THESIS

on

THE MALPIGHIAN BODIES OF THE KIDNEY.

A STUDY OF THEIR DEVELOPMENT, COMPARATIVE ANATOMY,

AND PATHOLOGY.

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Presented by

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for the Degree of

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INTRODUCTION.

The following Thesis which I have the honour to submit for the degree of Doctor of Medicine, and as a candidate for the Goodsir Memorial Fellowship, comprises the results of part of my work in the University Pathological Laboratory as a Crichton Research Scholar.

I have the greatest pleasure in expressing my sincere thanks and indebtedness to Professor Greenfield, not only for his suggestion of the subject of my work, but for the many facilities he has given me for carrying it out in his Laboratory.

Though originally intended to deal with Pathological changes only, the Thesis is chiefly a study of the Development of the Malpighian bodies of the Kidney. A knowledge of their minute Anatomy and Development was necessary to follow out certain

changes that occur in disease, and on looking up the literature of the subject I was surprised to find that very little was known about their Development, that most of the work had been done by German observers, and that their results were very contradictory. I had the good fortune to secure a number of Human Foetal kidneys, and have examined them very carefully. The results are here stated, and a record of many of the different stages in Development are shown in Photomicrographs. This is as far as I am aware the first time that photographs of the subject have appeared, the usual diagramatic drawings which are given as illustrations being made to order to suit any theory. The Development of the Malpighian bodies included a number of other closely related structures which could not be omitted; the Development of the Malpighian bodies really constitutes the greater part in the History of the Development of the whole Kidney.

In addition a Section has been added on Comparative Anatomy and Embryology in which the Malpighian bodies of the different orders of Vertebrates are compared. A few of the more interesting types are recorded among the Illustrations.

The Section on Pathology had to be shortened and a quantity of experimental work omitted.

To Professor Simpson and Dr. Halliday Croom my thanks are due for their kindness in allowing me Embryological material from the Royal Maternity Hospital. To the late Professor Rutherford I owe a debt of gratitude for the help he gave me at the commencement of my research. I must also express my thanks to Dr. Welsh for his kindness in furnishing me with Pathological specimens and many valuable suggestions.

The Illustrations of the Thesis have been enclosed in a separate cover to lessen the bulk of one volume, and to allow of more convenient reference from the text. The Photomicrographs have been prepared by Mr. Richard Muir, to whom I am deeply indebted for his excellent reproductions of the microscopic appearances, and for the help he has given me throughout my work in the Laboratory.

The slides & microscopic specimens have been left under the care of Professor Greenfield in the Pathological Laboratory of the University. If necessary they can be obtained from him.

A short Historical Survey

of the Anatomy of the

Malpighian bodies of the Kidney.

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HISTORICAL SURVEY OF THE ANATOMY OF THE MALPIGHIAN

BODIES OF THE KIDNEY.

Our knowledge of the Malpighian bodies of the
Kidney may be said to date back to the end of the 17th
century.

Malpighi the great Italian anatomist described
them in this work "De Renibus" published about the
year 1688, and ever since then they have borne his
name.   Malpighi regarded them as internal glands of
the Kidney concerned in the elaboration of urine from
the blood.   He recognised that they were mainly vas-
cular structures, and also believed that each was the
starting point of a urinary tube.

During the next century little further was known
about them till Ruysch injected the renal artery, and
found that the injected material accumulated in the
Malpighian bodies, which were thus rendered conspicu-
ous to the naked eye.   Ruysch and other later observ-
ers, who followed the same plan of injecting the renal
artery, often noticed that the injected material es-
caped from the Malpighian bodies along the urinary
tubules.   From this they were led to conclude that
there was a direct connection between the lumen of
the blood vessels and the urinary tubules,

an error which was one of the foundations for the belief in exhalent arteries.

Very little was known about their structure and function, even in the beginning of the present century, for we find Huschke in 1828 and Müller in 1830 advocating the view that the Malpighian bodies were structures lying among the urinary tubes but quite independent of them.

In 1842 Bowman (Bb.6) read his remarkable paper "On the Anatomy and Physiology of the Kidney" before the Royal Society. By it our knowledge of the Anatomy and Physiology of the Kidney was raised at one bound from a state of ignorance to a level very little exceeded at the present day. Bowman showed that the Malpighian body was the dilated extremity of a urinary tube, in which hung a number of capillary loops. The outer wall or capsule of the Malpighian body he believed to be merely an expansion of the basement membrane of the tubule, and this outer wall is now known as Bowman's Capsule. Bowman considered it to be a simple homogenous and transparent membrane in which no structure could be discovered. He laid stress on the fact that it was never reflected over the vessels, but allowed them to penetrate it opposite the beginning of the

