Rhomboideus; (5) from the number of their divisions, as the Biceps and Triceps; (6) from their points of attachment, as the Sternoclavicularis, Sternohyoideus, Sternothyroideus.

In the description of a muscle, the term **origin** is meant to imply its more fixed or central attachment; and the term **insertion** the movable point on which the force of the muscle is applied; but the origin is absolutely fixed in only a small number of muscles, such as those of the face which are attached by one extremity to immovable bones, and by the other to the movable integument; in the greater number, the muscle can be made to act from either extremity.

In the dissection of the muscles, attention should be directed to the exact **origin**, **insertion**, and **actions** of each, and to its more important **relations** with surrounding parts. While accurate knowledge of the points of attachment of the muscles is of great importance in the determination of their actions, it is not to be regarded as conclusive. The action of the muscle deduced from its attachments, or even by pulling on it in the dead subject, is not necessarily its action in the living. By pulling, for example, on the Brachioradialis in the cadaver the hand may be slightly supinated when in the prone position and slightly pronated when in the supine position, but there is no evidence that these actions are performed by the muscle during life. It is impossible for an individual to throw into action any one muscle; in other words, movements, not muscles, are represented in the central nervous system. To carry out a movement a definite combination of muscles is called into play, and the individual has no power either to leave out a muscle from this combination or to add one to it. One (or more) muscle of the combination is the chief moving force; when this muscle passes over more than one joint other muscles (**synergic muscles**) come into play to inhibit the movements not required; a third set of muscles (**fixation muscles**) fix the limb—i.e., in the case of the limb-movements—and also prevent disturbances of the equilibrium of the body generally. As an example, the movement of the closing of the fist may be considered: (1) the prime movers are the Flexores digitorum, Flexor pollicis longus, and the small muscles of the thumb; (2) the synergic muscles are the Extensor carpi, which prevent flexion of the wrist; while (3) the fixation muscles are the Biceps and Triceps brachii, which steady the elbow and shoulder. A further point which must be borne in mind in considering the actions of muscles is that in certain positions a movement can be effected by gravity, and in such a case the muscles acting are the antagonists of those which might be supposed to be in action. Thus in flexing the trunk when no resistance is interposed the Sacrospinales contract to regulate the action of gravity, and the Iliac abdominii are relaxed.¹

By a consideration of the action of the muscles, the surgeon is able to explain the causes of displacement in various forms of fracture, and the causes which produce distortion in various deformities, and, consequently, to adopt appropriate treatment in each case. The relations, also, of some of the muscles, especially those in immediate apposition with the larger bloodvessels, and the surface markings they produce, should be remembered, as they form useful guides in the application of ligatures to those vessels.

**MECHANICS OF MUSCLE.²**

In studying the mechanical action of muscles the individual muscle cannot always be treated as a single unit, since different parts of the same muscle may have entirely different actions, as with the Pectoralis major, the Deltoidei, and the Trapezius where the nerve impulses control and stimulate different portions of the

¹ Consult in this connection the Croceian Lectures (1903) on "Muscular Movements and Their Representation in the Central Nervous System," by Charles E. Boevoit, M.D.

² R. Fick. Ed. ii. in Barthieben’s Handbuch der Anatomie des Menschen.
muscle in succession or at different times. Most muscles are, however, in a mechanical sense units. But in either case the muscle fibers constitute the elementary motor elements.

![Fig. 361](image1)

**The Direction of the Muscle Pull.** In those muscles where the fibers always run in a straight line from origin to insertion in all positions of the joint, a straight line joining the middle of the surface of origin with the middle of the insertion surface will give the direction of the pull (Fig. 361). If, however, the muscle or its tendon is bent out of a straight line by a bony process or ligament so that it runs over a pulley-like arrangement, the direction of the muscle pull is naturally bent out of line. The direction of the pull in such cases is from the middle point of insertion to the middle point of the pulley where the muscle or tendon is bent. Muscles or tendons of muscles which pass over more than one joint and pass through more than
one pulley may be resolved, so far as the direction of the pull is concerned, into two
or more units or single-joint muscles (Fig. 362). The tendons of the Flexor pro-
dfundus digitorum, for example, pass through several pulleys formed by fibrous
sheaths. The direction of the pull is different for each joint and varies for each
joint according to the position of the bones. The direction is determined in each
case, however, by a straight line between the centers of the pulleys on either side of
the joint (Fig. 363). The direction of the pull in any of the segments would not
be altered by any change in the position or origin of the muscle belly above the
proximal pulley.

The Action of the Muscle Pull on the Tendon.—Where the muscle fibers are parallel
or nearly parallel to the direction of the tendon the entire strength of the muscle
contraction acts in the direction of the tendon.

