sound and noise. Noise

affects our tympanic membrane as an irregular succession of shocks and we

are conscious of a jarring of the auditory apparatus; whereas a musical

sound is smooth and pleasant because the tympanic membrane is thrown into

successive periodic vibrations to which the auditory receptor (sense organ

of hearing) has been attuned. To produce musical sounds, a body must

vibrate with the regularity of a pendulum, but it must be capable of

imparting sharper or quicker shocks to the air than the pendulum. All

musical sounds, however they are produced and by whatever means they are

propagated, may be distinguished by three different qualities:

(1) Loudness, (2) Pitch, (3) Quality, timbre or klang, as the Germans call

it.

Loudness depends upon the amount of energy expended in producing the sound.

If I rub a tuning-fork with a well-rosined bow, I set it in vibration by

the resistance offered to the rosined hair; and if while it is vibrating I

again apply the bow, thus expending more energy, the note produced is

louder. Repeating the action several times, the width of excursion of the

prongs of the tuning-fork is increased. This I can demonstrate, not merely

by the loudness of the sound which can be heard, but by sight; for if a

small mirror be fixed on one of the prongs and a beam of light be cast upon

the mirror, the light being again reflected on to the screen, you will see

the spot of light dance up and down, and the more energetically the

tuning-fork is bowed the greater is the amplitude of the oscillation of the

spot of light. The duration of the time occupied is the same in traversing

a longer as in traversing a shorter space, as is the case of the swinging

pendulum. The vibrating prongs of the tuning-fork throw the air into

vibrations which are conveyed to the ear and produce the sensation of

sound. The duration of time occupied in the vibrations of the tuning-fork

is therefore independent of the space passed over. The greater or less

energy expended does not influence the duration of time occupied by the

vibration; it only influences the amplitude of the vibration.

The second quality of musical sounds is the pitch, and the pitch depends

upon the number of vibrations that a sounding body makes in each second of

time. The most unmusical ear can distinguish a high note from a low one,

even when the interval is not great. Low notes are characterised by a

relatively small number of vibrations, and as the pitch rises so the number

of vibrations increase. This can be proved in many ways. Take, for example,

two tuning-forks of different size: the shorter produces a considerably

higher pitched note than the longer one. If a mirror be attached to one of

the prongs of each fork, and a beam of light be cast upon each mirror

successively and then reflected in a revolving mirror, the oscillating spot

of light is converted into a series of waves; and if the waves obtained by

reflecting the light from the mirror of the smaller one be counted and

compared with those reflected from the mirror attached to the larger fork,

it will be found that the number of waves reflected from the smaller fork

is proportionally to the difference in the pitch more numerous than the

waves reflected from the larger. The air is thrown into corresponding

periodic vibrations according to the rate of vibration of the

sound-producing body.

Thirdly, the quality, timbre, or klang depends upon the overtones, in

respect to which I could cite many experiments to prove that whenever a

body vibrates, other bodies near it may be set in vibration, but only on

condition that such bodies shall be capable themselves of producing the

same note. A number of different forms of resonators can be used to

illustrate this law; a law indeed which is of the greatest importance in

connection with the mechanism of the human voice. Although notes are of the

same loudness and pitch when played on different instruments or spoken or

sung by different individuals, yet even a person with no ear for music can

easily detect a difference in the quality of the sound and is able to

recognise the nature of the instrument or the timbre of the voice. This

difference in the timbre is due to harmonics or overtones. Could we but see

the sonorous waves in the air during the transmission of the sound of a

voice, we should see stamped on it the conditions of motion upon which its

characteristic qualities depended; which is due to the fact that every

vocal sound whose vibrations have a complex form can be decomposed into a

series of simple notes all belonging to the harmonic series. These

harmonics or overtones will be considered later when dealing with the

timbre or quality of the human voice.

The vocal instrument is unlike any other musical instrument; it most nearly

approaches a reed instrument. The clarionet and the oboe are examples of

reed instruments, in which the reed does not alter but by means of stops

the length of the column of air in the resonating pipe varies and

determines the pitch of the fundamental note. The organ-pipe with the

vibrating tongue of metal serving as the reed is perhaps the nearest

approach to the vocal organ; but here again it is the length of the pipe

which determines the pitch of the note.

The vocal instrument may be said to consist of three parts: (1) the

bellows; (2) the membranous reed contained in the larynx, which by the

actions of groups of muscles can be altered in tension and thus variation

in pitch determined; (3) the resonator, which consists of the mouth, the

throat, the larynx, the nose, and air sinuses contained in the bones of the

skull, also the windpipe, the bronchial tubes, and the lungs. The main and

important part of the resonator, however, is situated above the glottis

(the opening between the vocal cords, \_vide\_ fig. 6), and it is capable of

only slight variations in length and of many and important variations in

form. In the production of musical sounds its chief influence is upon the

quality of the overtones and therefore upon the timbre of the voice;

moreover, the movable structures of the resonator, the lower jaw, the lips,

the tongue, the soft palate, can, by changing the form of the resonator,

not only impress upon the sound waves particular overtones as they issue

from the mouth, but simultaneously can effect the combination of vowels and

consonants with the formation of syllables, the combination of syllables

with the formation of words, and the combination of words with the

formation of articulate language. The reed portion of the instrument acting

alone can only express emotional feeling; the resonator, the effector of

articulate speech, is the instrument of intelligence, will, and feeling. It

must not, however, be thought that the vocal instrument consists of two

separately usable parts, for phonation (except in the whispered voice)

always accompanies articulation.

In speech, and more especially in singing, there is an art of breathing.

Ordinary inspiration and expiration necessary for the oxygenation of the

blood is performed automatically and unconsciously. But in singing the

respiratory apparatus is used like the bellows of a musical instrument, and

it is controlled and directed by the will; the art of breathing properly is

fundamental for the proper production of the singing voice and the speaking

voice of the orator. It is necessary always to maintain in the lungs, which

act as the bellows, a sufficient reserve of air to finish a phrase;

therefore when the opportunity arises it is desirable to take in as much

air as possible through the nostrils, and without any apparent effort; the

expenditure of the air in the lungs must be controlled and regulated by the

power of the will in such a manner as to produce efficiency in loudness

with economy of expenditure. It must be remembered, moreover, that mere

loudness of sound does not necessarily imply carrying power of the voice,

either when speaking or singing. Carrying power, as we shall see later,

depends as much upon the proper use of the resonator as upon the force of

expulsion of the air by the bellows. Again, a soft note, especially an

aspirate, owing to the vocal chink being widely opened, may be the cause of

an expenditure of a larger amount of air than a loud-sounding note.

Observations upon anencephalous monsters (infants born without the great

brain) show that breathing and crying can occur without the cerebral

hemispheres; moreover, Goltz's dog, in which all the brain had been removed

except the stem and base, was able to bark, growl, and snarl, indicating

that the primitive function of the vocal instrument can be performed by the

lower centres of the brain situated in the medulla oblongata. But the

animal growled and barked when the attendant, who fed it daily, approached

to give it food, which was a clear indication that the bark and growl had

lost both its affective and cognitive significance; it was, indeed, a

purely automatic reflex action. It was dependent upon a stimulus arousing

an excitation in an instinctive automatic nervous mechanism in the medulla

oblongata and spinal cord presiding over synergic groups of muscles

habitually brought into action for this simplest form of vocalisation,

connected with the primitive emotion of anger.

I will now consider at greater length each part of the vocal instrument.

I. THE BELLOWS

[Illustration: Fig 1]

[Description: FIG. 1.--Front view of the thorax showing the breastbone, to

which on either side are attached the (shaded) rib cartilages. The

remainder of the thoracic cage is formed by the ribs attached behind to the

spine, which is only seen below. The lungs are represented filling the

chest cavity, except a little to the left of the breastbone, below where

the pericardium is shown (black). It can be seen that the ribs slope

forwards and downwards, and that they increase in length from above

downwards, so that if elevated by the muscles attached to them, they will

tend to push forward the elastic cartilages and breastbone and so increase

the antero-posterior diameter of the chest; moreover, the ribs being

elastic will tend to give a little at the angle, and so the lateral

diameter of the chest will be increased.]

The bellows consists of the lungs enclosed in the movable thorax. The

latter may be likened to a cage; it is formed by the spine behind and the

ribs, which are attached by cartilages to the breastbone (sternum) in front

(\_vide\_ fig. 1). The ribs and cartilages, as the diagram shows, form a

series of hoops which increase in length from above downwards; moreover,

they slope obliquely downwards and inwards (\_vide\_ fig. 2). The ribs are

jointed behind to the vertebrae in such a way that muscles attached to them

can, by shortening, elevate them; the effect is that the longer ribs are

raised, and pushing forward the breastbone and cartilages, the thoracic

cage enlarges from before back; but being elastic, the hoops will give a

little and cause some expansion from side to side; moreover, when the ribs

are raised, each one is rotated on its axis in such a way that the lower

border tends towards eversion; the total effect of this rotation is a

lateral expansion of the whole thorax. Between the ribs and the cartilages

the space is filled by the intercostal muscles (\_vide\_ fig. 2), the action

of which, in conjunction with other muscles, is to elevate the ribs. It is,

however, unnecessary to enter into anatomical details, and describe all

those muscles which elevate and rotate the ribs, and thereby cause

enlargement of the thorax in its antero-posterior and lateral diameters.

There is, however, one muscle which forms the floor of the thoracic cage

called the diaphragm that requires more than a passing notice (\_vide\_ fig.

2), inasmuch as it is the most effective agent in the expansion of the

chest. It consists of a central tendinous portion, above which lies the

heart, contained in its bag or pericardium; on either side attached to the

central tendon on the one hand and to the spine behind, to the last rib

laterally, and to the cartilages of the lowest six ribs anteriorly, is a

sheet of muscle fibres which form on either side of the chest a dome-like

partition between the lungs and the abdominal cavity (\_vide\_ fig. 2). The

phrenic nerve arises from the spinal cord in the upper cervical region and

descends through the neck and chest to the diaphragm; it is therefore a

special nerve of respiration. There are two--one on each side supplying the

two sheets of muscle fibres. When innervation currents flow down these

nerves the two muscular halves of the diaphragm contract, and the floor of

the chest on either side descends; thus the vertical diameter increases.

Now the elastic lungs are covered with a smooth pleura which is reflected

from them on to the inner side of the wall of the thorax, leaving no space

between; consequently when the chest expands in all three directions the

elastic lungs expand correspondingly. But when either voluntarily or

automatically the nerve currents that cause contraction of the muscles of

expansion cease, the elastic structures of the lungs and thorax, including

the muscles, recoil, the diaphragm ascends, and the ribs by the force of

gravity tend to fall into the position of rest. During expansion of the

chest a negative pressure is established in the air passages and air flows

into them from without. In contraction of the chest there is a positive

pressure in the air passages, and air is expelled; in normal quiet

breathing an ebb and flow of air takes place rhythmically and

subconsciously; thus in the ordinary speaking of conversation we do not

require to exercise any voluntary effort in controlling the breathing, but

the orator and more especially the singer uses his knowledge and experience

in the voluntary control of his breath, and he is thus enabled to use his

vocal instrument in the most effective manner.

[Illustration: FIG. 2

Adapted from Quain's "Anatomy" by permission of Messrs. Longmans, Green &

Co.]

[Description: FIG. 2.--Diagram modified from Quain's "Anatomy" to show the

attachment of the diaphragm by fleshy pillars to the spinal column, to the

rib cartilages, and lower end of the breastbone and last rib. The muscular

fibres, intercostals, and elevators of the ribs are seen, and it will be

observed that their action would be to rotate and elevate the ribs. The

dome-like shape of the diaphragm is seen, and it can be easily understood

that if the central tendon is fixed and the sheet of muscle fibres on

either side contracts, the floor of the chest on either side will flatten,

allowing the lungs to expand vertically. The joints of the ribs with the

spine can be seen, and the slope of the surface of the ribs is shown, so

that when elevation and rotation occur the chest will be increased in

diameter laterally.]