urinary tube.   Bowman examined the kidneys of
many different animals and found that there were
great varieties in the way the capsule was lined.
In many cases he found a lining of epithelium ex-
tending over the whole inner surface of the capsule,
but in others he could not detect the slightest ap-
pearance of it over more than one third of the cap-
sule.   In the frog he noticed that the cells lin-
ing the neck of the capsule were ciliated, but when
fairly in side the capsule the cilia disappeared,
and the epithelium beyond was of excessive delicacy
and translucency, nuclei were seldom present and the
cells had a great tendency to swell up on the addit-
ion of water.   Bowman showed that the vascular
portion of the Malpighian body consisted of an af-
ferent arteriole which penetrated the basement mem-
brane and broke up into a number of capillary loops,
which after forming festoons inside the capsule, u-
-nited to form a single trunk the efferent arteriole,
which again penetrated the capsule close to the entrance
of the afferent vessel.   He believed that the cap-
illary loops forming the Glomerulus hung free inside
the capsule, each capillary having a wall consisting
of a simple homogenous and transparent membrane.
Bowman insisted particularly on this that there was

no reflection of the capsule over the capillaries,
and no other tissue admitted into the capsule besides
blood vessels.   By the careful injection of the ren-
al artery he further pointed out how Ruysch and oth-
ers had been led into error owing to their having em-
ployed too great a pressure, thereby rupturing the cap-
illaries inside the capsule, and forcing the injected
material along the tubules.

Bowman's paper was soon criticised by a number
of German observers.

Gerlach (Bb.21)in 1845 showed that the capillary
tufts were not naked in the capsule as Bowman had de-
clared.   Gerlach described a single layer of flat
epithelium covering the tuft and continuous at the
base with the epithelium lining the capsule.

Kölliker (Bb.46)shortly afterwards found the same,
and further showed that the membrane of epithelial
cells which covered the tuft, dipped down into the
spaces between the capillaries, everywhere separat-
ing them from the cavity of the urinary canal.

Bidder (Bb.4)in the same year described a part-
ition of fine epithelium covering the Glomerulus ,
and continuous at its base with the tunica propria.

Remak (Bb.64)in 1855 described the development of
the Kidney.   He considered that the Malpighian body

was formed by an invagination of the end or one side of a urinary tubule by the ingrowth of bloodvessels. According to Remak therefore the epithelium lining the convoluted tube and Bowman's capsule, and that covering the capillaries were continuous structures, originally the same, but altered during the further process of development.

Schweigger Seidel (Bb.76) in 1865 laid stress on the fact that during the development of the Kidney, the epithelium covering the glomerulus consisted of large cells which covered and penetrated between the capillaries. The presence of such a marked layer of cells in the foetus, he argued, implied the existence of a continuous layer of cells in the adult.

Heidenhain (Bb.34) also drew attention to the way the membrane dipped down between the capillaries, dividing the Glomerulus into lobules.

Many other observers demonstrated this epithelial investment of the glomerulus and its presence has been universally admitted. Of the blood vessels composing the glomerulus, Bowman showed that there was usually a single afferent and a single efferent artery, the afferent being slightly larger and hav-ing a thicker wall than the efferent. The afferent artery breaks up into from four to eight branches, (Ludwig (Bb) 52), immediately after entering the capsule, and these form capillary loops. Besides capillaries

Ryndowsky (Bb¾)has described lymphatic vessels in the
glomerulus, and many believe in the presence of a cer-
tain amount of fine connective tissue lying between
and supporting the capillaries.   The structure of
Bowman's capsule is not fully settled.   Bowman be-
lieved it to be a homogenous membrane, and this is the
view generally adopted.   Ludwig (Bb½)considered it
to be a mosaic of cells closely resembling those com-
posing the wall of the blood and lymphatic capillar-
ies, and Roth (Bb69)thought it to be made up of endo-
thelial cells.   Recently in 1897 Rühle (Bb¾)has
stated it to be composed of thin fibrils, and he has
described its continuation into the glomerulus as a
fine thread like structure with numerous pores.
In the foetus it is indistinguishable, the wall being
in many cases apparently formed by the surrounding
connective tissue.   In old age it becomes marked and
appears to be as Bowman described it, a simple homo-
genous membrane.

The cells lining Bowman's capsule are continuous
as Bowman showed, with the cells lining the convol-
uted tubule, and vary in character in different anim-
als.

Some of these variations will be treated of later
on.   From a consideration of the development of the
Malpighian bodies, the cells lining Bowman's capsule

and those covering the glomerulus have been regarded
as part of the epithelium of a urinary tube specially
differentiated for the performance of a different
function.   But sufficient stress has not been laid
on the fact that they differ not only from the cells
of the tubules but from one another.