In pinnate muscles, however, only a portion of the strength of contraction is effi-
cient in the direction of the tendon, since a portion of the pull would tend to draw
the tendon to one side, this is mostly annulled by pressure of surrounding parts.
In bipinnate muscles this lateral pull is counterbalanced. If, for example, the muscle
fibers are inserted into the tendon at an angle of 60
°
 degrees (Fig. 364), it is easy to determine by the
parallelogram of forces that the strength of the pull
along the direction of the tendon is equal to one-half
the muscle pull.

\[ T = \text{tendon, } m = \text{strength and direction of muscle pull.} \]
\[ t = \text{component acting in the direction of the tendon.} \]
\[ \phi = \text{angle of insertion of muscle fibers into tendon.} \]
\[ \cos \phi = \frac{t}{m} \]
\[ \cos 60^\circ = 0.50000 \]
\[ 0.5 = \frac{t}{m} \]
\[ t = \frac{1}{2} m \]

If \[ \phi = 72^\circ 30' \]
\[ \cos = \frac{1}{2} \]
\[ \phi = 41^\circ 20' \]
\[ \cos = \frac{1}{2} \]
\[ \phi = 90^\circ \]
\[ \cos = 0 \]
\[ \phi = 0^\circ \]
\[ \cos = 1 \]

The more acute the angle \( \phi \), that is the smaller
the angle, the greater the component acting in the
direction of the tendon pull. At 41° 20' three-fourths
of the pull would be exerted in the direction of the
tendon and at 0° the entire strength. On the other
hand, the greater the angle the smaller the tendon component; at 72° 30' one-third
the muscle strength would act in the direction of the tendon and at 90° the tendon
component would be nil.

The Strength of Muscles.—The strength of a muscle depends upon the number of
fibers in what is known as the physiological cross-section, that is, a section which
passes through practically all of the fibers. In a muscle with parallel or nearly
parallel fibers which have the same direction as the tendon this corresponds to the
anatomical cross-section, but in unipinnate and bipinnate muscles the physiological
cross-section may be nearly at right angles to the anatomical cross-section as shown
in Fig. 365. Since Huber has shown that muscle fibers in a single fasciculus of a
given muscle vary greatly in length, in some fasciculi from 9 mm. to 30.4 mm., it
is unlikely that the physiological cross-section will pass through all the fibers.
Estimates have been made of the strength of muscles and it is probable that coarse-fi-
bered muscles are somewhat stronger per square centimeter of physiological
cross-section than are the fine-fibered muscles. Fick estimates the average strength as about 10 kg. per square cm. This is known as the absolute muscle strength. The total strength of a muscle would be equal to the number of square centimeters in its physiological cross-section \( \times \) 10 kg.

The Work Accomplished by Muscles.—For practical uses this should be expressed in kilogrammeters. In order to reckon the amount of work which a muscle can perform under the most favorable conditions it is necessary to know (1) its physiological cross-section (2) the maximum shortening, and (3) the position of the joint when the latter is obtained.

Work = lifted weight \( \times \) height through which the weight is lifted; or

Work = tension \( \times \) distance; tension = physiological cross-section \( \times \) absolute muscle strength.

If a muscle has a physiological cross-section of 5 sq. cm. its tension strength = 5 \( \times \) 10 or 50 kg. If it shortens 5 cm., the work = 50 \( \times \) .05 = 2.5 kilogrammeters. If one determines then the physiological cross-section and multiplies the absolute muscle strength, 10 kg. by this, the amount of tension is easily obtained. Then one must determine only the amount of shortening of the muscle for any particular position of the joint in order to determine the amount of work the muscle can do, since work = tension \( \times \) distance.

The tension of a muscle is, however, not constant during the course of contraction but is continually decreasing during contraction. It is at a maximum at the beginning and gradually decreases.

This can be illustrated by the work diagram Fig. 366.

- \( A M \) = (ordinate) = tension.
- \( A V \) = (abscissa) = shortening.
- \( A D \) = tension of muscle in extended or antagonistic position.
- \( A V \) = amount of actual shortening.
- \( A M \) = tension in midposition = absolute muscle strength.
- \( D V \) = shows how the tension sinks from maximum (in the extended position of the muscle) where it is about double that in the midposition (\( M \)) to nothing on complete contraction.
$\Delta ADV$ – work diagram, in reality the hypothenose is not straight but has a concave curve. The $\Delta$ has the same area as the rectangle $AM\cdot M'V$. $AM$ = the average tension.

Work = $AM \times AV$ kilogrammeters if the size of the ordinate as expressed in kilograms and the abscissa in meters.

![Diagram of muscle tension and shortening](image)

Although the muscle works with a changing tension, yet the accomplishment is the same as if it were contracting with the tension of the midposition.

In reality the amount of work is somewhat greater since even in extreme contraction the muscle still retains a certain amount of tension so that the maximum amount of work is more nearly like $ADX$. We know that a muscle may have an extreme actual shortening of about 80 per cent. of its length when the tendon of insertion is cut.

The trapezoid $ADSV$ represents more nearly the amount of work, but since there are only approximate values and $ADSV$ is not much larger than $AMM'V$, we may use the latter.

Only the tension and amount of shortening are needed to determine the amount of work of the muscle. Neither the lever arm nor the fiber angle in pinnate muscles need be considered.

The diagram Fig. 367 shows that the lever arm is of no importance for determining the amount of work the muscle performs.

$JB$ and $JB'$ = two bones jointed at $J$. $CD$ and $EF$ = the direction of the pull of two muscles of equal cross-section, each having a muscle tension of 1000 gms.