[Illustration: FIG 3]

[Description: FIG 3.--Diagram after Barth to illustrate the changes in the

diaphragm, the chest, and abdomen in ordinary inspiration \_b-b\_', and

expiration \_a-a\_', and in voluntary inspiration \_d-d\_' and expiration

\_c-c\_', for vocalisation In normal breathing the position of the chest and

abdomen in inspiration and expiration is represented respectively by the

lines \_b\_ and \_a\_; the position of the diaphragm is represented by \_b\_' and

\_a\_'. In breathing for vocalisation the position of the chest and abdomen

is represented by the lines \_d\_ and \_e\_, and the diaphragm by \_d\_' and

\_c\_'; it will be observed that in voluntary costal breathing \_d-d\_ the

expansion of the chest is much greater and also the diaphragm \_d\_' sinks

deeper, but by the contraction of the abdominal muscles the protrusion of

the belly wall \_d\_ is much less than in normal breathing \_b\_.]

A glance at the diagram (fig. 3) shows the changes in the shape of the

thorax in normal subconscious automatic breathing, and the changes in the

voluntary conscious breathing of vocalisation. It will be observed that

there are marked differences: when voluntary control is exercised, the

expansion of the chest is greater in all directions; moreover, by voluntary

conscious effort the contraction of the chest is much greater in all

directions; the result is that a larger amount of air can be taken into the

bellows and a larger amount expelled. The mind can therefore bring into

play at will more muscular forces, and so control and regulate those forces

as to produce infinite variations in the pressure of the air in the

sound-pipe of the vocal instrument. But the forces which tend to contract

the chest and drive the air out of the lungs would be ineffective if there

were not simultaneously the power of closing the sound-pipe; this we shall

see is accomplished by the synergic action of the muscles which make tense

and approximate the vocal cords. Although the elastic recoil of the lungs

and the structure of the expanded thorax is the main force employed in

normal breathing and to some extent in vocalisation (for it keeps up a

constant steady pressure), the mind, by exercising control over the

continuance of elevation of the ribs and contraction of the abdominal

muscles, regulates the force of the expiratory blast of air so as to employ

the bellows most efficiently in vocalisation. Not only does the contraction

of the abdominal muscles permit of control over the expulsion of the air,

but by fixing the cartilages of the lowest six ribs it prevents the

diaphragm drawing them upwards and \_inwards\_ (\_vide\_ fig. 2). The greatest

expansion is just above the waistband (\_vide\_ fig. 3). We are not conscious

of the contraction of the diaphragm; we are conscious of the position of

the walls of the chest and abdomen; the messages the mind receives relating

to the amount of air in the bellows at our disposal come from sensations

derived from the structures forming the wall of the chest and abdomen, viz.

the position of the ribs, their degree of elevation and forward protrusion

combined with the feeling that the ribs are falling back into the position

of rest; besides there is the feeling that the abdominal muscles can

contract no more--a feeling which should never be allowed to arise before

we become conscious of the necessity of replenishing the supply of air.

This should be effected by quickly drawing in air through the nostrils

without apparent effort and to as full extent as opportunity offers between

the phrases. By intelligence and perseverance the guiding sense which

informs the singer of the amount of air at his disposal, and when and how

it should be replenished and voluntarily used, is of fundamental importance

to good vocalisation. Collar-bone breathing is deprecated by some

authorities, but I see no reason why the apices of the lungs should not be

expanded, and seeing the frequency with which tubercle occurs in this

region, it might by improving the circulation and nutrition be even

beneficial. The proper mode of breathing comes almost natural to some

individuals; to others it requires patient cultivation under a teacher who

understands the art of singing and the importance of the correct methods of

breathing.

The more powerfully the abdominal muscles contract the laxer must become

the diaphragm muscle; and by the law of the reciprocal innervation of

antagonistic muscles it is probable that with the augmented innervation

currents to the expiratory centre of the medulla there is a corresponding

inhibition of the innervation currents to the inspiratory centre (\_vide\_

fig. 18, page 101). These centres in the medulla preside over the centres

in the spinal cord which are in direct relation to the inspiratory and

expiratory muscles. It is, however, probable that there is a direct

relation between the brain and the spinal nerve centres which control the

costal and abdominal muscles independently of the respiratory centres of

the medulla oblongata (\_vide\_ fig. 18). The best method of breathing is

that which is most natural; there should not be a protruded abdomen on the

one hand, nor an unduly inflated chest on the other hand; the maximum

expansion should involve the lower part of the chest and the uppermost part

of the abdomen on a level of an inch or more below the tip of the

breastbone; the expansion of the ribs should be maintained as long as

possible. In short phrases the movement may be limited to an ascent of the

diaphragm, over which we have not the same control as we have of the

elevation of the ribs; but it is better to reserve the costal air, over

which we have more voluntary control, for maintaining a continuous pressure

and for varying the pressure.

II. THE REED

I will now pass on to the consideration of the voice-box, or larynx,

containing the reed portion of the vocal instrument.

[Illustration: FIG. 4 From Behnke's "Mechanism of the Human Voice"]

[Description: FIG. 4.--The cartilages of the larynx or voice-box. A large

portion of the shield cartilage on the right side has been cut away, in

order to show the two pyramid cartilages; these are seen jointed by their

bases with the ring cartilage; anteriorly are seen the two vocal processes

which give attachment to the two vocal cords (white ligaments), which

extend across the voice-box to be inserted in front in the angle of the

shield cartilage. Groups of muscles pull upon these cartilages in such a

manner as to increase, or diminish, the chink between the vocal cord in

ordinary inspiration and expiration; in phonation a group of muscles

approximate the cords, while another muscle makes them tense.]

\_The Larynx\_.--The larynx is situated at the top of the sound-pipe (trachea

or windpipe), and consists of a framework of cartilages articulated or

jointed with one another so as to permit of movement (\_vide\_ fig. 4). The

cartilages are called by names which indicate their form and shape: (1)

shield or thyroid, (2) the ring or cricoid, and (3) a pair of pyramidal or

arytenoid cartilages. Besides these there is the epiglottis, which from its

situation above the glottis acts more or less as a lid. The shield

cartilage is attached by ligaments and muscles to the bone (hyoid) in the

root of the tongue, a pair of muscles also connect this cartilage with the

sternum or breastbone. The ring cartilage is attached to the windpipe by

its lower border; by its upper border in front it is connected with the

inner surface of the shield cartilage by a ligament; it is also jointed on

either side with the shield cartilage. The posterior part of the ring

cartilage is much wider than the anterior portion, and seated upon its

upper and posterior rim and articulated with it by separate joints are the

two pyramidal cartilages (\_vide\_ fig. 4). The two vocal cords as shown in

the diagram are attached to the shield cartilage in front, their

attachments being close together; posteriorly they are attached to the

pyramidal cartilages. It is necessary, however, to describe a little more

fully these attachments. Extending forwards from the base of the pyramids

are processes termed the "vocal processes," and these processes give

attachment to the elastic fibres of which the vocal cords mainly consist.

There are certain groups of muscles which by their attachment to the

cartilages of the larynx and their action on the joints are able to

separate the vocal cords or approximate them; these are termed respectively

abductor and adductor muscles (figs. 5 and 6). In normal respiration the

posterior ring-pyramidal muscles contract synergically with the muscles of

inspiration and by separating the vocal cords open wide the glottis,

whereby there is a free entrance of air to the windpipe; during expiration

this muscle ceases to contract and the aperture of the glottis becomes

narrower (\_vide\_ fig. 10). But when the pressure is required to be raised

in the air passages, as in the simple reflex act of coughing or in

vocalisation, the glottis must be closed by approximation of the vocal

cords, and this is effected by a group of muscles termed the adductors,

which pull on the pyramid cartilages in such a way that the vocal processes

are drawn towards one another in the manner shown in fig. 7. Besides the

abductor and adductor groups of muscles, there is a muscle which acts in

conjunction with the adductor group, and by its attachments to the shield

cartilage above and the ring cartilage below makes tense the vocal cords

(\_vide\_ fig. 5); it is of interest to note that this muscle has a separate

nerve supply to that of the abductor and adductor muscles.

[Illustration: FIG. 5

Diagram after Testut (modified), showing the larynx from the front.]

[Illustration: FIG. 6

Diagram after Testut (modified), showing the posterior view of the larynx

with the muscles.]

On the top of the pyramid cartilages, in the folds of mucous membrane which

cover the whole inside of the larynx are two little pieces of yellow

elastic cartilage; and in the folds of mucous membrane uniting these

cartilages with the leaf-like lid cartilage (epiglottis) is a thin sheet of

muscle fibres which acts in conjunction with the fibres between the two

pyramid cartilages (\_vide\_ fig. 8). I must also direct especial attention

to a muscle belonging to the adductor group, which has another important

function especially related to vocalisation: it is sometimes called the

vocal muscle; it runs from the pyramid cartilage to the shield cartilage;

it apparently consists of two portions, an external, which acts with the

lateral ring-shield muscle and helps to approximate the vocal cords; and

another portion situated within the vocal cord itself, which by contracting

shortens the vocal cord and probably allows only the free edge to vibrate;

moreover, when not contracting, by virtue of the perfect elasticity of

muscle the whole thickness of the cord, including this vocal muscle, can be

stretched and thrown into vibration (\_vide\_ fig. 8). In the production of

chest notes the whole vocal cord is vibrating, the difference in the pitch

depending upon the tension produced by the contraction of the tensor

(ring-shield) muscle. When, however, the change from the lower to the upper

register occurs, as the photographs taken by Dr. French and reproduced in a

lecture at the Royal Institution by Sir Felix Semon show, the vocal cords

become shorter, thicker, and rounder; and this can be explained by

supposing that the inner portion of the vocal muscle contracts at the break

from the lower to the upper register (\_vide\_ fig. 11); and that as a result

only the free edges of the cords vibrate, causing a change in the quality

of the tone. As the scale is ascended the photographs show that the cords

become longer and tenser, which we may presume is due to the continued

action of the tensor muscle. Another explanation is possible, viz. that in

the lower register the two edges of the vocal cords are comparatively thick

strings. When the break occurs, owing to the contraction of the inner

portion of the vocal muscle, we have a transformation into thin strings, at

first short, but as the pitch of the note rises, the thin string formed by

the edge of the vocal cord is stretched and made longer by the tensor. It

should be mentioned that Aikin and many other good authorities do not hold

this view.

[Illustration: FIG. 7 A-A', Ring cartilage. B, Shield cartilage. 1, Pyramid

cartilage. 2, Vocal process, with 2', its position after contraction of

muscle. 3, Postero-external base of pyramid, giving attachment to abductor

and adductor muscles at rest, with 3', its new position after contraction

of the muscles. 4, Centre of movement of the pyramid cartilage. 5, The

vocal cords at rest. 5', Their new position after contraction of the

abductor and adductor muscles, respectively seen in I and II. 6, The

interligamentous, with 7, the intercartilaginous chink of the glottis. 8,

The arrow indicating respectively in I and II the action of the abductor

and adductor in opening and closing the glottis.]

[Description: FIG. 7.--Diagram after Testut (modified), showing: (i.) the

action of the abductor muscle upon the pyramid cartilages in separating the

vocal cords; (ii.) the action of the adductor muscles in approximating the

vocal cords.]

[Illustration: FIG. 8]

[Description: FIG. 8.--Diagram after Testut (modified) with hinder portion

of larynx and windpipe cut away, showing the conical cavity of the

sound-pipe below the vocal cords. The ventricle above the vocal cords is

seen with the surface sloping upwards towards the mid line.]

A diagram showing a vertical section through the middle of the larynx at

right angles to the vocal cords shows some important facts in connection

with the mechanism of this portion of the vocal instrument (\_vide\_ fig. 8).

It will be observed that the sound-pipe just beneath the membranous reed

assumes the form of a cone, thus the expired air is driven like a wedge

against the closed glottis. Another fact of importance may be observed,

that above the vocal cords on either side is a pouch called a ventricle,

and the upper surfaces of the vocal cords slope somewhat upwards from

without inwards, so that the pressure of the air from above tends to press

the edges together. The force of the expiratory blast of air from below

overcomes the forces which approximate the edges of the cords and throws

them into vibration. With each vibration of the membranous reeds the valve

is opened, and as in the case of the siren a little puff of air escapes;

thus successive rhythmical undulations of the air are produced,

constituting the sound waves. The pitch of the note depends upon the number

of waves per second, and the \_register\_ of the voice therefore depends upon

two factors: (1) the size of the voice-box, or larynx, and the length of

the cords, and (2) the action of the neuro-muscular mechanism whereby the

length, approximation, and tension of the vocal cords can be modified when

singing from the lowest note to the highest note of the register.