It is to the alterations that take place in dis-
ease that we have to turn for further information;
in the normal adult kidney the anatomical appearances
of the cells is very similar, but in many forms of
disease alterations in structure take place, which
give us a clue to their real significance.   It is
found that the cells lining Bowman's capsule react
in quite a different manner to those covering the
glomerulus.   The latter have more of the nature of
glandular cells elsewhere, but the cells lining Bow-
man's capsule react not as a glandular epithelium
but very much the same as the cells lining the inner
wall of an artery.   Professor Greenfield in his
Resume of Renal Pathology, published in the New
Sydenham Society's Atlas in 1879 described the cells
lining Bowman's capsule as closely resembling those
which form the endothelium of blood vessels, and
pointed out that in many forms of Nephritis they

proliferated and gave rise to organised fibrous tissue which eventually compressed and obliterated the glomerulus.

It seemed contrary to generally accepted ideas that a glandular epithelium should behave in this way, and to arrive at the explanation I was led to study the development of the Malpighian bodies. The most recent accounts of this stated that the epithelium of the Malpighian bodies was derived from the Wolffian duct, which is now believed to be Epiblastic. That Epiblastic cells should react in disease like the endothelium of an artery seemed more unlikely still. On further investigation I found that the views on development were most conflicting, and that really little was known.

I have gone carefully into the development and have also made some observations on the Comparative Anatomy of the Malpighian bodies. These are recorded in the following sections.

THE DEVELOPMENT OF THE HUMAN KIDNEY

WITH ESPECIAL REFERENCE TO THE

MALPIGHIAN BODIES.

DEVELOPMENT OF THE HUMAN KIDNEY.

In the Kidney of man and the higher Vertebrates
the origin of Malpighian bodies is so closely re-
lated to the origin of other structures, and their
further development plays such an important part,
that it is necessary to consider some of the main
facts of the history of the development of the
whole organ.

The development of the kidney has been worked
at by a great number of Embryologists, but most of
the observations have been made on embryos of the
higher Vertebrates other than man, especially on
those of the chick, rabbit, dog and pig.   That
there is a close similarity between the histories
of development of the kidneys in these animals is
a fact generally admitted, and the different re-
sults recorded by different observers are not to
be explained by the difference in material examined.
My own observations have been made for the most
part on the kidney of the Human embryo, and all the
photo-micrographs in this section are from the
Human kidney.   I have also examined the developing
kidney in the chick and the mouse, and find in
them a close resemblance.

The Kidney of man corresponds to the Metanephros
of comparative anatomy, which is the most highly dif-
ferentiated of the urinary organs of Vertebrates.
In the embryo there is at an early stage a well dev-
eloped Mesonephros which for a time appears to be the functional excretory organ.   According to Marshall (Bb.55.)
the Mesonephros or Wolffian body begins to form about
the 18th day of intra-uterine life and attains its
greatest development at the end of the 8th week,
after which it atrophies and is replaced by the per-
manent kidney.

The presence of a Pronephros or Head Kidney in
the Human embryo is doubtful.   Janosik (Bb.40.) has
described one in an embryo 18 days old.   Marshall
says of it, that if present at all it must be ex-
tremely rudimentary and evanescent.

The Wolffian body is generally admitted to be
derived from the Mesoblast, either of the Intermed-
iate cell mass, Sedgwick (Bb.76.), or the peritoneal
epithelium Braun, (Bb. 9.), as segmentally arranged
strings of cells which acquire lumens, and at a later
period open into the Wolffian duct.   Waldeyer (Bb.87.)
on the other hand believed that the Wolffian body
was an outgrowth from the Wolffian duct.   Braun and
Kölliker (Bb.45.) were of the opinion that each of

the Wolffian tubules was derived from peritoneal epithelium, and that at an early stage they opened at one end into the body cavity.   This opening was denied by Fürbringer (Bb.20.).   Sedgwick denied that the peritoneal epithelium was the chief factor in their formation, and gave as their origin the cells of the Intermediate Cell mass.   Balfour (Bb 2.) believed that they arose independently of the Wolffian duct, but that their history varied in different animals.   In the lower Vertebrates e.g. in Elasmobranchs they were formed from the intermediate cell mass, but had peritoneal openings from the very first. In the Amniota there was no attachment to peritoneum.

The Malpighian bodies of the Mesonephros are formed at the end of the tubules, and are therefore derived from the peritoneal epithelium or intermediate cell mass, if we accept the opinion of the majority of these authors.

The Wolffian duct is the functional excretory duct of the Mesonephros, and is believed, as above stated, to have an origin independent of the Wolffian body.   Owing to the important part it is said to take in the later formation of the Metanephros, mention must be made of some of the views regarding its formation.   The older Embryologists, and especially Balfour (Bb 2.), held that it was a Mesoblastic structure.   In the lower vertebrates the development

of which Balfour studied particularly in Elasmo-
branchs, he found that the Wolffian duct arose from
the Segmental duct, which was formed from Mesoblast.
Of the Urino-genital organs in Vertebrates Balfour
said, "Whatever may have been the primitive origin of
the system, its Mesoblastic origin in Vertebrates
cannot in my opinion be denied." (Bb. 2.).