The centers of the attachments are such that perpendiculars $Je$ and $Jc$ to $CD$ and $EF$ are equal to 40 and 23 mm. respectively, $Jc = 40$ mm. and $Je = 23$ mm. The static moments are equal to $1000 \times 40$ and $1000 \times 23$, therefore the first muscle can hold a much larger load ($L$) on the bone $JB'$ at $H'$ (100 mm. from $J$) than the second muscle whose load can be designated as $L'$.

Equilibrium exists for the first muscle if

$L \times 100 = 1000 \times 40$ or $L = \frac{1000 \times 40}{100} = 400$ gms.

For the second muscle $L' \times 100 = 1000 \times 23$.

$L' = \frac{1000 \times 23}{100} = 230$ gms.

If we suppose $JB$ to be fixed and $JB'$ to move in the plane of the paper about $J$ and the muscle $CD$ to shorten 5 mm. $Cd = CD - 5$ mm. and with the tension of 1000 gms., $JB'$ will take the position $JB''$ and the load ($L$) will be lifted from $H'$ to $H''$. 

Digitized by Google
If the second muscle likewise shortens 5 mm., then \( E_J = E_J - 5 \text{ mm.} \), and with the tension of 1000 gms. the bone \( J B \) will take the position \( J B' \) and the weight or load (\( W \)) will be lifted from \( H' \) to \( HP \). The question now is to prove that the work done is the same in both cases, namely, 5 \( \times \) 1000 grammillimeters.

If so, 400 \( \times \) \( H' \) \( H'' = 230 \times \) \( H' \) \( H'' = 5000 \text{ grammillimeters.} \)

Since the two radii \( C d \) and \( C d' \) are very long as compared with the arc \( d d' \) we may consider this short arc as as a line \( \perp \) to \( C D \) at \( d' \); likewise the arc \( f f' \) may be considered as a straight line \( \perp \) to \( E F \). In the same manner we can consider the short arcs \( F f, D d, H' H'' \) and \( H' H'' \perp \) to the line \( J B' \). The sides \( D d' \) and \( F f' \) of the \( \triangle D d' f \) and \( F f' f' \) are each 5 mm.

The lever arm \( D J = 60 \text{ mm.} \) and \( J F = 30 \text{ mm.} \)

The \( \triangle D d' d' \) is similar to the \( \triangle D e J \)

\[
\begin{align*}
\text{hence } D d & : 5 :: 60 : 40 \quad D d = \frac{300}{40} \\
\text{also } H' H'' : D d :: 100 : 60 \\
H' H'' : \frac{300}{40} :: 100 : 60 \quad H' H'' = \frac{300}{24}
\end{align*}
\]

The \( \triangle F f f' \) is similar to \( F e J \)

\[
\begin{align*}
\text{hence } F f & : 5 :: 30 : 23 \quad F f = \frac{150}{23} \\
\text{also } H' H'' : F f :: 100 : 30 \\
H' H'' : \frac{150}{23} :: 100 : 30 \quad H' H'' = \frac{1500}{69}
\end{align*}
\]

\[
\therefore \quad 400 \times \frac{300}{24} = 230 \times \frac{1500}{69} = 5000
\]

Thus we see that the work of the two muscles depends on the size of the contraction and on the tension and not on the lever arm in very small contractions or in.
the summation of such contractions and therefore for large contractions. In the first muscle a large load is moved through a short distance and in the second muscle a lighter load is moved through a greater distance.

The amount of work accomplished by pinnate muscles is not dependent upon the angle of insertion of the muscle fibers into the tendon, as will be seen by the following diagram Fig. 368.

\[ T' T = \text{direction of the tendon pull.} \]
\[ w a = \text{direction of muscle fiber before contraction.} \]
\[ m' = \text{direction of muscle fiber after contraction.} \]
\[ r = \text{amount of contraction.} \]
\[ m = \text{tension of the muscle.} \]
\[ \phi = \text{angle of insertion of muscle fiber.} \]
\[ t = \text{tendon component} = m \times \cos \phi = \text{the weight carried by the tendon to balance the muscle tension.} \]
\[ d = \text{distance tendon is drawn up.} \]
(1) \[ m \times r = \text{work done by the muscle fiber.} \]
(2) \[ t \times d = \text{work done by the movement of the tendon.} \]

If we consider the distance \( r \) as being very short then the line \( b e \) can be dealt with as though it were perpendicular to \( a c \).

Then \[ r = d \times \cos \phi \text{ or } d = \frac{r}{\cos \phi} \]

Since \[ t = m \times \cos \phi \text{ or } m = \frac{t}{\cos \phi} \]

\[ m \times r = \frac{t}{\cos \phi} \times d \times \cos \phi = t \times d \]

If this is true for very minute contractions it is likewise true for a series of such contraction and hence for larger contractions.

If we assume that \( \phi = 60^\circ \), \( m = 10 \text{ kg.} \) and \( r = 5 \text{ mm.} \), the work done by the contracting muscle fiber \( = m \times r = 10 \times 5 \text{ kilogrammillimeters.} \)

\[ \cos \angle 60^\circ = \frac{1}{2}; \text{ hence } t = \frac{1}{2} m; \text{ and } d = \frac{r}{\frac{1}{2}} = 2r; \frac{1}{2} m = 5 \text{ kg.}; \text{ and } 2 r = 10 \text{ mm.} \]
hence \( t = 50 \text{ kilogrammillimeters or the work done by the movement of the tendon in lifting the load of 5 kg. a distance of 10 mm.} \), and is exactly the same as that done by the muscle fiber. The load on the tendon is but one-half the tension of the muscle, but the distance through which the load is lifted is twice that of the amount of shortening of the muscle.