Thus the compass of the--

Bass voice is D to f 75- 354 vibs. per sec.

Tenor " c " c'' 133- 562 " "

Contralto " e " g'' 167- 795 " "

Soprano " b " f''' 239-1417 " "

The complete compass of the human voice therefore ranges from about D 75 to

f''' 1417 vibrations per second, but the quality of the same notes varies

in different individuals.

[Illustration: Fig. 9]

[Description: Fig. 9.--\_Description of the laryngoscope and its mode of

use\_.--The laryngoscope consists of a concave mirror which is fixed on the

forehead with a band in such a way that the right eye looks through the

hole in the middle. This mirror reflects the light from a lamp placed

behind the right side of the patient, who is told to open the mouth and put

out the tongue. The observer holds the tongue out gently with a napkin and

reflects the light from the mirror on his forehead on to the back of the

throat. The small mirror, set at an angle of 45° with the shaft, is of

varying size, from half an inch to one inch in diameter, and may be fixed

in a handle according to the size required. The mirror is warmed to prevent

the moisture of the breath obscuring the image, and it is introduced into

the back of the throat in such a manner that the glottis appears reflected

in it. The light from the lamp is reflected by the concave mirror on to the

small mirror, which, owing to its angle of 45°, illuminates the glottis and

reflects the image of the glottis with the vocal cords.]

The discovery of the laryngoscope by Garcia enabled him by its means to see

the vocal cords in action and how the reed portion of the vocal instrument

works (\_vide\_ fig. 9 and description). The chink of the glottis or the

opening between the vocal cords as seen in the mirror of the laryngoscope

varies in size. The vocal cords or ligaments appear dead white and contrast

with the surrounding pink mucous membrane covering the remaining structures

of the larynx. Fig. 10 shows the appearance of the glottis in respiration

and vocalisation. The vocal cords of a man are about seven-twelfths of an

inch in length, and those of a boy (before the voice breaks) or of a woman

are about five-twelfths of an inch; and there is a corresponding difference

in size of the voice-box or larynx. This difference in length of the vocal

cords accounts for the difference in the pitch of the speaking voice and

the register of the singing voice of the two sexes. We should also expect a

constant difference in the length of the cords of a tenor and a bass in the

male, and of the contralto and soprano in the female, but such is not the

case. It is not possible to determine by laryngoscopic examination what is

the natural register of an individual's voice. The vocal cords may be as

long in the tenor as in the bass; this shows what an important part the

resonator plays in the timbre or quality of the voice. Still, it is

generally speaking true, that a small larynx is more often associated with

a higher pitch of voice than a large larynx.

[Illustration: Fig. 10]

[Description: Fig. 10.--Diagram (modified from Aikin) illustrating the

condition of the vocal cords in respiration, whispering, and phonation. (1)

Ordinary breathing; the cords are separated and the windpipe can be seen.

(2) Deep inspiration; the cords are widely separated and a greater extent

of the windpipe is visible. (3) During the whisper the vocal cords are

separated, leaving free vent for air through the glottis; consequently

there is no vibration and no sound produced by the cords. (4) The soft

vocal note, or aspirate, shows that the chink of the glottis is not

completely closed, and especially the rima respiratoria (the space between

the vocal processes of the pyramidal cartilages.) (5) Strong vocal note,

produced in singing notes of the lower register. (6) Strong vocal note,

produced in singing notes of the higher register.]

Musical notes are comprised between 27 and 4000 vibrations per second. The

extent and limit of the voice may be given as between C 65 vibrations per

second and f''' 1417 vibrations per second, but this is most exceptional,

it is seldom above c''' 1044 per second. The compass of a well-developed

singer is about two to two and a half octaves. The normal pitch, usually

called the "diapason normal," is that of a tuning-fork giving 433

vibrations per second. Now what does the laryngoscope teach regarding the

change occurring in the vocal cords during the singing of the two to two

and a half octaves? If the vocal cords are observed by means of the

laryngoscope during phonation, no change is \_seen\_, owing to the rapidity

of the vibrations, although a scale of an octave may be sung; in the lower

notes, however, the vocal cords are seen not so closely approximated as in

the very high notes. This may account for the difficulty experienced in

singing high notes piano. Sir Felix Semon in a Friday evening lecture at

the Royal Institution showed some remarkable photographs, by Dr. French, of

the larynx of two great singers, a contralto and a high soprano, during

vocalisation, which exhibit changes in the length of the vocal cords and in

the size of the slit between them. Moreover, the photographs show that the

vocal cords at the break from the lower to the upper register exhibit

characteristic changes.

[Illustration: Fig. 11]

[Description: Fig. 11.--Drawings after Dr. French's photographs in Sir

Felix Semon's lecture on the Voice, (1) Appearance of vocal cords of

contralto singer when singing F# to D; it will be observed that the cords

increase in length with the rise of the pitch, presumably the whole cord is

vibrating, including the inner strand of the vocal muscle. At the break

from D to E (3 and 4) the cords suddenly become shorter and thicker;

presumably the inner portion of the vocal muscle (thyro-arytenoid) is

contracting strongly, permitting only the edge of the cord to vibrate. For

the next octave the cords are stretched longer and longer; this may be

explained by the increasing force of contraction of the tensor muscle

stretching the cords and the contained muscle, which is also contracted.]

When we desire to produce a particular vocal sound, a mental perception of

the sound, which is almost instinctive in a person with a musical ear,

awakens by association motor centres in the brain that preside over the

innervation currents necessary for the approximation and minute alterations

in the tensions of the vocal cords requisite for the production of a

particular note. We are not conscious of any kinæsthetic (sense of

movement) guiding sensations from the laryngeal muscles, but we are of the

muscles of the tongue, lips, and jaw in the production of articulate

sounds. It is remarkable that there are hardly any sensory nerve endings in

the vocal cords and muscles of the larynx, consequently it is not

surprising to find that the ear is the guiding sense for correct modulation

of the loudness and pitch of the speaking as well as the singing voice. In

reading music, visual symbols produced by one individual awakens in the

mind of another mental auditory perceptions of sound varying in pitch,

duration, and loudness. Complex neuro-muscular mechanisms preside over

these two functions of the vocal instrument. The instrument is under the

control of the will as regards the production of the notes in loudness and

duration, but not so as regards pitch; for without the untaught instinctive

sense of the mental perception of musical sounds correct intonation cannot

be obtained by any effort of the will. The untaught ability of correct

appreciation of variations in the pitch of notes and the memorising and

producing of the same vocally are termed a musical ear. A gift even to a

number of people of poor intelligence, it may or may not be associated with

the sense of rhythm, which, as we have seen, is dependent upon the mental

perception of successive movements associated with a sound. Both correct

modulation and rhythm are essential for melody. The sense of hearing is the

primary incitation to the voice. This accounts for the fact that children

who have learnt to speak, and suffer in early life with ear disease, lose

the use of their vocal instrument unless they are trained by lip language

and imitation to speak. The remarkable case of Helen Keller, who was born

blind and deaf, and yet learned by the tactile motor sensibility of the

fingers to feel the vibrations of the vocal organ and translate the

perceptions of these vibrations into movements of the lips and tongue

necessary for articulation, is one of the most remarkable facts in

physiological psychology. Her voice, however, was monotonous, and lacked

the modulation in pitch of a musical voice. Music meant little to her but

beat and pulsation. She could not sing and she could not play the piano.

The fact that Beethoven composed some of his grandest symphonies when stone

deaf shows the extraordinary musical faculty he must have preserved to bear

in his mind the grand harmonies that he associated with visual symbols.

Still, it is impossible that Beethoven, had he been deaf in his early

childhood, could ever have developed into the great musical genius that he

became.

[Illustration: Fig. 12]

[Description: Fig. 12.--Diagram showing the position of the larynx in

respect to the resonator and tongue. The position of the vocal cords is

shown, but really they would not be seen unless one half of the shield

cartilage were cut away so as to show the interior of the voice-box. Sound

vibrations are represented issuing from the larynx, and here they become

modified by the resonator; the throat portion of the resonator is shown

continuous with the nasal passages; the mouth portion of the resonator is

not in action, owing to the closure of the jaw and lips. The white spaces

in the bones of the skull are air sinuses. In such a condition of the

resonator, as in humming a tune, the sound waves must issue by the nasal

passages, and therefore they acquire a nasal character.]

III. THE RESONATOR AND ARTICULATOR

\_The Resonator\_.--The resonator is an irregular-shaped tube with a bend in

the middle; the vertical portion is formed by the larynx and pharynx, the

horizontal by the mouth. The length of the resonator, from the vocal cords

to the lips, is about 6.5 to 7 inches (\_vide\_ fig. 12). The walls of the

vertical portion are formed by the vertebral column and the muscles of the

pharynx behind, the cartilages of the larynx and the muscles of the pharynx

at the sides, and the thyroid cartilage, the epiglottis, and the root of

the tongue in front; these structures form the walls of the throat and are

all covered with a mucous membrane. This portion of the resonator passage

can be enlarged to a slight degree by traction upon the larynx below

(sterno-thyroid muscle), by looseness of the pharyngeal muscles, and still

more by the forward placement of the tongue; the converse is true as

regards diminution in size. The horizontal portion of the resonator tube

(the mouth) has for its roof the soft palate and the hard palate, the

tongue for its floor, and cheeks, lips, jaw, and teeth for its walls. The

interior dimensions of this portion of the resonator can be greatly

modified by movements of the jaw, the soft palate, and the tongue, while

the shape and form of its orifice is modified by the lips.

There are accessory resonator cavities, and the most important of these is

the nose; its cavity is entirely enclosed in bone and cartilage,

consequently it is immovable; this cavity may or may not be closed to the

sonorous waves by the elevation of the soft palate. When the mouth is

closed, as in the production of the consonant m, e.g. in singing \_me\_, a

nasal quality is imparted to the voice, and if a mirror be placed under the

nostrils it will be seen by the vapour on it that the sound waves have

issued from the nose; consequently the nasal portion of the resonator has

imparted its characteristic quality to the sound. The air sinuses in the

upper jaws, frontal bones, and sphenoid bones act as accessory resonators;

likewise the bronchi, windpipe, and lungs; but all these are of lesser

importance compared with the principal resonating chamber of the mouth and

throat. If the mouth be closed and a tune be hummed the whole of the

resonating chambers are in action, and the sound being emitted from the

nose the nasal quality is especially marked. But no sound waves are

produced unless the air finds an exit; thus a tune cannot be hummed if both

mouth and nostrils are closed.

From the description that I have given above, it will be observed that the

mouth, controlled by the movements of the jaw, tongue, and lips, is best

adapted for the purpose of articulate speech; and that the throat, which is

less actively movable and contains the vocal cords, must have greater

influence on the sound vibrations without participating in the articulation

of words. While the vocal cords serve the purpose of the reed, the

resonator forms the body of the vocal instrument. Every sound passes

through it; every vowel and consonant in the production of syllables and

words must be formed by it, and the whole character and individual

qualities of the speaking as well as the singing voice depend in great part

upon the manner in which it is used.

The acoustic effect is due to the resonances generated by hollow spaces of

the resonator, and Dr. Aikin, in his work on "The Voice," points out that

we can study the resonances yielded by these hollow spaces by whispering

the vocal sounds; but it is necessary to put the resonator under favourable

conditions for the most efficient production. When a vowel sound is

whispered the glottis is open (\_vide\_ fig. 10) and the vocal cords are not

thrown into vibration; yet each vowel sound is associated with a distinct

musical note, and we can produce a whole octave by alteration of the

resonator in whispering the vowel sounds. In order to do this efficiently

it is necessary to use the bellows and the resonator to the best advantage;

therefore, after taking a deep inspiration in the manner previously

described, the air is expelled through the open glottis into the resonating

cavity, which (as fig. 13 shows) is placed under different conditions

according to the particular vowel sound whispered. In all cases the mouth

is opened, keeping the front teeth about one inch apart; the tongue should

be in contact with the lower dental arch and lie as flat on the floor of

the mouth as the production of the particular vowel sound will permit. When

this is done, and a vowel sound whispered, a distinctly resonant note can

be heard. Helmholtz and a number of distinguished German physicists and

physiologists have analysed the vowel sounds in the whispering voice and

obtained very different results. If their experiments show nothing else,

they certainly indicate that there are no universally fixed resonances for

any particular vowel sound. Some of the discrepancies may (as Aikin points

out) be due to the conditions of the experiment not being conducted under

the same conditions. Aikin, indeed, asserts that if the directions given

above be fulfilled, there will be variations between full-grown men and

women of one or two tones, and between different men and different women of

one or two semi-tones, and not much more. As he truly affirms, if the tube

is six inches long a variation of three-quarters of an inch could only make

a difference of a whole tone in the resonance, and he implies that the

different results obtained by these different experimenters were due to the

faulty use of the resonator.