Recently the view has gained more general ac-
ceptance that the Wolffian duct is formed from Epi-
blast. The study of its origin in the human em-
bryo is rendered difficult by the impossibility of
acquiring suitable specimens. Kollmann(Bb. 47.) has
described its formation in a human embryo about a
fortnight old. He found a pair of longitudinal
grooves in the Epiblast, which he considered formed
a solid column of cells, and described them as be-
coming detached about the 3rd week from the remain-
ing Epiblast, and sinking into the Mesoblast of the
Intermediate Cell masses. About the same time a
lumen was formed. Schäfer (Bb. 74.) considers it to
be an Epiblastic structure. On the other hand
Marshall is in favour of its being Mesoblastic in
all animals.

The Ureter arises from the dorsal aspect of the
Wolffian duct near its hinder extremity. This was

described by Kupffer (Bb. 48.), and has been confirmed by numerous observers.   The origin of the tubules of the kidney has been a matter of much dispute, and there have been for many years, and still are, two distinct opinions.

The older opinion and one that has received the more support is, that the kidney tubules arise as continuous outgrowths from cells in the pelvis of the kidney, which have been originally derived from the Wolffian duct through the outgrowth of the ureter. In other words, that they are branches of the ureter, which is in turn a branch of the Wolffian duct.   According to the advocates of this view all the tubules of the Kidney including the epithelium lining Bowman's capsule and that covering the Glomerulus are derived from cells, which were originally part of the Wolffian duct.   They are therefore to be regarded as Mesoblastic or Epiblastic according as we regard the origin of the duct as Mesoblastic or Epiblastic. If the cells lining Bowman's capsule be derived from Epiblast we can scarcely consider them as likely to assume the characters of endothelium.

The alternative view of the development of the glandular portions of the kidney is that they arise independently of the ureter and its branches, and only

unite with these at a later stage.   The kidney is
supposed by the advocates of this view to develope
in a manner similar to the Wolffian body.   The sup-
porters of both opinions allow that the Ureter and
Collecting tubes are branches which arise in contin-
uity from the Wolffian duct.   The difference then is
one with regard to the origin of the Malpighian bod-
ies and tubules beyond the Collecting Tubes.

The first clear account of the development of the
kidney appears to have been given by Remak (Bb.64.) in
1855.   He traced it in the embryo of the chick, rabbit,
dog, and cat, and described columns of cells which
grew from the pelvis to the cortex and formed the ur-
inary tubes.   His description of the formation of
the Malpighian body led to the common belief that it
consisted in the invagination of the wall of the end
of a urinary tube by an ingrowth of capillaries.
Remak described the end of one of the epithelial col-
umns curving round what afterwards became the Glomer-
ulus, and which by its further growth formed a basin
shaped invaginated swelling either at the end or in
a side wall of the tube.   Remak considered that the
epithelium covering the tuft was a continuation of
the membrane propria of the tubule.

Before Remak other observers Burdach (1828)
Müller (1830) and Rathke (1833) are quoted by
Hamburger (Bb. 29.) in a recent paper, as having ex-
pressed the views that the tubules of the kidney arose
as buddings from the Ureter branches.

Waldeyer (Bb 87.) and Toldt (Bb 84.) were strongly
of the opinion that all the tubules of the kidney were
developed from the Ureter. Kölliker (Bb 46.) described
the same. Löwe (Bb 57.) described all the tubules as
arising from the ureter but believed that the Glomeru-
lus arose as an independent structure in the cortex.

Pye (Bb 61.) and Ribbert (Bb 65.) described the
formation of the Malpighian bodies very carefully.
They both considered that the Collecting tubules each
ran from the pelvis to the cortex of the kidney and
immediately under the capsule bent completely round
with a short end which developed into Malpighian body,
Convoluted tubules, and Henle's loop. All were there-
fore branches of the ureter, and in continuity from
the very first. With these observations most of the
later authors agree. Hortolès (Bb 37.), Golgi (Bb 24.),
Nagel (Bb 57.), and Berry Haycraft (Bb 32.), all consider
the different parts of the tubules, and Malpighian
bodies to be in continuity from the very first, and to
arise as outgrowths from the ureter.

The second view that the glandular portion of the
kidney has an origin independent of the Ureter has
also received considerable support.   Thayssen (Bb 83.)
was the first to definitely state the opinion that
the Collecting and Junctional tubules were formed as
hollow buds from the ureter, while the Malpighian
bodies and their appertaining Convoluted tubules
and Henle's loops were developed independently from
solid masses of cells in the "Nierenanlage."   Each
Malpighian body arose from a solid mass of cells in
which a split like lumen appeared, a description
very different to that given by Remak and Toldt.
Thayssen did not describe the union of the two systems.