If \( \phi = 41^\circ 20' \) then \( \cos \phi = \frac{4}{5} \)
hence \( t = \frac{4}{5} m \) and \( d = \frac{4}{5} r \) and \( t d = m r \)

In pinnate muscles, then, we have the rather unexpected condition in which the same amount of movement of the tendon can be accomplished with less contraction of the muscle than in muscles where the fibers have the same direction as the tendon.

**The Action of Muscles on Joints.**—If we consider now the action of a single muscle extending over a single joint in which one bone is fixed and the other movable, we
will find that muscle pull can be resolved into two components, a turning component and a friction or pressure component as shown in Fig. 369.

\[ DF = \text{the fixed bone from which the muscle takes its origin.} \]
\[ DK = \text{the movable bone.} \]
\[ OL = \text{a line from the middle of origin to the middle of insertion.} \]
\[ IM = \text{size and direction of the muscle pull.} \]

If the parallelogram is constructed with \( It \) and \( Mb \) \( \perp \) to \( DK \), then \( It \) = the turning component and \( Ib \) = the component which acts against the joint.

The size of the two components depends upon the insertion angle \( \phi \). The smaller this angle the smaller the turning component, and the nearer this angle \( \phi \) is to \( 90^\circ \) the larger the turning component.

\[ It = IM \times \sin \phi \]
\[ Ib = IM \times \cos \phi \]

If \( \phi = 90^\circ \) \( \cos \phi = 0 \), \( \sin \phi = 1 \)

hence \( Ib = 0 \) and \( It = Im \)

If \( \phi = 0^\circ \) \( \cos \phi = 1 \), \( \sin \phi = 0 \)

hence \( Ib = 1 \) and \( It = 0 \)

With movements of the bone \( DK \) the angle of insertion is continually changing, and hence the two components are changing in value.

If, for example, the distance from origin 0 to the joint D is greater than from D to I, as in the Brachialis or Biceps muscles, the turning component increases until the insertion angle \( \phi = 90^\circ \), which is the optimum angle for muscle action, while the pressure component gradually decreases. If the movement continues beyond
this point the turning component gradually decreases and the pressure component changes into a component which tends to draw the two bones apart and which gradually increases as shown in Fig. 370.

When the bone $DK$ is in such a position that the insertion angle $\phi = 41^\circ 20'$ the pressure component $= \frac{1}{2} IM$ and the turning component $\frac{1}{2} IM$, at $60^\circ$ the two components are equal, at $90^\circ$ the pressure component $= 0$ and the turning component $= IM$ and at $131^\circ 21'$ the pressure component has been converted into a pulling component $= \frac{1}{4} IM$ and the turning component $= \frac{3}{4} IM$.

![Fig. 371](image)

If, for example, the distance from the origin $O$ to the joint $D$ is less than the distance from the insertion $I$ to the joint $D$, as in the Brachioradialis muscle, the insertion angle increases with the flexion but never reaches $90^\circ$. The turning component gradually increases to a certain point and then slowly decreases as shown in Fig. 371, while the pressure component gradually decreases and then slowly increases. It always remains large and its action is always in the direction of the joint.

**Levers.**—The majority of the muscles of the body act on bones as the power on levers. Levers of the I class are the most common, as the action of the Biceps, and the Brachialis muscles on the forearm bones. Levers of the II class are found in movements of the head where the occipito-atlantal joint acts as the fulcrum and the muscles on the back of the neck as the power. Another common example is

![Fig. 372](image)

the foot when one raises the body by contracting the Gastrocnemius and Soleus. Here the ankle-joint acts as the fulcrum and the pressure of the toes on the ground as the weight. This is frequently, though wrongly, considered a lever of the II Class. If one were to stand on one's head with the legs up and with a weight on the plantar surface of the toes, it is easy to see that we would have a lever of the I Class if the weight were raised by contraction of the Gastrocnemius muscle. The confusion has arisen by not considering the fact that the fulcrum and the power in all three classes of levers must have a common basis of action, as shown in Fig. 372.
DEVELOPMENT OF THE MUSCLES

If the fulcrum rests on the earth the power must either directly or indirectly push from the earth or be attached to the earth either by gravity or otherwise if it pulls toward the earth. If the power were attached to the weight no lever action could be obtained.

There are no levers of the II Class represented in the body.

DEVELOPMENT OF THE MUSCLES.

Both the cross-striated and smooth muscles, with the exception of a few that are of ectodermal origin, arise from the mesoderm. The intrinsic muscles of the trunk are derived from the myotomes while the muscles of the head and limbs differentiate directly from the mesoderm.

The Myotomic Muscles.—The intrinsic muscles of the trunk which are derived directly from the myotomes are conveniently treated in two groups, the deep muscles of the back and the thoraco-abdominal muscles.