In ordinary conversation much faulty pronunciation is overlooked so long as

the words themselves are intelligible, but in singing and public speaking

every misuse of the resonator is magnified and does not pass unnoticed.

Increased loudness of the voice will not improve its carrying power if the

resonator is improperly used; it will often lead to a rise of pitch and the

production of a harsh, shrill tone associated with a sense of strain and

effort. Aikin claims that by studying the whispering voice we can find for

every vowel sound that position of the resonator which gives us the maximum

of resonance. By percussing[A] the resonator in the position for the

production of the various vowel sounds you will observe a distinct

difference in the pitch of the note produced. I will first produce the

vowel sound \_oo\_ and proceed with the vowel sounds to \_i\_; you will observe

that the pitch rises an octave; that this is due to the changes in the form

of the resonator is shown when I percuss the resonator in the position of

the different vowel sounds. You will observe that I start the scale of C

with \_oo\_ on f and proceed through a series of vowel sounds as in

whispering \_who\_, \_owe\_, \_or\_, \_on\_, \_ah\_. I rise a fifth from f to c, and

the diagram shows the change in the form of the resonator cavity to be

mainly due to the position of the dorsum of the tongue. Proceeding from

\_ah\_ to the middle tone of the speaking register, we ascend the scale to

\_i\_ as in \_me\_, and the dorsum of the tongue now reaches the roof of the

mouth; but the tongue not only rises, it comes forward, and the front

segment of the resonator is made a little smaller at every step of the

scale while the back segment becomes a little larger. I consider this

diagram of Aikin to be more representative of the changes in the resonator

than the description of Helmholtz, who stated that the form of the

resonator during the production of the vowel sound \_u\_ and \_o\_ is that of a

globular flask with a short neck; during the production of \_a\_ that of a

funnel with the wide extremity directed forward; of \_e\_ and \_i\_ that of a

globular flask with a long narrow neck.

[Footnote A: This was done by the lecturer placing his left forefinger on

the outside of the right cheek, then striking it with the tip of the middle

finger of the right hand, just in the same way as he would percuss the

chest.--F.W.M.]

[Illustration: FIG. 13 I & II To face page 47]

[Description: FIG. 13.--Diagram after Aikin.

1. To show position of tongue and lips in the production of the vowel

sounds \_a, o, oo\_.

2. To show successive positions of the tongue in the production of the

vowel sounds \_a, ei, e, i\_.]

I have already said that Helmholtz showed that each vowel sound has its

particular overtones, and the quality or "timbre" of the voice depends upon

the proportional strength of these overtones. Helmholtz was able by means

of resonators to find out what were the overtones for each vowel sound when

a particular note was sung. The flame manometer of König (\_vide\_ fig. 14)

shows that if the same note be sung with different vowels the serrated

flame image in the mirror is different for each vowel, and if a more

complicated form of this instrument be used (such as I show you in a

picture on the screen) the overtones of the vowel sounds can be analysed.

You will observe that this instrument consists of a number of resonators

placed in front of a series of membranes which cover capsules, each capsule

being connected with a jet of gas.

[Illustration: FIG. 14

Four-sided revolving mirror

Images of gas jets

Resonators, with capsules connected with gas jets]

[Description: FIG. 14.--König's flame manometer. The fundamental note C is

sung on a vowel sound in front of the instrument; the lowest resonator is

proper to that note and the air in it is thrown into corresponding periodic

rhythmical vibrations, which are communicated through an intervening

membrane to the gas in the capsule at the back of the resonator; but the

gas is connected with the lighted jet, the flame of which is reflected in

the mirror, the result being that the flame vibrates. When the mirror is

made to revolve by turning the handle the reflected image shows a number of

teeth corresponding to the number of vibrations produced by the note which

was sung. The remaining resonators of the harmonic series with their

capsules and gas-jets respond in the same manner to the overtones proper to

each vowel sound when the fundamental note is sung.]

Each resonator corresponds from below upwards to the harmonics of the

fundamental note c. In order to know if the sound of the voice contains

harmonics and what they are, it is necessary to sing the fundamental note c

on some particular vowel sound; the resonators corresponding to the

particular harmonics of the vowel sound are thus set in action, and a

glance at the revolving mirror shows which particular gas jets vibrate.

Experiments conducted with this instrument show that the vowel \_U=oo\_ is

composed of the fundamental note very strong and the third harmonic (viz.

g) is fairly pronounced.

\_O\_ (\_on\_) contains the fundamental note, the second harmonic (the octave

c') very strong, and the third and fourth harmonics but weak.

The vowel \_A\_ (\_ah\_) contains besides the fundamental note, the second

harmonic, weak; the third, strong; and the fourth, weak.

The vowel \_E\_ (\_a\_) has relatively a feeble fundamental note, the octave

above, the second harmonic, is weak, and the third weak; whereas the fourth

is very strong, and the fifth weak.

The vowel \_I\_ (\_ee\_) has very high harmonics, especially the fifth, which

is strongly marked.

We see from these facts that there is a correspondence between the

existence of the higher harmonics and the diminished length of the

resonator. They are not the same in all individuals; for they depend also

upon the \_timbre\_ of the voice of the person pronouncing them, or the

special character of the language used, as well as upon the pitch of the

fundamental notes employed.

Helmholtz inferred that if the particular quality of the vowel sounds is

due to the reinforcement of the fundamental tone by particular overtones,

he ought to be able to produce synthetically these vowel sounds by

combining the series of overtones with the fundamental note. This he

actually accomplished by the use of stopped organ pipes which gave sensibly

simple notes.

\* \* \* \* \*

Having thus shown that the fundamental note is dependent upon the tension

of the vocal cords--the reed portion of the instrument--and the quality,

timbre, or "klang" upon the resonator, I will pass on to the formation of

syllables and words of articulate speech by the combination of vowel sounds

and consonants.

"The articulate sounds called consonants are sounds produced by the

vibrations of certain easily movable portions of the mouth and throat; and

they have a different sound according as they are accompanied by voice or

not" (Hermann).

The emission of sounds from the resonator may be modified by interruption

or constriction in three situations, at each of which added vibrations may

occur, (1) At the lips, the constriction being formed by the two lips, or

by the upper or lower lip with the lower or upper dental arch. (2) Between

the tongue and the palate, the constriction being caused by the opposition

of the tip of the tongue to the anterior portion of the hard palate or the

posterior surface of the dental arch. (3) At the fauces, the constriction

being due to approximation of the root of the tongue and the soft palate.

Consonants can only be produced in conjunction with a vowel sound,

consequently the air is thrown into sonorous waves of a complex character,

in part dependent upon the shape of the resonator for the production of the

vowel, in part dependent upon the vibrations at each of these situations

mentioned above. Consonants may accordingly be classified as they are

formed at the three places of interruption--lips, teeth, and fauces

respectively: (1) labial; (2) dental; (3) guttural.

The sounds formed at each of the places of interruption are divided into--

1. \_Explosives\_.--At one of the situations mentioned the resonator is

suddenly opened or closed during the expulsion of air--(\_a\_) without the

aid of voice, p, t, k; (\_b\_) with the aid of voice, b, d, g. When one of

these consonants begins a syllable, opening of the resonator is necessary,

e.g. pa; when it ends a syllable, closure is necessary, e.g. ap. No sharp

distinction is possible between p and b, t and d, and k and g if they are

whispered.

2. \_Aspirates\_.--The resonator is constricted at one of the points

mentioned so that the current of air either expired or inspired rushes

through a small slit. Here again we may form two classes: (\_a\_) without the

aid of the voice, f, s (sharp), ch, guttural; (\_b\_) with the aid of voice,

v, z, y. The consonants s and l are formed when the passage in front is

closed by elevation of the tongue against the upper dental arch so that the

air can only escape at the sides between the molar teeth: sh is formed by

the expulsion of the current of air through two narrow slits, viz. (1)

between the front of the tongue and the hard palate, the other between the

nearly closed teeth. If a space be left between the tip of the tongue and

the upper teeth two consonant sounds can be produced, one without the aid

of the voice--th (hard) as in that; the other with the aid of voice--th

(soft) as in thunder. Ch is a guttural produced near the front of the

mouth, e.g. in Christ, or near the back as in Bach.

3. \_Resonants\_.--In the production of the consonant m, and sometimes n, the

nasal resonator comes into play because the soft palate is not raised at

all and the sound waves produced in the larynx find a free passage through

the nose, while the mouth portion of the resonator is completely closed by

the lips. The sounds thus produced are very telling in the singing voice.

4. \_Vibratory Sounds\_.--There are three situations in which the consonant r

may be formed, but in the English language it is produced by the vibration

of the tip of the tongue in the constricted portion of the cavity of the

mouth, formed by the tongue and the teeth.

The consonants have been grouped by Hermann as follows:--

| |Labials.|Dentals. |Gutturals.|

|1. Explosives-- | | | |

|a. Without the voice|P |T |K |

|b. With the voice |B |D |G |

|2. Aspirates-- | | | |

|a. Without the voice|F |S (hard), L, Sh,|Ch |

| | |Th (hard) | |

|b. With the voice |V |Z, L, Th, Zh |Y in yes |

| | |(soft) | |

|3. Resonants |M |N |N (nasal) |

|4. Vibratory sounds|Labial R|Lingual R |Guttural R|

H is the sound produced in the larynx by the quick rushing of the air

through the widely opened glottis.

Hermann's classification which I have given is especially valuable as

regards the speaking voice, but Aikin classifies the consonants from the

singing point of view, according to the more or less complete closure of

the resonator.

CLASSIFICATION OF CONSONANTS (AIKIN)

Jaw fully open H, L, K, G

" less " T, D, N, R

" nearly closed, lips closed P, B, M

" " " upper lip on lower teeth F, V

" quite closed S, Z, J, N, Ch, Sh

Aikin, moreover, points out that the English language is so full of

closures that it is difficult to keep the resonator open, and that accounts

for one of the principal difficulties in singing it.

"The converse of this may be said of Italian, in which most words end in

pure vowels which keep the resonator open. In fact, it is this circumstance

which has made the Italian language the basis of every point of voice

culture and the producer of so many wonderful singers." As an example

compare the English word 'voice,' which begins with closure and ends with

closure, and the Italian 'voce,' pronounced \_voché\_, with its two open

vowel sounds. The vowel sound ah on the note c is the middle tone of the

speaking register, and as we know, can be used all day long without

fatigue; therefore in training the voice the endeavour should be made to

develop the register above and below this middle tone. In speaking there is

always a tendency under emotional excitement, especially if associated with

anger, to raise the pitch of the voice, whereas the tender emotions lead

rather to a lowering of the pitch. Interrogation generally leads to a rise

of the pitch; thus, as Helmholtz pointed out, in the following sentence

there is a decided fall in the pitch--"I have been for a walk"; whereas in

"Have you been for a walk?" there is a decided rise of pitch. If you utter

the sentence "Who are you?" there is a very definite rise of pitch on

'are.'

PATHOLOGICAL DEGENERATIVE CHANGES PRODUCING SPEECH DEFECTS

AND WHAT THEY TEACH

As I have before remarked, children utter vowel sounds before consonants,

and I used this as an argument that phonation preceded articulation; but

there is another reason for supposing that articulate sounds are of later

development phylogenetically, as well as ontogenetically. Not only are they

more dependent for their proper production on intelligence, but in those

disorders of speech which occur as a result of degenerative processes of

the central nervous system the difficulty of articulate speech precedes

that of phonation. Take, for example, bulbar paralysis, a form of

progressive muscular atrophy, a disease due to a progressive decay and

destruction of the motor nerve cells presiding over the movements of the

tongue, lips, and larynx, hence often called glosso-labial-laryngeal palsy.