Riedel (Bb 67.) described a very similar process.
He showed that the Malpighian body was a solid mass
of cells, which developed a lumen continuous with the
Convoluted tube.   He further described the union of
the two systems;   the Collecting tubule ended under
the capsule in a dilated vesicle the Ampulla, which
gave off a side branch to join the developing Convol-
uted tubule.   In this way all became continuous with
the ureter.

Bornhaupt (Bb 5), Braun (Bb 9.), and Furbringer
(Bb 20.), agreed in the main with Thayssen and Riedel,
that the Malpighian bodies and secreting tubules arose
from Mesoblast, and united with the Collecting tub-

ules at a later stage.

Braun considered that in Lizards the cells
which gave rise to the Malpighian bodies and secret-
ing tubules were developed from irregular strings
of peritoneal epithelium.   Fürbringer believed
them to be differentiations of the dorsal tubules
of the Wolffian body.   Sedgwick (Bb 76.) while ad-
mitting their independent development, denied that
they were formed from peritoneal epithelium, but
described a blastema of cells in the chick continu-
ous in front with the blastema of the Wolffian body.
The kidney blastema as well as the blastema of the
Wolffian body, he believed to be developed from the
mesoblast of the Intermediate cell mass.   Hamburger
(Bb 29.) 1890 is the latest observer who has described
fully the separate origin of the secreting portion
of the kidney.   Schäfer takes the same view in the
Embryological portion of Quain's text book of Ana-
tomy, and states that the Malpighian bodies, Henle's
loops and the Convoluted tubules arise from portions
of the Intermediate Cell mass, which are situated
posterior to the Wolffian body.   This is practic-
ally the same as Sedgwick described.   Hamburger
worked at the development of the kidney tubules
principally in the mouse.   His description agrees
with that given by Thayssen, but is more minute.

The figures illustrating his paper are very diagram-
matic, and with some of them I find it impossible to
agree, but on the whole my own observations have led me
to conclude with this group of authors, that the two
systems arise independently, and are not continuous
structures from the very first.   To avoid errors
in illustration I have selected examples of different
stages in the process, and record them in the Photo-
micrographs appended.

Unfortunately I have not been able to obtain
specimens of the human kidney at its earliest stages,
but have examined many from the third month onwards.
As the process of formation of new Malpighian bodies
and tubules goes on up to the time of birth, and
during that time the processes are similar, it is
quite reasonable to suppose that the same takes place
before the third month.   It is very unlikely that
the first Malpighian bodies are outgrowths from the
ureter and that subsequently the remainder which
form a vast majority, develope independently of the
ureter.   The tissue surrounding the ureter branches
which gives rise to the Malpighian bodies has been
shown by numerous observers to be present from the
very first, and is formed according to the later
authorities from the mesoblast of the intermediate
cell mass.

Before passing to the mode of formation of an individual Malpighian body and its tubule, it is is necessary to state shortly a few facts concerning the **early history** of the development of the kidney.

The ureter is said by **Marshall** (Bb 55.) to begin to form about the early part of the 4th week of intra-uterine life.   A budding of the hinder end of the Wolffian duct takes place to form a solid column of cells, which gradually grows forward until its anterior end occupies the position of the pelvis of the future kidney.   In the chick Sedgwick has shown that the kidney blastema closely invests the anterior end of the ureter.   Kölliker (Bb 45.) described in a human embryo of 8.5 mm long the kidney as a single club shaped structure connected by a straight canal with the sinus urogenitalis.   Its club shaped anterior end was surrounded by a thick accumulation of mesoderm cells.   Kölliker believed that this meso-dermic investment gave rise to the blood vessels and connective tissue of the kidney.   Phisalix (Bb 60.) showed that in an embryo 10 m m long the kidney con-sisted of a cylindrical sac with widened lumen sur-rounded by a dense mass of mesoblast.

Schäfer describes a similar investment, and states that it is derived from the intermediate cell mass.

All observers are agreed that the pelvis of the kidney is formed from the anterior dilated extremity of the ureter, and that from it branches arise which form the calyces and collecting tubules. The branches are at first solid but acquire lumens. The distal end of the ureter at the same time becomes detached from the Wolffian duct and opens into the Urogenital sinus.