The deep muscles of the back extend from the sacral to the occipital region and vary much in length and size. They act chiefly on the vertebral column. The shorter muscles, such as the Interspinales, Intertransversari, the deeper layers of the Multifidus, the Rotatores, Levatores costarum, Obliquus capitis inferior, Obliquus capitis superior and Rectus capitis posterior minor which extend between adjoining vertebrae, retain the primitive segmentation of the myotomes. Other muscles, such as the Splenius capitis, Splenius cervicis, Sacrospinalis, Semispinalis, Multifidus, Iliocostalis, Longissimus, Spinales, Semispinales, and Rectus capitis posterior major, which extend over several vertebrae, are formed by the fusion of successive myotomes and the splitting into longitudinal columns.

The fascia lumbodorsalis develops between the true myotomic muscles and the more superficial ones which migrate over the back such as the Trapezius, Rhomboideus, and Latissimus.

The anterior vertebral muscles, the Longus colli, Longus capitis, Rectus capitis anterior and Rectus capitis lateralis are derived from the ventral part of the cervical myotomes as are probably also the Scaleni.

The thoraco-abdominal muscles arise through the ventral extension of the thoracic myotomes into the body wall. This process takes place coincident with the ventral extension of the ribs. In the thoracic region the primitive myotomic segments still persist as the intercostal muscles, but over the abdomen these ventral myotomic processes fuse into a sheet which splits in various ways to form the Rectus, the Obliquus externus and internus, and the Transversalis. Such muscles as the Pectoralis major and minor and the Serratus anterior do not belong to the above group.

The Ventrolateral Muscles of the Neck.—The intrinsic muscles of the tongue, the Infrahyoid muscles and the diaphragm are derived from a more or less continuous premuscle mass which extends on each side from the tongue into the lateral region of the upper half of the neck and into it early extend the hypoglossal and branches of the upper cervical nerves. The two halves which form the Infrahyoid muscles and the diaphragm are at first widely separated from each other by the heart. As the latter descends into the thorax the diaphragmatic portion of each lateral mass is carried with its nerve down into the thorax and the laterally placed Infrahyoid muscles move toward the midventral line of the neck.

Muscles of the Shoulder Girdle and Arm.—The Trapezius and Sternocleidomastoidus arise from a common premuscle mass in the occipital region just caudal to the last branchial arch; as the mass increases in size it spreads downward to the shoulder girdle to which it later becomes attached. It also spreads backward and downward to the spinous processes, gaining attachment at a still later period.
The Levator scapulae, Serratus anterior and the Rhomboïds arise from premuscle tissue in the lower cervical region and undergo extensive migration.

The Latissimus dorsi and Teres major are associated in their origin from the premuscle sheath of the arm as are also the two Pectoral muscles when the arm bud lies in the lower cervical region.

The intrinsic muscles of the arm develop in situ from the mesoderm of the arm bud and probably do not receive cells or buds from the myotomes. The nerves enter the arm bud when it still lies in the cervical region and as the arm shifts caudally over the thorax the lower cervical nerves which unite to form the brachial plexus, acquire a caudal direction.

**The Muscles of the Leg.**—The muscles of the leg like those of the arm develop in situ from the mesoderm of the leg bud, the myotomes apparently taking no part in their formation.

**The Muscles of the Head.**—The muscles of the orbit arise from the mesoderm over the dorsal and caudal sides of the optic stalk.

The muscles of mastication arise from the mesoderm of the mandibular arch. The mandibular division of the trigeminal nerve enters this premuscle mass before it splits into the Temporal, Masseter and Pterygoideus.

The facial muscles (muscles of expression) arise from the mesoderm of the hyoid arch. The facial nerve enters this mass before it begins to split, and as the muscle mass spreads out over the face and head and neck it splits more or less incompletely into the various muscles.

The early differentiation of the muscular system apparently goes on independently of the nervous system and only later does it appear that muscles are dependent on the functional stimuli of the nerves for their continued existence and growth. Although the nervous system does not influence muscle differentiation, the nerves, owing to their early attachments to the muscle rudiments, are in a general way indicators of the position of origin of many of the muscles and likewise in many instances the nerves indicate the paths along which the developing muscles have migrated during development. The muscle of the diaphragm, for example, has its origin in the region of the fourth and fifth cervical segments. The phrenic nerve enters the muscle mass while the latter is in this region and is drawn out as the diaphragm migrates through the thorax. The Trapezius and Sternocephalioideus arise in the lateral occipital region as a common muscle mass, into which at a very early period the nervus accessorius extends and as the muscle mass migrates and extends caudally the nerve is carried with it. The Pectoralis major and minor arise in the cervical region, receive their nerves while in this position and as the muscle mass migrates and extends caudally over the thorax the nerves are carried along. The Latissimus dorsi and Serratus anterior are excellent examples of migrating muscles whose nerve supply indicates their origin in the cervical region. The Rectus abdominis and the other abdominal muscles migrate or shift from a lateral to a ventrolateral or abdominal position, carried with them the nerves.

The facial nerve, which early enters the common facial muscle mass of the second branchial or hyoid arch, is dragged about with the muscle as it spreads over the head and face and neck, and as the muscle splits into the various muscles of expression, the nerve is correspondingly split. The mandibular division of the trigeminal nerve enters at an early time the muscle mass in the mandibular arch and as this mass splits and migrates apart to form the muscles of mastication the nerve splits into its various branches.