In this disease the lips, tongue, throat, and often the larynx are

paralysed on both sides. "The symptoms are, so to speak, grouped about the

tongue as a centre, and it is in this organ that the earliest symptoms are

usually manifested." (Gowers). Imperfect articulation of those sounds in

which the tongue is chiefly concerned, viz. the lingual consonants l, r, n,

and t, causing indistinctness of speech, is the first symptom; the lips

then become affected and there is difficulty in the pronunciation of sounds

in which the lips are concerned, viz. u, o, p, b, and m. Eventually

articulate speech becomes impossible, and the only expression remaining to

the patient is laryngeal phonation, slightly modulated and broken into the

rhythm of formless syllables.

The laryngeal palsy \_rarely\_ becomes complete. The nervous structures in

the \_physiological mechanism\_ of speech and phonation are affected in this

disease; but there are degenerative diseases of the brain in which the

\_psychical mechanism\_ of speech is affected, e.g. General Paralysis of the

Insane, in which the affection of speech and hand-writing is quite

characteristic. There is at first a hesitancy which may only be perceptible

to practised ears, but in which there is no real fault of articulation once

it is started; sometimes preparatory to and during the utterance there is a

tremulous motion about the muscles of the mouth. The hesitation increases,

and instead of a steady flow of modulated, articulate sounds, speech is

broken up into a succession of irregular, jerky, syllabic fragments,

without modulation, and often accompanied by a tremulous vibration of the

voice. Syllables are unconsciously dropped out, blurred, or run into one

another, or imperfectly uttered; especially is difficulty found with

consonants, particularly explosive sounds, b, p, m; again, linguals and

dentals are difficult to utter. Similar defects occur in written as in

vocal speech; the syllables and even the letters are disjointed; there is a

fine tremor in the writing, and inco-ordination in the movements of the

pen. Silent thoughts leave out syllables and words in the framing of

sentences; consequently they are not expressed by the hand. The ideation of

a written or spoken word is based upon the association of the component

syllables, and the difficulty arises primarily from the progressive

impairment of this function of association upon which spoken and written

language so largely depends. Examination of the brain in this disease

explains the cause of the speech trouble and the progressive dementia (loss

of mind) and paralysis with which it is associated. There is a wasting of

the cerebral hemispheres, especially of the frontal lobes, a portion of the

brain which, later on, we shall see is intimately associated with the

function of articulate speech.

THE CEREBRAL MECHANISM OF SPEECH AND SONG

Neither vocalisation nor articulation are essentially human. Many of the

lower animals, e.g. parrots, possess the power of articulate speech, and

birds can be taught to pipe tunes. The essential difference between the

articulate speech of the parrot and the human being is that the parrot

merely imitates sounds, it does not employ these articulate sounds to

express judgments; likewise there are imbecile human beings who,

parrot-like, repeat phrases which are meaningless. Articulate speech, even

when employed by a primitive savage, always expresses a judgment. Even in

the simple psychic process of recalling the name aroused by the sight of a

common object in daily use, and in affixing the verbal sign to that object,

a judgment is expressed. But that judgment is based upon innumerable

experiences primarily acquired through our special senses, whereby we have

obtained a knowledge of the properties and uses of the object. This

statement implies that the whole brain is consciously and unconsciously in

action. There is, however, a concentration of psychic action in those

portions of the brain which are essential for articulate speech;

consequently the word, as it is mentally heard, mentally seen, and mentally

felt (by the movements of the jaw, tongue, lips, and soft palate), occupies

the field of clear consciousness; but the concept is also the nucleus of an

immense constellation of subconscious psychic processes with which it has

been associated by experiences in the past. In language, articulate sounds

are generally employed as objective signs attached to objects with which

they have no natural tie.

In considering the relation of the Brain to the Voice we have not only a

physiological but a psychological problem to deal with. Since language is

essentially a human attribute, we can only study the relation of the Brain

to Speech by observations on human beings who during life have suffered

from various speech defects, and then correlate these defects with the

anatomical changes found in the brain after death.

Between the vocal instrument of the primitive savage and that of the most

cultured singer or orator there is little or no discoverable difference;

neither by careful naked-eye inspection of the brain, nor aided by the

highest powers of the microscope, should we be able to discover any

sufficient structural difference to account for the great difference in the

powers of performance of the vocal instrument of the one as compared with

that of the other; nor is there any sufficient difference in size or minute

structure of the brain to account for the vast store of intellectual

experiences and knowledge of the one as compared with the other. The

cultured being descended from cultured beings inherits tendencies whereby

particular modes of motion or vibration which have been experienced by

ancestors are more readily aroused in the central nervous system; when

similar stimuli producing similar modes of motion affect the sense organs.

But suppose there were an island inhabited only by deaf mutes, upon which a

ship was wrecked, and the sole survivors of the wreck were infants who had

never used the voice except for crying, would these infants acquire

articulate speech and musical vocalisation? I should answer, No. They would

only be able to imitate the deaf mutes in their gesture language and

possibly the musical sounds of birds; for the language a child learns is

that which it hears; they might however develop a simple natural language

to express their emotions by vocal sounds. The child of English-speaking

parents would not be able spontaneously to utter English words if born in a

foreign country and left soon after birth amongst people who could not

speak a word of English, although it would possess a potential facility to

speak the language of its ancestors and race.

It is necessary, however, before proceeding further, to say a few words

explanatory of the brain and its structure, and the reader is referred to

figs. 15, 16, 17. The brain consists of (1) the great brain or cerebrum,

(2) the small brain or cerebellum, and (3) the stem of the brain, which is

continuous with the spinal cord. The cerebro-spinal axis consists of grey

matter and white matter. The grey matter covers the surface of the cerebrum

and cerebellum, the white matter being internal. The stem of the brain, the

medulla oblongata, and the spinal cord, consists externally of white

matter, the grey matter being internal. The grey matter consists for the

most part of nerve cells (ganglion cells), and the white matter consists of

nerve fibres; it is white on account of the phosphoretted fatty

sheath--myelin--that covers the essential axial conducting portion of the

nerve fibres. If, however, the nervous system be examined microscopically

by suitable staining methods, it will be found that the grey and white

matters are inseparably connected, for the axial fibres of the nerves in

the white matter are really prolongations of the ganglion cells of the grey

matter; in fact the nervous system consists of countless myriads of nervous

units or neurones; and although there are structural differences in the

nervous units or neurones, they are all constructed on the same general

architectural plan (\_vide\_ fig. 15). They may be divided into groups,

systems, and communities; but there are structural differences of the

separate systems, groups, and communities which may be correlated with

differences of function. The systems may be divided into: (1) afferent

sensory, including the special senses and general sensibility; (2) motor

efferent; (3) association.

[Illustration: Fig. 15]

[Description: FIG. 15.--Diagrammatic representation of a motor neurone

magnified 300 diameters. Whereas the nerve cell and its branching processes

(the dendrons) form but a minute speck of protoplasm, the nerve fibre which

arises from it, although microscopic in diameter, extends a very long

distance; in some cases it is a yard long; consequently only a minute

fraction of the nerve fibre is represented in the diagram.]

The great brain or cerebrum consists of two halves equal in weight, termed

hemispheres, right and left; and the grey matter covering their surface is

thrown into folds with fissures between, thus increasing enormously the

superficial area of the grey matter and of the neurones of which it

consists without increasing the size of the head. The pattern of the folds

or convolutions shows a general similarity in all human beings, certain

fissures being always present; and around these fissures which are

constantly present are situated fibre systems and communities of neurones

having particular functions (\_vide\_ fig. 16.) Thus there is a significance

in the convolutional pattern of the brain. But just as there are no two

faces alike, so there are no two brains alike in their pattern; and just as

it is rare to find the two halves of the face quite symmetrical, so the two

halves of the brain are seldom exactly alike in their pattern. Although

each hemisphere is especially related to the opposite half of the body, the

two are unified in function by a great bridge of nerve fibres, called the

corpus callosum, which unites them. The cortical centres or structures with

specialised functions localised in particular regions of one hemisphere are

associated by fibres passing to the same region in the opposite hemisphere

by this bridge.

[Illustration: Fig. 16]

[Description: FIG. 16.--Diagram of the left hemisphere of the brain showing

localised centres, of which the functions are known. It will be observed

that the centres for the special senses, tactile, muscular, hearing, and

vision, are all situated behind the central fissure. The tactile-motor

kinæsthetic sense occupies the whole of the post-central convolution; the

centre for hearing (and in the left hemisphere memory of words) is shown at

the end of the first temporal convolution, but the portion shaded by no

means indicates the whole of the grey cortex which possesses this function;

a large portion of this centre cannot be seen because it lies within the

fissure forming the upper surface of the temporal lobe. Behind this is the

angular gyrus which is connected with visual word memory. The half-vision

centre, and by this is meant the portion of brain which receives

impressions from each half of the field of vision, is situated for the most

part on the inner (unseen) surface of the occipital lobe. In front of the

central fissure is situated the motor area, or that region destruction of

which causes paralysis of the muscles moving the structures of the opposite

half of the body. If the situations indicated by black dots be excited by

an interrupted electric current, movements of the limbs, trunk, and face

occur in the precise order shown, from the great toe to the larynx. In

front of this precentral convolution are the three frontal convolutions,

and it would seem that the functions of these convolutions are higher

movements and attention in fixation of the eyes; moreover, in the lowest

frontal region, indicated by fine dots, we have Broca's convolution, which

is associated with motor speech; above at the base of the second middle

frontal convolution is the portion of cortex in which is localised the

function of writing. Taste and smell functions reside in brain cortex only

a small portion of which can be seen, viz. that at the tip of the temporal

lobe.]

Muscles and groups of muscles on the two sides of the body which invariably

act together may thus be innervated from either hemisphere, e.g. the

muscles of the larynx, the trunk, and upper part of the face.

Gall, the founder of the doctrine of Phrenology, wrecked his fame as a

scientist by associating mental faculties with conditions of the skull

instead of conditions of the brain beneath; nevertheless, he deserves the

highest credit for his discoveries and deductions, for he was the first to

point out that that part of the brain with which psychic processes are

connected must be the cerebral hemispheres. He said, if we compare man with

animals we find that the sensory functions of animals are much finer and

more highly developed than in man; in man, on the other hand, we find

intelligence much more highly developed than in animals. Upon comparing the

corresponding anatomical conditions, we see, he said, that in animals the

deeper situated parts of the brain are relatively more developed and the

hemispheres less developed than in man; in man, the hemispheres so surpass

in development those of animals that we can find no analogy. Gall therefore

argued that we must consider the cerebral hemispheres to be the seat of the

higher functions of the mind. We must moreover acknowledge that the

following deductions of Gall are quite sound: "The convolutions ought to be

recognised as the parts where the instincts, feelings, thoughts, talents,

the affective qualities in general, and the moral and intellectual forces

are exercised." The Paris Academy of Science appointed a commission of

inquiry, May, 1808, which declared the doctrine of Gall to be erroneous.

Gall moreover surmised that the faculty of language lay in the frontal

lobes, and Bouillaud supported Gall's proposition by citing cases in which

speech had been affected during life, and in which after death the frontal

lobes were found to be damaged by disease. A great controversy ensued in

France; popular imagination was stirred up especially in the republic by

the doctrine of Gall, which was an attempt to materialise and localise

psychic processes. Unfortunately Gall's imagination, encouraged by a

widespread wave of popular sympathy, overstepped his judgment and launched

him into speculative hypotheses unsupported by facts. His doctrine of

Phrenology was shown to be absolutely illogical; consequently it was

forgotten that he was the pioneer of cerebral localisation.