Great importance has been attached by the German writers to the cells which line the pelvis of the developing kidney. According to the first group of authors mentioned they give rise to all the tubules of the kidney, while others only allow that they form the collecting, and perhaps the junctional tubules. In the human kidney at the middle of the third month, the cells lining the pelvis and occupying the position of the papillae, have the following characteristics. Each cell is cylindrical, and from two to three times as long as it is broad. They are usually arranged in columns of two cells deep with a central lumen, in other places they form masses of considerable size especially at the apices of the papillae. Where there is a lumen it is narrow, and the margins of the cells forming it are flat and continuous. The opposite ends of the cells are tapering, and between them are placed the tapering

ends of the cells in the deeper layer, the broad ends
of the cells of the deeper layer are therefore outer-
most, and present a regular border, but do not seem to
have a definite basement membrane, but are closely
surrounded by embryonic connective tissue and blood
vessels.   Each cell has an oval nucleus with one or
two deeply staining granules.   The nucleus is nearer
the broad extremity of the cell, and the protoplasm
is large in amount and stains very lightly.   As the
columns approach the cortex they grow less in size
and divide dichotomously, the cells form a single
layer, and become shorter, with the nucleus relatively
larger, and placed deeper in the cell.   In the cor-
tex each tubule has a well marked lumen, the cells
are cubical with a larger and more deeply staining
nucleus, and relatively little protoplasm.   The
tubules run fairly straight in a radiating manner to-
wards the cortex, divide dichotomously once or twice
and end in dilatations, the so called Ampullae, im-
mediately under the capsule.   The appearance of each
Ampulla varies at different stages, and will be de-
scribed more fully in connection with the formation
of the Malpighian bodies.   It is of great importance
and constitutes the growing end of the collecting
tube, and is the part with which the convoluted tub-

ules unite.   The Pyramids or Renculi appear to be
formed early, and each is represented by a mass of
the cells above described.   From these masses of cells
spring the collecting tubules, each of which gives or-
igin to the primitive cone of Ludwig.   At this early
stage there is no great difference between cortex and
medulla, and the earliest Malpighian bodies are found
among the collecting tubes close to the pelvis.

The lobulation of the kidney is not well seen at
first, but becomes more marked during further growth.
In the third month the kidney is a flattened elong-
ated body with an indentation at the Hilum where the
ureter enters.   In the 5th and 6th months lobulation
becomes marked, the number of lobules varying with
the number of pyramids, usually about sixteen, but
varying from eight to twenty.   From the 7th month
onwards the lobulation becomes less marked, but can
still be traced for some time after birth.

The relation of Malpighian bodies and convolut-
ed tubules to the collecting tubules would seem at
first sight to be a simple matter to decide, but it
is really a most difficult question, as the different
opinions of skilled observers show.   Before dis-
cussing it, the methods that have been employed in
investigation may be noticed.   Some of these are
obviously misleading.   The earlier observers exam-

ined sections, but owing to the imperfect means of cutting them sufficiently thin, could not appreciate the fine distinctions necessary to establish the independence of structures. Their method of staining was also imperfect. Ribbert (Bb 65.) in his paper on the development of the Malpighian bodies in 1880, laid stress on the fact that their development was more easily traced in the kidneys of older foetuses where the connective tissue was not so abundant. In the very young kidney he found the connective tissue cells so numerous and staining so like the cells of the tubules, that he could not distinguish between them. I am convinced that this was the reason of his description of the tubules being continuous structures, because he examined specimens in which the tubules had already united.

Many observers have made Isolation preparations by various methods of maceration and teasing the tubules from their surrounding connective tissue. Hamburger used this method in conjunction with serial sections, but found it to be impracticable in the very young kidney owing to the large amount of connective tissue.

The condensed layer of mesoblast under the capsule renders isolation impossible, and even in the later stages when the tubules have united they are very fragile, and often break even when cut in section as may be seen in Fig. (*ll.*). The cells which form the Malpighian bodies and convoluted tubules are at first indistinguishable from the connective tissue cells, and could not be isolated from them. Colberg (Bb *13.*) injected the blood vessels with coloured material, this is recognised to be of very little use in newly formed and forming tissues. Under the capsule there are few capillaries formed, and those already formed are so delicate that rupture of their walls is inevitable. The capillaries of the glomerulus are not formed at first, and do not push in the wall of a tubule in the way described by Remak and Toldt. This may have led Colberg to give the name of "Pseudo-glomeruli," to structures which are really Malpighian bodies at an early stage before the formation of capillaries in them.

The only reliable method of examination is by the careful preparation of a series of thin sections. The tissue examined should be well fixed and hardened, and cut in paraffin.

The sections best adapted for the purpose are those cut parallel to the collecting tubules, longitudinal sections through the widest portion of the kidney including the pelvis show the most detail. Transverse and tangential sections should also be made.   Owing to the tortuosity of the convoluted tubules even at an early period, it is difficult to obtain a section in which a continuous lumen appears, but the examination of a consecutive series of sections shows whether they are continuous or not. The method of serial sections has been made use of by most of the later observers, and their results are conflicting.   The method is tedious, and often difficult, but seems to be the only satisfactory one. Of staining reagents I have tried many, and find Heidenhain's Iron alum Haematoxylin method gives the best results.   By it there is a greater differentiation between the different structures than by any other method I have tried, it is also very suitable for photographic work.   A counter stain of Rubin and Orange improves the appearance of the section, and is of value in staining the cells of the convoluted tubules when they have become well developed.