The nerve supply then serves as a key to the common origin of certain groups of muscles. The muscles supplied by the oculomotor nerve arise from a single mass in the eye region; the lingual muscles arise from a common mass supplied by the hypoglossal nerve.
Striped or Voluntary Muscle.—Striped or voluntary muscle is composed of bundles of fibers each enclosed in a delicate web called the perimysium in contradistinction to the sheath of areolar tissue which invests the entire muscle, the epimysium. The bundles are termed fasciculi; they are prismatic in shape, of different sizes in different muscles, and are for the most part placed parallel to one another, though they have a tendency to converge toward their tendinous attachments. Each fasciculus is made up of a strand of fibers, which also run parallel with each other, and are separated from one another by a delicate connective tissue derived from the perimysium and termed endomysium. This does not form the sheath of the fibers, but serves to support the bloodvessels and nerves ramifying between them.

A muscular fiber may be said to consist of a soft contractile substance, enclosed in a tubular sheath named by Bowman the sarcolemma. The fibers are cylindrical or prismatic in shape (Fig. 373), and are of no great length, not exceeding, as a rule, 40 mm. Huber has recently found that the muscle fibers in the adductor muscle of the thigh of the rabbit vary greatly in length even in the same fasciculus. In a fasciculus 40 mm. in length the fibers varied from 30.4 mm. to 9 mm. in length. Their breadth varies in man from 0.01 to 0.1 mm. As a rule, the fibers do not divide or anastomose; but occasionally, especially in the tongue and facial muscles, they may be seen to divide into several branches. In the substance of the muscle, the fibers end by tapering extremities which are joined to the ends of other fibers by the sarcolemma. At the tendinous end of the muscle the sarcolemma appears to blend with a small bundle of fibers, into which the tendon becomes subdivided, while the muscular substance ends abruptly and can be readily made to retract from the point of junction. The areolar tissue between the fibers appears to be prolonged more or less into the tendon, so as to form a kind of sheath around the tendon bundles for a longer or shorter distance. When muscular fibers are attached to skin or mucous membranes, their fibers become continuous with those of the areolar tissue.

The sarcolemma, or tubular sheath of the fiber, is a transparent, elastic, and apparently homogeneous membrane of considerable toughness, so that it sometimes remains entire when the included substance is ruptured. On the internal surface of the sarcolemma in mammalia, and also in the substance of the fiber in frogs, elongated nuclei are seen, and in connection with these is a little granular protoplasm.

Upon examination of a voluntary muscular fiber by transmitted light, it is

---

1Anat. Rec., 1916, 11.
found to be marked by alternate light and dark bands or strie, which pass transversely across the fiber (Fig. 374). When examined by polarized light the dark bands are found to be doubly refracting (anisotropic), while the clear stripes are singly refracting (isotropic). The dark and light bands are of nearly equal breadth, and alternate with great regularity; they vary in breadth from about 1 to 2μ. If the surface be carefully focussed, rows of granules will be detected at the points of junction of the dark and light bands, and very fine longitudinal lines may be seen running through the dark bands and joining these granules together. By treating the specimen with certain reagents (e.g., chloride of gold) fine lines may be seen running transversely between the granules and uniting them together. This appearance is believed to be due to a reticulum or network of interstitial substance lying between the contractile portions of the muscle. The longitudinal striation gives the fiber the appearance of being made up of a bundle of fibrils which have been termed sarcostyles or muscle columns, and if the fiber be hardened in alcohol, it can be broken up longitudinally and the sarcostyles separated from each other (Fig. 375). The reticulum, with its longitudinal and transverse meshes, is called sarcoplasma.

In a transverse section, the muscular fiber is seen to be divided into a number of areas, called the areas of Cohnheim, more or less polyhedral in shape and consisting of the transversely divided sarcostyles, surrounded by transparent sarcoplasma (Fig. 373).

Upon closer examination, and by somewhat altering the focus, the appearances become more complicated, and are susceptible of various interpretations. The transverse striation, which in Fig. 374 appears as a mere alternation of dark and light bands, is resolved into the appearance seen in Fig. 375, which shows a series of broad dark bands, separated by light bands, each of which is divided into two
by a dark dotted line. This line is termed Dobie's line or Krause's membrane (Fig. 376, k), because it was believed by Krause to be an actual membrane, continuous with the sarcolemma, and dividing the light band into two compartments. In addition to the membrane of Krause, fine clear lines may be made out, with a sufficiently high power, crossing the center of the dark band; these are known as the lines of Hensen (Fig. 376, H).

Schafer has worked out the minute anatomy of muscular fiber, particularly in the wing muscles of insects, which are peculiarly adapted for this purpose on account of the large amount of interstitial sarcoplasm which separates the sarcostyles. In the following description that given by Schafer will be closely followed.

A sarcostyle may be said to be made up of successive portions, each of which is termed a sarcomere. The sarcomere is situated between two membranes of Krause and consists of (1) a central dark part, which forms a portion of the dark band of the whole fiber, and is named a sarcous element. This sarcous element really consists of two parts, superimposed one on the top of the other, and when the fiber is stretched these parts become separated from each other at the line of Hensen (Fig. 376, A). (2) On either side of this central dark portion is a clear layer, most visible when the fiber is extended; this is situated between the dark center and the membrane of Krause, and when the sarcomeres are joined together to form the sarcostyle, constitutes the light band of the striated muscular fiber.