SPEECH AND RIGHT-HANDEDNESS

The next step in Cerebral Localisation was made by a French physician, Marc

Dax, who first observed that disease of the left half of the cerebrum

producing paralysis of the right half of the body (right hemiplegia) was

associated with loss of articulate speech. This observation led to the

establishment of a most important fact in connection with speech, viz. that

right-handed people use their left cerebral hemisphere as the executive

portion of the brain in speech. Subsequently it was shown that when

left-handed people were paralysed on the left side by disease of the right

hemisphere, they lost their powers of speech. But the great majority of

people are born right-handed, consequently the right hand being especially

the instrument of the mind in the majority of people, the left hemisphere

is the leading hemisphere; and since probably specialisation of function of

the right hand (dexterity) has been so closely associated with that other

instrument of the mind, the vocal instrument of articulate speech, the two

have now become inseparable; for are not graphic signs and verbal signs

intimately interwoven in the development of language and human

intelligence?

What has determined the predominance of the left hemisphere in speech? I

can find no adequate anatomical explanation. There is no difference in

weight of the two hemispheres in normal brains. Moreover, I am unable to

subscribe to the opinion that there is any evidence to show that the left

hemisphere receives a larger supply of blood than the right. Another theory

advanced to explain localisation of speech and right-handedness in the left

hemisphere is that the heavier organs, lung and liver, being on the right

side have determined a mechanical advantage which has led to

right-handedness in the great majority of people. This theory has, however,

been disposed of by the fact that cases in which there has been a complete

transposition of the viscera have not been left-handed in a larger

proportion of cases. The great majority of people, modern and ancient,

civilised and uncivilised, use the right hand by preference. Even graphic

representations on the sun-baked clay records of Assyria, and the drawings

on rocks, tusks, and horns of animals of the flint-weapon men of

prehistoric times show that man was then right-handed. There is a

difference of opinion whether anthropoid apes use the right hand in

preference to the left. Professor Cunningham, who made a special study of

this subject, asserts that they use either hand indifferently; so also does

the infant at first, and the idiot in a considerable number of cases. Then

why should man, even primitive, have chosen the right hand as the

instrument of the mind? Seeing that there is no apparent anatomical reason,

we may ask ourselves the question: Is it the result of an acquired useful

habit to which anatomical conditions may subsequently have contributed as a

co-efficient? Primitive man depended largely upon gesture language, and the

placing of the hand over the heart is universally understood to signify

love and fidelity. Uneducated deaf mutes, whose only means of communicating

with their fellow-men is by gestures, not only use this sign, but imply

hatred also by holding the hand over the heart accompanied by the sign of

negation. Moreover, pointing to the heart accompanied by a cry of pain or

joy would indicate respectively death of an enemy or friend. Again,

primitive man protected himself from the weapons of his enemies by holding

the shield in his left hand, thus covering the heart and leaving the right

hand free to wield his spear. The question whether it would have been to

his advantage to use either hand indifferently for spear and shield has

been, to my mind, solved by the fact that in the long procession of ages

evolution has determined right-handed specialisation as being more

advantageous to the progress of mankind than ambidexterity.

Right-handedness is an inherited character in the same sense as the

potential power of speech.

LOCALISATION OF SPEECH CENTRES IN THE BRAIN

In 1863 Broca showed the importance in all right-handed people (that is in

about ninety-five per cent of all human beings) of the third \_left\_ frontal

convolution for speech (\_vide\_ figs. 16 and 17); when this is destroyed by

disease, although the patient can understand what is said and can

understand written and printed language, the power of articulate speech is

lost. \_Motor Aphasia\_. This portion of the brain is concerned with the

revival of the motor images, and has been termed by Dr. Bastian "the

glosso-kinæsthetic centre," or the cortical grey matter, in which the

images of the sense of movement of the lips and tongue are formed (\_vide\_

fig. 17). A destruction of a similar portion of the cortex in a

right-handed person produces no loss of speech; but if the person is

left-handed there is aphasia, because he, being left-handed, uses the third

\_right\_ inferior frontal convolution for speech. These facts have for long

been accepted by most neurologists, but recently doubts have been cast upon

this fundamental principle of cerebral localisation by a most distinguished

French neurologist, M. Marie; he has pointed out that a destructive lesion

of the cortex may be accompanied by subcortical damage, which interrupts

fibres coming from other parts of the brain connected with speech.

In the study of speech defects it is useful to employ a diagram; a certain

part of the brain corresponds to the \_Speech Zone\_ there indicated, and

lesions injuring any part of this area in the left hemisphere cause speech

defects (\_vide\_ fig. 17). All neurologists, M. Marie included, admit this,

and the whole question therefore is: Is a destruction of certain limited

regions of the superficial grey matter the cause of different forms of

speech defects, or are they not due more to the destruction of subcortical

systems of fibres, which lie beneath this cortical speech zone?

There is a certain portion of the speech zone which is assumed to be

connected with the revival of written or printed language, and is called

the \_visual word-centre\_. There is another region connected with the memory

of spoken words--the \_auditory word-centre\_; you will observe that it is

situated in the posterior third of the first temporal convolution, but this

does not comprise nearly the whole of it, for there is an extensive surface

of grey matter lying unseen within the fissure, called the transverse

convolutions, or gyri. Lesions of either of these regions give rise to

\_Sensory Aphasia\_, which means a loss of speech due to inability to revive

in memory the articulate sounds which serve as verbal symbols, or the

graphic signs which serve as visual symbols for language.

[Illustration: FIG. 17]

[Description: FIG. 17.--Diagram to illustrate the Speech Zone of the left

hemisphere (Bastian). This scheme is used to explain the mechanism of

speech, but probably the centres are not precisely limited, as shown in the

diagram; it serves, however, to explain disorders of speech. Destruction of

the brain substance in front of the central fissure gives rise to what is

termed Motor Aphasia and Motor Agraphia, because the patient no longer

recalls the images of the movements necessary for expressing himself in

articulate speech or by writing. Destructive lesions behind the central

fissure may damage the portion of the brain connected with the mental

perception of the sounds of articulate language, or the portion of the

brain connected with the mental perception of language in the form of

printed or written words--Sensory Aphasia; the former entails inability to

speak, the latter inability to read.

This speech zone acts as a whole, and many disorders of speech may arise

from destructive lesions within its limits. It has a special arterial

supply, viz. the middle cerebral, which divides into two main branches--an

anterior, which supplies the motor portion, and a posterior, which supplies

the posterior sensory portion. The anterior divides into two branches and

the posterior into three branches, consequently various limited portions of

the speech zone may be deprived of blood supply by blocking of one of these

branches. The speech zone of the left hemisphere directly controls the

centres in the medulla oblongata that preside over articulation and

phonation; innervation currents are represented by the arrows coming from

the higher to the lower centres.]

These several cortical regions are connected by systems of subcortical

fibres to two regions in front of the ascending frontal convolution (\_vide\_

fig. 17), called respectively the "glosso-kinæsthetic" (sense of movement

of tongue) and the "cheiro-kinæsthetic" (sense of movement of hand) centres.

Now a person may become hemiplegic and lose his speech owing either to the

blood clotting in a diseased vessel, or to detachment of a small clot from

the heart, which, swept into the circulation, may plug one of the arteries

of the brain. The arteries branch and supply different regions,

consequently a limited portion of the great brain may undergo destruction,

giving rise to certain localising symptoms, according to the situation of

the area which has been deprived of its blood supply. Upon the death of the

patient, a correlation of the symptoms observed during life and the loss of

brain substance found at the \_post-mortem\_ examination has enabled

neurologists to associate certain parts of the brain surface with certain

functions; but M. Marie very rightly says: None of the older observations

by Broca and others can be accepted because they were not examined by

methods which would reveal the extent of the damage; the only cases which

should be considered as scientifically reliable are those in which a

careful examination by sections and microscopic investigation have

determined how far subcortical structures and systems of fibres uniting

various parts of the cortex in the speech zone have been damaged. Marie

maintains that the speech zone cannot be separated into these several

centres, and that destruction of Broca's convolution does not cause loss of

speech (\_vide\_ figs. 16, 17). There are at present two camps--those who

maintain the older views of precise cortical centres, and those who follow

Marie and insist upon a revision.

Herbert Spencer says that "our intellectual operations are indeed mostly

confined to the auditory feelings as integrated into words and the visual

feelings as integrated into ideas of objects, their relations and their

motions."

Stricker by introspection and concentration of attention upon his own

speech-production came to the conclusion that the primary revival of words

was by the feeling of movements of the muscles of articulation; but there

is a fallacy here, for the more the attention is concentrated upon any

mental process the more is the expressive side brought into prominence in

consciousness. This can be explained by the fact that there is in

consequence of attention an increased outflow of innervation currents to

special lower executive centres, thence to the muscles, but every change of

tension in the speech muscles is followed by reciprocal incoming

impressions appertaining to the sense and feeling of the movement. The more

intense the sense of movement, the greater will be the effect upon

consciousness. In fact, a person who reads and thinks by articulating the

words, does so because experience has taught him that he can concentrate

his attention more perfectly; therefore his memory or understanding of the

subject read or thought of will be increased. Very many people think and

commit to memory by this method of concentrating attention; they probably

do not belong to the quick, perceptive, imaginative class, but rather to

those who have power of application and who have educated their minds by

close voluntary attention. Galton found a large proportion of the Fellows

of the Royal Society were of this motor type. But the fact that certain

individuals make use of this faculty more than others does not destroy the

arguments in favour of the primary revival of words in the great majority

of persons by a subconscious process in the auditory centre, which is

followed immediately by correlated revival of sensori-motor images.

Although the sensori-motor images of speech can be revived, it is almost

impossible without moving the hand to revive kinæsthetic impressions

concerned in writing a word. Both Ballet and Stricker admit this fact, and

it tends to prove that the sense of hearing is the primary incitation to

speech.

Charcot in reference to the interpretation of speech defects divided

persons into four classes--auditives, visuals, motors, and indifferents.

There are really no separate classes, but only different kinds of

word-memory in different degrees of excellence as regards the first three;

and as regards the fourth there is no one kind of memory developed to a

preponderating degree. Bastian doubts the second class, but does not deny

that the visual type may exist; for Galton has undoubtedly shown that

visual memory and power of recall of visual word images varies immensely in

different individuals, and it is unquestionable that certain individuals

possess the visualising faculty to an extraordinary degree; some few,

moreover, can see mentally every word that is uttered; they give their

attention to the visual symbolic equivalent and not to the auditory. Such

persons may, as Ribot supposes, habitually think and represent objects by

visual typographic images. Lord Macaulay and Sir James Paget were notable

possessors of this visualising faculty. The former is said to have been

able to read a column of "The Times" and repeat it \_verbatim\_; the latter

could deliver his lectures \_verbatim\_ as he had written them. Both saw

mentally the print or MS. in front of them.

Nevertheless it is a question of degree how much motor images enter into

silent thought and into the primary revival of words in different

individuals. Mach in "Analysis of Sensations" says: "It is true that in my

own case words (of which I think) reverberate loudly in my ear. Moreover, I

have no doubt that thoughts may be directly excited by the ringing of a

house-bell, by the whistle of a locomotive, etc., that small children and

even dogs understand words which they cannot repeat. Nevertheless I have

been convinced by Stricker that the ordinary and most familiar, though not

the only possible way, by which speech is comprehended is really \_motor\_

and that we should be badly off if we were without it. I can cite

corroborations of this view from my own experience. I frequently see

strangers who are endeavouring to follow my remarks slightly moving their

lips."

THE PRIMARY SITE OF REVIVAL OF WORDS IN SILENT THOUGHT

Since destructive lesions of the speech zone of the left hemisphere in

right-handed persons leads to inability to revive the memory pictures of

the sounds of words as heard in ordinary speech, the revival of visual

impressions as seen in printed or written characters, and of the

kinæsthetic (sense of movement) impressions concerned with the alterations

of the minute tensions of the muscle structures employed in the

articulation of words, it must be presumed that the left hemisphere in

right-handed persons is dominant in speech and silent thought; it may even

dominate the use of the left hand for many movements. But does not the

right hemisphere take a part? Yes; and I will give my reasons later for

supposing that the whole brain is in action. During the voluntary recall of

words in speech and thought by virtue of the intimate association tracts

connecting the grey matter of the whole speech zone, it is not a single

part of this zone which is in action, but the whole of it; and when we

assign to definite parts of the speech zone different functions in

connection with language, we really refer to areas in which the process is

most active or is primarily initiated, for the whole brain is in action

just as it is in the recognition of an object which we see, hear, feel, or

move. What really comes before us is contributed more by the mind itself

than by the present object.