The presence of dilated spaces lined with ep-
ithelium in the cortex of the developing kidney has
long been known.   Valentin (Bb 85.) in 1835 describ-
ed club shaped structures from which he believed both
cortex and medulla were formed.   They are the "Am
pullae" of the German writers, and have long been
recognised as the peripheral ends of the ureter
branches, or future collecting tubules.   They are
situated almost immediately under the capsule, or
close to the interlobular septa, and often show a
dichotomous division.   In some animals the branches
from the Ampullae are more numerous.   I have never
seen more than two in the human kidney.   The cells
forming the wall of the Ampulla are arranged in a
single row, and are cubical in shape, with large
deeply staining nuclei.   They are sharply defined
from the surrounding tissue, and during the process
of hardening often shrink from it, leaving a space.
Toldt (Bb 84.) described the cells of the collecting
tubes as forming by proliferation solid cells cones,
which at a later stage became hollow, and gave rise
to the convoluted tubules.   Ribbert (Bb 65.) showed
that each Ampulla divided into two branches, which
curved round under the capsule, then descended par-

allel to the ascending tube.   The descending limbs
were short, and soon became curved,   a Malpighian
body forming in the hollow of the lowest curve.
The lumen was continuous throughout.   But Ribbert
examined the kidneys at a late stage of development,
generally about the time of natural birth, and his
description is quite true of that stage, he appar-
ently did not see the earlier stages.

Golgi appears to have described the process
very fully. (Bb 23.) (Unfortunately I have been un-
able to obtain his paper).   His diagram of the
development of the urinary tubules appears in al-
most all the text books.   He apparently believed
in the division of the collecting tube into two
branches under the capsule, each branch curving
round and descending in the manner described by
Ribbert.   Other observers have come to the same
conclusions.   Berry Haycraft (Bb 32.) in 1895.   All
the foregoing authors have figured in diagrams a
stage which does exist, but is a comparatively late
one.   Fig. (//.) shows the continuity of Malpighian
body convoluted tube and collecting tube almost dia-
grammatically, and is very similar to Golgi's dia-
gram.   Almost all have noted the dense layer of
mesoblast which surrounds the Ampullae.   Ribbert

found it too dense in the young kidney for a satis-
factory examination.   Remak, Toldt, and **Schweigger**
Seidel, recognised the large amount of connective
tissue, and believed it was formed from the dense layer
under the capsule.

Thayssen (Bb 83.) was the first to bring into
prominence the view that the Malpighian bodies, and
convoluted tubules were not branches from the col-
lecting tubule, but were formed in close proximity
to it from the layer of condensed mesoblast.   Other
observers came to a similar conclusion.   Riedel
(Bb 67.) gave a more complete description of the pro-
cess.   He showed that a layer of mesoblastic cells
surrounded the ureter branches, and as the kidney
grew, remained in the periphery of the lobules, and
formed masses of epithelial cells closely surround-
ing the Ampullae, but distinctly separate from them.
In the masses of cells thus developed lumens appear-
ed, and at the same time they became continuous with
the collecting tubes.   Braun (Bb 9.), Bornhaupt
(Bb 5.), Sedgwick (Bb 76.), Balfour (Bb 2.), and
others were convinced that the Malpighian bodies
and convoluted tubules arose independently of the
Ureter branches.   Of late years the opposite view
has received the most support, and agreeing with
Thayssen we only find Hamburger (Bb 29.) 1890,

Schäfer (Bb 74.), and Hertwig (Bb 35.).

My own observations led me at first to believe
that all the kidney tubules were branches from the
collecting tubes, but I could never find the early
stages which should have been easily seen if that
view were correct.   In the thick layer of the cap-
sule, cells are seen which show a gradual transit-
ion in appearance from embryonic connective tissue
cells to a character closely resembling that of the
epithelial cells of the early convoluted tubules.
Between these cells and those of the Ampullae there
is always a distinct line of separation, and in the
majority of instances there is a space, where the
tubule has shrunk during the process of hardening.
The careful examination of serial sections has con-
vinced me that these masses of cells which appear
under the capsule, and in the interlobular septa,
                                               and
are quite independent of the ureter branches, give
rise to Malpighian bodies, convoluted tubules, and
Henle's loop, uniting always with a short branch
from the Ampullae.