When the sarcostyle is extended, the clear intervals are well-marked and plainly to be seen; when, on the other hand, the sarcostyle is contracted, that is to say, when the muscle is in a state of contraction, these clear portions are very small or they may have disappeared altogether (Fig. 376, B). When the sarcostyle is stretched to its full extent, not only is the clear portion well-marked, but the dark portion—the sarcous element—is separated into its two constituents along the line of Hensen. The sarcous element does not lie free in the sarcomere, for when the sarcostyle is stretched, so as to render the clear portion visible, very fine lines, which are probably septa, may be seen running through it from the sarcous element to the membrane of Krause.

Schafer explains these phenomena in the following way: He considers that each sarcous element is made up of a number of longitudinal channels, which open into the clear part toward the membrane of Krause but are closed at the line of Hensen. When the muscular fiber is contracted the clear part of the muscular substance is driven into these channels or tubes, and is therefore hidden from sight, but at the same time it swells up the sarcous element and widens and shortens the sarcomere. When, on the other hand, the fiber is extended, this clear substance is driven out of the tubes and collects between the sarcous element and the membrane of Krause, and gives the appearance of the light part between these two structures; by this means it elongates and narrows the sarcomere.

If this view be true, it is a matter of great interest, and, as Schafer has shown, harmonizes the contraction of muscle with the ameboid action of protoplasm. In an ameboid cell, there is a framework of spongioplasm, which stains with hematoxylin and similar reagents, enclosing in its meshes a clear substance, hyaloplasm, which will not stain with these reagents. Under stimulation the hyaloplasm passes into the pores of the spongioplasm; without stimulation it tends to pass out as in the formation of pseudopodia. In muscle there is the same thing, viz., a framework of spongioplasm staining with hematoxylin—the substance of the sarcous element—and this encloses a clear hyaloplasm, the clear substance of the sarcomere, which resists staining with this reagent. During contraction of the muscle—i.e., stimulation—this clear substance passes into the pores of the spongioplasm; while during extension of the muscle—i.e., when there is no stimulation—it tends to pass out of the spongioplasm.

In this way the contraction is brought about: under stimulation the proto-
plasmatic material (the clear substance of the sarcomere) recedes into the sarcous element, causing the sarcomere to widen out and shorten. The contraction of the muscle is merely the sum total of this widening out and shortening of these bodies.

**Vessels and Nerves of Striped Muscle.**—The capillaries of striped muscle are very abundant, and form a sort of rectangular network, the branches of which run longitudinally in the endomysium between the muscular fibers, and are joined at short intervals by transverse anastomosing branches. In the red muscles of the rabbit dilatations occur on the transverse branches of the capillary network. The larger vascular channels, arteries and veins, are found only in the perimysium, between the muscular fasciculi. Nerves are profusely distributed to striped muscle. Their mode of termination is described on page 730. The existence of lymphatic vessels in striped muscle has not been ascertained, though they have been found in tendons and in the sheaths of the muscles.

Ossification of muscular tissue as a result of repeated strain or injury is not infrequent. It is oftenest found about the tendon of the Adductor longus and Vastus medialis in horsemen, or in the Pectoralis major and Deltoides of soldiers. It may take the form of exostoses firmly fixed to the bone—e.g., "rider's bone" on the femur—or of layers or spicules of bone lying in the muscles or their fascia and tendons. Buzon states that these bony deposits are preceded by a hemorrhagic myositis due to injury, the effused blood organizing and being finally converted into bone. In the rarer disease, progressive myositis ossificans, there is an unexplained tendency for practically any of the voluntary muscles to become converted into solid and brittle bony masses which are completely rigid.

**TENDONS, APONEUROSIS, AND FASCIA.**

Tendons are white, glistening, fibrous cords, varying in length and thickness, sometimes round, sometimes flattened, and devoid of elasticity. They consist almost entirely of white fibrous tissue, the fibrils of which have an undulating course parallel with each other and are firmly united together. When boiled in water tendon is almost completely converted into gelatin, the white fibers being composed of the albuminoid collagen, which is often regarded as the anhydride of gelatin. They are very sparingly supplied with bloodvessels, the smaller tendons presenting in their interior no trace of them. Nerves supplying tendons have special modifications of their terminal fibers, named organs of Golgi.

Aponeuroses are flattened or ribbon-shaped tendons, of a pearly white color, iridescent, glistening, and similar in structure to the tendons. They are only sparingly supplied with bloodvessels.

The tendons and aponeuroses are connected, on the one hand, with the muscles, and, on the other hand, with the movable structures, as the bones, cartilages ligaments, and fibrous membranes (for instance, the sclera). Where the muscular fibers are in a direct line with those of the tendon or aponeurosis, the two are directly continuous. But where the muscular fibers join the tendon or aponeurosis at an oblique angle, they end, according to Kölliker, in rounded extremities which are received into corresponding depressions on the surface of the latter, the connective tissue between the muscular fibers being continuous with that of the tendon. The latter mode of attachment occurs in all the pinniform and bipenniform muscles, and in those muscles the tendons of which commence in a membranous form, as the Gastrocnemius and Soleus.