There is, however, a direct functional association between the auditory and

glosso-kinæsthetic (sense of movement of the tongue) centres on the one

hand and the visual and cheiro-kinæsthetic (sense of movement of the hand)

on the other. No less intimate must be the connection between the auditory

word-centre and the visual word-centre; they must necessarily be called

into association actively in successive units of time, as in reading aloud

or writing from dictation. Educated deaf mutes think with revived visual

symbols either of lips or fingers. Words are to a great extent symbols

whereby we carry on thought, and thinking becomes more elaborate and

complex as we rise in the scale of civilisation, because more and more are

verbal symbols instituted for concrete visual images.

In which portion of the brain are words primarily and principally revived

during the process of thinking? I have already alluded to the views of

Stricker and those who follow him, viz. that words are the revived images

of the feelings of the sense of movement, caused by the alteration in the

tension of the muscles of articulation occurring during speech, with or

without phonation. There is another which I think the correct view, that

words are revived in thought primarily as auditory images, so that the

sense of hearing is essential for articulation as well as phonation; the

two operations of the vocal organ as an instrument of the mind being

inseparable. The arguments in favour of this are:--

1. The part of the brain concerned with the sense of hearing develops

earlier and the nerve fibres found in this situation are myelinated[1] at

an earlier period of development of the brain than the portion connected

with the sense of movement of the muscles of articulation.

[Footnote 1: The covering of the fibres by a sheath of phosphoretted fat

serving to insulate the conductile portion of the nerve is an indication

that the fibre has commenced to function as a conductor of nervous

impulses.]

2. As a rule, the child's first ideas of language come through the sense of

hearing; articulate speech is next evolved, in fact the child speaks only

that which it has heard; it learns first to repeat the names of persons and

objects with which it comes into relation, associating visual images with

auditory symbols.

An example of this was communicated by Darwin to Romanes. One of his

children who was just beginning to speak, called a duck a "quack." By an

appreciation of the resemblance of qualities it next extended the term

"quack" to denote all birds and insects on the one hand, and all fluid

objects on the other. Lastly, by a still more delicate appreciation of

resemblance the child called all coins "quack" because on the back of a

French sou it had seen the representation of an eagle (Romanes' "Mental

Evolution in Man," p. 183). Later on, children who have been educated

acquire a knowledge of the application of visual symbols, and how to

represent them by drawing and writing, and associate them with persons and

objects.

3. There is more definiteness of impression and readiness of recall for

auditory than for articulatory motor sense feelings.

4. After the acquirement of speech by the child, auditory feelings are

still necessary for articulate speech processes; for if it were not so, how

could we explain the fact that a child up to the fifth or sixth year in

full possession of speech will become dumb if it loses the sense of hearing

from middle-ear disease, unless it be educated later by lip language.

5. Cases have been recorded of bilateral lesion of the auditory centre of

the brain producing loss of hearing and loss of speech, the motor centres

being unaffected. This is called Wernicke's sensory aphasia. The following

case occurring in my own practice is probably the most complete instance

recorded.

CASE OF DEAFNESS ARISING FROM DESTRUCTION OF THE AUDITORY CENTRES IN THE

BRAIN CAUSING LOSS OF SPEECH

A woman at the age of twenty suddenly became unconscious and remained so

for three hours; on recovery of consciousness it was found she could not

speak; this condition remained for a fortnight; speech gradually returned,

although it was impaired for a month or more. She married, but soon after

marriage she suddenly lost her hearing completely, remaining permanently

stone deaf; and although she could understand anything of a simple

character when written, and was able imperfectly to copy sentences, she was

unable to speak. Once, however, under great emotional excitement, while I

was examining her by written questions, she uttered, "Is that." But she was

never heard to speak again during the subsequent five years that she lived.

The utterance of those two words, however, showed that the loss of speech

was not due to a defect of the physiological mechanism of the vocal

instrument of speech, nor to the motor centres in the brain that preside

over its movements in the production of articulate speech. She recognised

pictures and expressed satisfaction or dissatisfaction when correct or

incorrect names were written beneath the pictures; moreover, in many ways,

by gestures, facial expression, and curious noises of a high-pitched,

musical, whining character, showed that she was not markedly deficient in

intelligence. Although in an asylum and partially paralysed, she was not

really insane in the proper sense, but incapable of taking care of herself.

When other patients were getting into mischief this patient would give a

warning to the attendants by the utterance of inarticulate sounds, showing

that she was able to comprehend what was taking place around and reason

thereon, indicating thereby that although stone deaf and dumb, it was

probable that she possessed the power of silent thought. I observed that

during emotional excitement the pitch of the sounds she uttered increased

markedly with the increase of excitement. After having been discharged from

Claybury Asylum she was sent to Colney Hatch Asylum. Upon one of my visits

to that institution I learnt that she had been admitted, and upon my

entering the ward, although more than a year had elapsed since I last saw

her, she immediately and from afar recognised me; and by facial expression,

gesture, and the utterance of inarticulate sounds showed her great pleasure

and satisfaction in seeing one who had taken a great interest in her case.

This poor woman must have felt some satisfaction in knowing that someone

had interpreted her mental condition, for of course, her husband and

friends did not understand why she could not speak. I may mention that the

first attack of loss of speech was attributed to hysteria.

This woman died of tuberculosis seven years after the second attack, and

examination of the brain \_post-mortem\_ revealed the cause of the deafness.

There was destruction of the centre of hearing in both hemispheres (\_vide\_

fig. 17), caused by blocking of an artery supplying in each hemisphere that

particular region with blood. The cause of the blocking of the two arteries

was discovered, for little warty vegetations were found on the mitral valve

of the left side of the heart. I interpreted the two attacks thus: one of

these warty vegetations had become detached, and escaping into the arterial

circulation, entered the left carotid artery and eventually stuck in the

posterior branch of the middle cerebral artery, causing a temporary loss of

word memory, consequently a disturbance of the whole speech zone of the

left hemisphere. This would account for the deafness to spoken language and

loss of speech for a fortnight, with impairment for more than a month,

following the first attack. But both ears are represented in each half of

the brain; that is to say, sound vibrations entering either ear, although

they produce vibrations only in one auditory nerve, nevertheless proceed

subsequently to both auditory centres. The path most open, however, for

transmission is to the opposite hemisphere; thus the right hemisphere

receives most vibrations from the left ear and \_vice versa\_. Consequently

the auditory centre in the right hemisphere was able very soon to take on

the function of associating verbal sounds with the sense of movement of

articulate speech and recovery took place. \_But\_, when by a second attack

the corresponding vessel of the opposite half of the brain was blocked the

terminal avenues, and the central stations for the reception of the

particular modes of motion associated with sound vibration of all kinds

were destroyed \_in toto\_; and the patient became stone deaf. It would have

been extremely interesting to have seen whether, having lost that portion

of the brain which constitutes the primary incitation of speech, this

patient could have been taught lip language.

There is no doubt that persons who become deaf from destruction of the

peripheral sense organ late in life do not lose the power of speech, and

children who are stone deaf from ear disease and dumb in consequence can be

trained to learn to speak by watching and imitating the movements of

articulation. Helen Keller indeed, although blind, was able to learn to

speak by the education of the tactile motor sense. By placing the hand on

the vocal instrument she appreciated by the tactile motor sense the

movements associated with phonation and articulation. The tactile motor

sense by education replaced in her the auditory and visual senses. The

following physiological experiment throws light on this subject. A dog that

had been deprived of sight by removal of the eyes when it was a puppy found

its way about as well as a normal dog; but an animal made blind by removal

of the occipital lobes of the brain was quite stupid and had great

difficulty in finding its way about. Helen Keller's brain, as shown by her

accomplishments in later life, was a remarkable one; not long after birth

she became deaf and blind, consequently there was practically only one

avenue of intelligence left open for the education of that brain, viz. the

tactile kinæsthetic. But the tactile motor sense is the active sense that

waits upon and contributes to every other sense. The hand is the instrument

of the mind and the agent of the will; consequently the tactile motor sense

is intimately associated in its structural representation in the brain with

every other sense. This avenue being open in Helen Keller, was used by her

teacher to the greatest possible advantage, and all the innate

potentialities of a brain naturally endowed with remarkable intellectual

powers were fully developed, and those cortical structures which normally

serve as the terminal stations (\_vide\_ fig. 16) for the reception and

analysis of light and sound vibrations were utilised to the full by Helen

Keller by means of association tracts connecting them with the tactile

motor central stations. The brain acts as a whole in even the simplest

mental processes by virtue of the fact that the so-called functional

centres in the brain are not isolated fields of consciousness, but are

inextricably associated one with another by association fibres.

THE PRIMARY REVIVAL OF SOME SENSATIONS IN THE BRAIN

I have on page 77 referred to Stricker's views on the primary revival of

words in the sense of movement of the lips and tongue. Mach ("Analysis of

the Sensations") says: "The supposition that the processes in the larynx

during singing have had something to do with the formation of the tonal

series I noticed in one of my earlier publications, but did not find it

tenable. Singing is connected in too extrinsic and accidental a manner with

hearing to bear out such an hypothesis. I can hear and imagine tones far

beyond the range of my own voice. In listening to an orchestral performance

with all the parts, or in having an hallucination of such a performance, it

is impossible for me to think that my understanding of this broad and

complicated sound-fabric has been effected by my \_one\_ larynx, which is,

moreover, no very practised singer. I consider the sensations which in

listening to singing are doubtless occasionally noticed in the larynx a

matter of subsidiary importance, like the pictures of the keys touched

which when I was more in practice sprang up immediately into my imagination

on hearing a performance on the piano or organ. When I imagine music, I

always distinctly hear the notes. Music can no more come into being merely

through the motor sensations accompanying musical performances, than a deaf

man can hear by watching the movements of players. I cannot therefore agree

with Stricker on this point" (comp. Stricker, "Du langage et de la

musique," Paris, 1885).

Of the motor type myself and having a fairly good untrained ear for music,

I find that to memorise a melody, whether played by an instrument or by an

orchestra, I must either try to sing or hum that melody in order to fix it

in my memory. Every time I do this, association processes are being set up

in the brain between the auditory centres and the centres of phonation; and

when I try to revive in my silent thoughts the melody again, I do so best

by humming aloud a few bars of the melody to start the revival and then

continuing the revival by maintaining the resonator in the position of

humming the tune, viz. with closed lips, so that the sound waves can only

escape through the nose; under such circumstances the only definite

conscious muscular sensation I have is from the effect of closure of the

lips; the sensations from the larynx are either non-existent or quite

ill-defined, although I hear mentally the tonal sensations of the melody.

No doubt by closing the lips in silent humming I am in some way

concentrating attention to the sensori-motor sphere of phonation and

articulation, and by reactive association with the auditory sphere

reinforcing the tonal sensations in the mind. The vocal cords (ligaments)

themselves contain very few nerve fibres; those that are seen in the deeper

structures of the cords and adjacent parts mainly proceed to the mucous

glands. This fact, which I have ascertained by numerous careful

examinations, is in accordance with the fact that there are no conscious

kinæsthetic impressions of alterations of position and tension of the vocal

cords. A comparative microscopic examination of the tip of the tongue and

the lips shows a remarkable difference, for these structures are beset with

innumerable sensory nerves, whereby every slightest alteration of tension

and minute variations in degrees of pressure of the covering skin is

associated with messages thereon to the brain. The sense of movement in

articulate speech is therefore explained by this fact. There is every

reason then to believe that auditory tonal images are the sole primary and

essential guides to the minute alterations of tension in the muscles of the

larynx necessary for the production of corresponding vocal sounds. By

humming a tune we concentrate our attention and thereby limit the activity

of neural processes to systems and communities of neurones employed for the

perception of tonal images and their activation in motor processes; and

this helps to fix the tune in the memory.

PSYCHIC MECHANISM OF THE VOICE

A musical speaking voice denotes generally a good singing voice, and it

must be remembered that articulation cannot be separated from phonation in

the psychic mechanism. In speaking, we are unconscious of the breath

necessary for the production of the voice. Not so, however, in effective

singing, the management of the breathing being of fundamental importance;

and it is no exaggeration to say that only the individual who knows how to

breathe knows how to sing effectually. A musical ear and sense of rhythm

are innate in some individuals; in others they are not innate and can only

be acquired to a variable degree of perfection by persevering efforts and

practice. The most intelligent persons may never be able to sing in tune,

or even time; the latter (sense of rhythm) is much more easily acquired by

practice than the former (correct intonation). This is easily intelligible,

for rhythmical movement appertains also to speech and other acts of human

beings, e.g. walking, dancing, running, swimming, etc.; moreover,

rhythmical periodicity characterises the beat of the heart and respiration.

But how does a trained singer learn to sing a song or to take part in an

opera? He has to study the performances of two parts for the vocal

instrument--the part written by the composer and the part written by the

poet or dramatist--and in order to present an artistic rendering, the

intellectual and emotional characters of each part must be blended in

harmonious combination. A singer will first read the words and understand

their meaning, then memorise them, so that the whole attention subsequently

may be given to applying the musical part to them and employing with proper

phrasing, which means more than knowing when to breathe; it means imparting

expression and feeling. A clever actor or orator can, if he possess a high

degree of intelligence and a fairly artistic temperament, so modulate his

voice as to convey to his audience the passions and emotions while feeling

none of them himself; so many great singers who are possessed of a good

musical ear, a good memory, and natural intelligence, although lacking in

supreme artistic temperament and conspicuous musical ability, are

nevertheless able to interpret by intonation and articulation the passions

and emotions which the composer has expressed in his music and the poet or

dramatist in his words. The intelligent artist possessed of the musical

ear, the sense of rhythm, and a well-formed vocal organ accomplishes this

by the conscious control and management of his breathing muscles and the

muscles of articulation, which by education and imitation he has brought

under complete control of the will. With him visual symbols of musical

notes are associated with the visual symbols of words in the mind, and the

visual symbols whether of the words or of the musical notes will serve to

revive in memory the sound of the one or the other, or of both. But he

produces that sound by alteration of tension in co-ordinated groups of

muscles necessary for vocalisation, viz. the muscles of phonation in the

larynx, the muscles of articulation in the tongue, lips, jaw, and palate,

and the muscles of costal respiration. \_The mind\_ of the orator, actor, and

dramatic singer exercises a profound influence upon the respiratory system

of nerves, and thereby produces the necessary variations in the force,

continuance, and volume of air required for vocal expression.

Sir Charles Bell, who discovered the respiratory system of nerves, pointed

out how the lungs, from being in the lower animals merely the means of

oxygenating the blood, become utilised in the act of expelling air from the

body for the production of audible sounds--the elements of human voice and

speech. Likewise he drew attention to the influence which powerful emotions

exercise upon the organ of respiration, including the countenance, e.g. the

dilated nostrils in anger. Again, "when the voice suffers interruption and

falters, and the face, neck, and chest are animated by strong passion

working from within the breast, language exerts its most commanding

influence."

In hemiplegia or paralysis of one half of the body, there is a difference

between the two sides for ordinary automatic unconscious diaphragmatic

breathing and voluntary or costal breathing. Thus in ordinary breathing the

movements are increased on the paralysed side, especially in the upper part

of the chest, while in voluntary breathing they are increased on the sound

side. Hughlings Jackson suggested the following theory to explain these

facts: "\_Ordinary breathing\_ is an automatic act governed by the

respiratory centre in the medulla. The respiratory centre is double, each

side being controlled or inhibited by higher centres on the opposite side

of the brain. Voluntary costal breathing, such as is employed in singing,

is of cerebral origin, and controlled by centres on the opposite side of

the brain, the impulses being sent down to the respective centres for the

associated movements of the muscles of articulation, phonation, and

breathing, in the same way as they are sent to the centres for the

movements of the arm or leg. With voluntary breathing the respiratory

centre in the medulla has nothing to do. It is in fact out of gear or

inhibited for the time being, so that the impulses from the brain pass by

or evade it. There are thus two sets of respiratory nerve fibres passing

from the brain--the one inhibiting or controlling to the opposite half of

the respiratory centre in the medulla; the other direct, evading the

respiratory centre and running the same course to the spinal centres for

the respiratory movements as the ordinary motor fibres do to the centres

for other movements. Both sets would be affected by the lesion (or damage)

which produced the hemiplegia. The inhibitory fibres being damaged, the

opposite half of the respiratory centre would be under diminished control

and therefore the movements of ordinary breathing on the paralysed side

would be exaggerated. The damage to the direct fibres would prevent the

passage of voluntary stimuli to the groups of respiratory muscles (as it

would do to the rest of the muscles of the paralysed side), and thus the

voluntary movement of respiration would be diminished--diminished only and

not completely abolished as in the limbs; because according to the theory

of Broadbent, in the case of such closely associated bilateral movements

the lower nervous respiratory centres of both sides would be activated from

either side of the brain." This certainly applies also to the muscles of

phonation, but not to the principal muscles of articulation, viz. the

tongue and lips. It is not exactly known what part of the cerebral cortex

controls the associated movements necessary for voluntary costal (rib)

respiration in singing; probably it is localised in the frontal lobe in

front of that part, stimulation of which gives rise to trunk movements

(\_vide\_ fig. 16). Whatever its situation, it must be connected by

association fibres with the centres of phonation and articulation.

[Illustration: FIG. 18]

[Description: FIG. 18.--The accompanying diagram is an attempt to explain

the course of innervation currents in phonation.

1. Represents the whole brain sending voluntary impulses \_V\_ to the regions

of the brain presiding over the mechanisms of voluntary breathing and

phonation. These two regions are associated in their action by fibres of

association \_A\_; moreover, the corresponding centres in the two halves of

the brain are unified in their action by association fibres \_A'\_ in the

great bridge connecting the two hemispheres (Corpus Callosum). On each side

of the centre for phonation are represented association fibres \_H\_ which

come from the centre of hearing; these fibres convey the guiding mental

images of sounds and determine exactly the liberation of innervation

currents from the centre of phonation to the lower centres by which the

required alterations in tension of the laryngeal muscles for the production

of the corresponding sounds are effected. Arrows are represented passing

from the centre of phonation to the lower centres in the medulla which

preside over the muscles of the jaw, tongue, lips, and larynx. Arrows

indicate also the passage of innervation currents from the centres in the

brain which preside over voluntary breathing. It will be observed that the

innervation currents which proceed from the brain pass over to the opposite

side of the spinal cord and are not represented as coming into relation

with the respiratory centre \_R\_. This centre, as we have seen, acts

automatically, and exercises especially its influence upon the diaphragm,

which is less under the control of the will than the elevators of the ribs

and the abdominal muscles.

The diagram also indicates why these actions of voluntary breathing and

phonation can be initiated in either hemisphere; it is because they are

always bilaterally associated in their action; consequently both the higher

centres in the brain and the lower centres in the medulla oblongata and

spinal cord are united by bridges of association fibres, the result being

that even if there is a destruction of the brain at \_a-b\_, still the mind

and will can act through both centres, although not so efficiently.

Likewise, if there is a destruction of the fibres proceeding from the brain

centres to the lower medullary and spinal centres, the will is still able

to act upon the muscles of phonation and breathing of both sides of the

body because of the intimate connection of the lower medullary and spinal

centres by association fibres.]

Experiments on animals and observations on human beings show that the

centres presiding over the muscles of the larynx are situated one in each

hemisphere, at the lower end of the ascending frontal convolution in close

association with that of the tongue, lips, and jaw. This is as we should

expect, for they form a part of the whole cerebral mechanism which presides

over the voice in speech and song. But because the muscles of the tongue,

the lower face muscles, and even the muscles of the jaw do not necessarily

and always work synchronously and similarly on the two sides, there is more

independence in their representation in the cerebral cortex. Consequently a

destruction of this region of the brain or the fibres which proceed from it

to the lower executive bulbar and spinal centres is followed by paralysis

of the muscles of the opposite side. Likewise stimulation with an

interrupted electric current applied to this region of the brain in monkeys

by suitable electrodes produces movements of the muscles of the lips,

tongue, and jaw of the opposite side only. Not so, however, stimulation of

the region which presides over the movements of the muscles of the larynx,

for then \_both\_ vocal cords are drawn together and made tense as in

phonation. It is therefore not surprising if removal or destruction of this

portion of the brain \_on one side\_ does not produce paralysis of the

muscles of phonation, which, always bilaterally associated in their

actions, are represented as a bilateral group in both halves of the brain.

These centres may be regarded as a part of the physiological mechanism, but

the brain acts as a whole in the psychic mechanism of speech and song. From

these facts it appears that there is: (1) An automatic mechanism for

respiration and elemental phonation (the cry) in the medulla oblongata

which can act independently of the higher centres in the brain and even

without them (\_vide\_ p. 18). (2) A cerebral conscious voluntary mechanism

which controls phonation either alone or associated with articulation. The

opening of the glottis by contraction of the abductor (posterior

ring-pyramid muscles) is especially associated with descent of the

diaphragm in inspiration in ordinary breathing; whereas the voluntary

breathing in singing is associated with contraction of the adductor and

tensor muscles of the vocal cords.

A perfect psychic mechanism is as necessary as the physiological mechanism

for the production of perfect vocalisation, especially for dramatic

singing. A person, on the one hand, may be endowed with a grand vocal

organ, but be a failure as a singer on account of incorrect intonation, of

uncertain rhythm or imperfect diction; on the other hand, a person only

endowed with a comparatively poor vocal instrument, but knowing how to use

it to the best advantage, is able to charm his audience; incapable of

vigorous sound production, he makes up for lack of power by correct

phrasing and emotional expression. We see then that the combination of a

perfect physiological and psychological mechanism is essential for

successful dramatic singing, the chief attributes of which are: (1) Control

of the breath, adequate volume, sustaining power, equality in the force of

expulsion of air to avoid an unpleasant vibrato, and capability of

producing and sustaining loud or soft tones throughout the register. (2)

Compass or range of voice of not less than two octaves with adequate

control by mental perception of the sounds of the necessary variation in

tension of the laryngeal muscles for correct intonation. (3) Rich quality

or timbre, due partly to the construction of the resonator, but in great

measure to its proper use under the control of the will. Something is

lacking in a performance, however perfect the vocalisation as regards

intonation and quality, if it fails to arouse enthusiasm or to stir up the

feelings of an audience by the expression of passion or sentiment through

the mentality of the singer.

The general public are becoming educated in music and are beginning to

realise that shouting two or three high-pitched chest notes does not

constitute dramatic singing--"a short \_beau moment\_ does not compensate for

a \_mauvais quart d'heure\_." It would be hard to describe or define the

qualities that make a voice appeal to the multitude. Different singers with

a similar timbre of voice and register may sing the same song correctly in

time, rhythm, and phrasing, and yet only one of them may produce that

sympathetic quality necessary to awaken not only the intellectual but the

affective side of the mind of the hearers. Undoubtedly the effects produced

upon the mind by dramatic song largely depend upon circumstances and

surroundings, also upon the association of ideas. Thus I was never more

stirred emotionally by the human voice than upon hearing a mad Frenchman

sing at my request the Marseillaise. Previously, when talking to him his

eyes had lacked lustre and his physiognomy was expressionless; but when

this broad-chested, six foot, burly, black-bearded maniac rolled out in a

magnificent full-chested baritone voice the song that has stirred the

emotions and passions of millions to their deepest depth, and aroused in

some hope, in others despair, as he made the building ring with "Aux armes,

citoyens, formez vos bataillons" I felt an emotional thrill down the spine

and a gulp in the throat, while the heart and respirations for an instant

stayed in their rhythmical course. Not only was I stirred by the effect of

the sounds heard, but by the change in the personality of the singer. It

awakened in my mind the scenes in the French Revolution so vividly

described by Carlyle. The man's facial expression and whole personality

suddenly appeared changed; he planted his foot firmly forward on the

ground, striking the attitude of a man carrying a musket, a flag, or a

pike; his eyes gleamed with fire and the lack-lustre expression had changed

to one of delirious excitement. A pike in his hand and a red cap on his

head would have completed the picture of a \_sans culotte\_. Dramatic song

therefore that does not evoke an emotional response is \_vox et præterea

nihil\_.

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