The fasciae are fibroseolar or aponeurotic laminae, of variable thickness and strength, found in all regions of the body, investing the softer and more delicate organs. During the process of development many of the cells of the mesoderm are differentiated into bones, muscles, vessels, etc., the cells of the mesoderm which are not so utilized form an investment for these structures and are differentiated into the true skin and the fasciae of the body. They have been subdivided, from the situations in which they occur, into superficial and deep.
The superficial fascia is found immediately beneath the integument over almost the entire surface of the body. It connects the skin with the deep fascia, and consists of fibroareolar tissue, containing in its meshes pellicles of fat in varying quantity. Fibro-areolar tissue is composed of white fibers and yellow elastic fibers intercrossing in all directions, and united together by a homogeneous cement or ground substance, the matrix.

The cells of areolar tissue are of four principal kinds: (1) Flattened lamellar cells, which may be either branched or unbranched. The branched lamellar cells are composed of clear cytoplasm, and contain oval nuclei; the processes of these cells may unite so as to form an open network, as in the cornea. The unbranched cells are joined edge to edge like the cells of an epithelium; the "tendon cells," presently to be described, are examples of this variety. (2) Clasmatocytes, large irregular cells characterized by the presence of granules or vacuoles in their protoplasm, and containing oval nuclei. (3) Granule cells (Mastzellen), which are ovoid or spheroidal in shape. They are formed of a soft protoplasm, containing granules which are basophil in character. (4) Plasma cells of Waldeyer, usually spheroidal and distinguished by containing a vacuolated protoplasm. The vacuoles are filled with fluid, and the protoplasm between the spaces is clear, with occasionally a few scattered basophil granules.

In addition to these four typical forms of connective-tissue corpuscles, areolar tissue may be seen to possess wandering cells, i.e., leucocytes which have emigrated from the neighboring vessels; in some instances, as in the choroid coat of the eye cells filled with granules of pigment (pigment cells) are found.

The cells lie in spaces in the ground substance between the bundles of fibers, and these spaces may be brought into view by treating the tissue with nitrate of silver and exposing it to the light. This will color the ground substance and leave the cell-spaces unstained.
Fat is entirely absent in the subcutaneous tissue of the eyelids, of the penis and scrotum, and of the labia minora. It varies in thickness in different parts of the body; in the groin it is so thick that it may be subdivided into several laminae. Beneath the fatty layer there is generally another layer of superficial fascia, comparatively devoid of adipose tissue, in which the trunks of the subcutaneous vessels and nerves are found, as the superficial epigastric vessels in the abdominal region, the superficial veins in the forearm, the saphenous veins in the leg and thigh, and the superficial lymph glands. Certain cutaneous muscles also are situated in the superficial fascia, as the Platysma in the neck, and the Orbicularis oculi around the eyelids. This fascia is most distinct at the lower part of the abdomen, perineum, and extremities; it is very thin in those regions where muscular fibers are inserted into the integument, as on the side of the neck, the face, and around the margin of the anus. It is very dense in the scalp, in the palms of the hands, and soles of the feet, forming a fibro-fatty layer, which binds the integument firmly to the underlying structures.

The superficial fascia connects the skin to the subjacent parts, facilitates the movement of the skin, serves as a soft nidus for the passage of vessels and nerves to the integument, and retains the warmth of the body, since the fat contained in its areole is a bad conductor of heat.

The deep fascia is a dense, inelastic, fibrous membrane, forming sheaths for the muscles, and in some cases affording them broad surfaces for attachment. It consists of shining tendinous fibers, placed parallel with one another, and connected together by other fibers disposed in a rectilinear manner. It forms a strong investment which not only binds down collectively the muscles in each region, but gives a separate sheath to each, as well as to the vessels and nerves. The fasciae are thick in unprotected situations, as on the lateral side of a limb, and thinner on the medial side. The deep fasciae assist the muscles in their actions, by the degree of tension and pressure they make upon their surfaces; the degree of tension and pressure is regulated by the associated muscles, as, for instance, by the Tensor fasciae latae and Gluteus maximus in the thigh, by the Biceps in the upper and lower extremities, and Palmaris longus in the hand. In the limbs, the fasciae not only invest the entire limb, but give off septa which separate the various muscles, and are attached to the periosteum; these prolongations of fasciae are usually spoken of as intermuscular septa.

The fasciae and muscles may be arranged, according to the general division of the body, into those of the head and neck; of the trunk; of the upper extremity; and of the lower extremity.

THE FASCIAE AND MUSCLES OF THE HEAD.

I. THE MUSCLE OF THE SCALP.

Epicranius.

The Skin of the Scalp.—This is thicker than in any other part of the body. It is intimately adherent to the superficial fascia, which attaches it firmly to the underlying aponeurosis and muscle. Movements of the muscle move the skin. The hair follicles are very closely set together, and extend throughout the whole thickness of the skin. It also contains a number of sebaceous glands.

The superficial fascia in the cranial region is a firm, dense, fibro-fatty layer, intimately adherent to the integument, and to the Epicranius and its tendinous aponeurosis; it is continuous, behind, with the superficial fascia at the back of the neck; and, laterally, is continued over the temporal fascia. It contains between its layers the superficial vessels and nerves and much granular fat.

The Epicranius (Occipitofrontalis) (Fig. 378) is a broad, musculo-fibrous layer,