The cells which form the layer under the cap-
sule, and constitute the interlobular septa, are very
numerous; those on the surface of the capsule, and
in the middle of the septum, are elongated with long

drawn out nuclei, and are arranged with their long axes parallel to the surface of the lobule. They are thus arranged for several layers, but as they lie deeper they become rounder and larger. In the deeper layers the cell outlines are difficult to see, there is little protoplasm, and the nucleus is large, round or oval and deeply staining. Over the Ampulla the cells take up an arrangement very like a cap fitting on its extremity. A transition in character between the cells can be seen. It is illustrated in Fig. (3.) which shows a very common appearance. The cells next the Ampulla are becoming arranged in a layer which is distinctly separated from it, the cells in this layer are almost columnar with large oval nuclei. In fig. (3.) two collecting tubes are shown ending in dilated extremities, the Ampullae. Over the end of each Ampulla lies a cap of cells as described above. Note the sharp line of demarcation between tube and cap, which is here emphasised by the contraction of the cells of the tubule during the process of hardening. Between the capsule and the cap there is not a similar distinction, the cells gradually change in character from the one to the other, and it is difficult to

say where the one begins and the other ends.   The
further development of this cap of cells clearly shows
that they become epithelial in character, the diffi-
cult question to decide is, whether they are continuous
with the epithelial cells of the collecting tube, or
whether they are independent structures arising from
the mesoblastic covering under the capsule.   Toldt
(Bb 84.) regarded them as solid cones, which were
thrown out by the collecting tubes, and pushed their
way through the condensed connective tissue as fing-
ers through a glove.   On examination of sections one
always finds a well marked line of separation between
the Ampullae and the caps or cones of Toldt.   In no
case have I seen them continuous, and the distinction
is well seen in several of the Figures.   The cells
of the two structures also differ in character.   An
early stage is seen in Fig. (3.), the cells nearest
the Ampulla become elongated and arranged with their
bases towards the tube, the more superficial layers
remain composed of ordinary embryonic connective
tissue cells.   Gradually more cells become elongat-
ed with larger nuclei until a mass of cells has been
formed over the Ampulla several layers deep.   Fig.
(4.) .   A second line of demarcation then begins
to appear on the other side of the cap between it and
the connective tissue, a definite mass of cells is

thus formed, which lies over the end of the Ampulla, and is definitely marked out from its surroundings. Fig. (4.). Berry Haycraft (Bb 32.) believed that the appearance was due to the end of the tube having been cut obliquely, and that the two structures were really continuous. In Fig.(5.) the Ampulla has been cut obliquely, and as a consequence there are a number of cells at the end of the tube which really are part of the wall, but which being cut obliquely, looks as if they formed a solid mass. But quite separate from this mass of cells is another under the capsule, the beginning of another convoluted tubule and Malpighian body.

The two structures in this Fig. cannot be said to be a continuation, and appearing solid because cut obliquely. The difference between the cells of the cap, and those of the Ampulla are here well seen. The cells in the cap take on a much deeper stain, their nuclei contain more chromatin than the nuclei of the cells of the tubule, and show evidence of active growth and division. If it be granted that the two structures are not continuations in the Figs. there remains still the possibility that the cap may be an out growth from some other part of the collecting tube, the side wall for instance, and the appearance may be due to its subsequently having curved round the end of the Ampulla. I have examined serial

sections very carefully, and find no indication of this being the case, in all, the cap appears to be a separate structure at this early stage.   In the later stages there sometimes seems to be a connection between the mass of cells after a lumen has begun to appear and the cap which is in process of formation. This is only what one would expcet, the cap in this case becomes detached from the mass of cells with the lumen, and is the origin of another system, the two are different stages of development of two separate tubules, but both belong to the same primitive cone, that is, both open into the one collecting tubule.

In Figs. (4. + 5.) one might suppose that the cap was really another collecting tubule curving round under the capsule in the way described by Ribbert, and that it appeared solid because the section was one cutting through the side wall all the way. Examination of serial sections proves that this is not the case.

I am strongly of the opinion that the cap of cells which appears over the end of each collecting tubule is a structure independent of that tubule, and further that it give rise to a Malpighian body, **convoluted** tubules, and Henle's loop.

Emery (Bb /7.) described a similar origin.   He
used only the method of serial sections, and found
that there appeared a Cell group between each Am-
pulla and the capsule.   From this Cell group there
developed a "vesicule renale" which was separated
from the collecting tube by a sharp contour, and
only united with it when the Malpighian body began
to form.

Hamburger (Bb 29.) came to the same conclusion.
He described the collecting tubules ending in Am-
pullae under the capsule, but separated from it by a
"Zellschicht" or "Zellmantel".   The cell mantle was
composed of cells with round or oval nuclei, which
were more deeply stained by carmine than the nuclei
of the cells of the surrounding connective tissue,
and it was always separated from the Ampulla by a
sharp contour.   By following their relations thro-
ugh a number of serial sections he was convinced
that "No Continuity existed at any point between the
"Anlage" and the Ampulla".   The "Anlage" gave rise
to the "geschlangelten Röhren", each of which be-
came united to the Ampulla by one end, while at the
opposite end there developed a Malpighian body.

The layer of cells in which these Caps or Cell
mantles appear is confined to the periphery of each

lobule, it follows therefore that new Malpighian bod-
ies and convoluted tubules only develope in the peri-
phery.   It is not correct to say that they develope
only under the capsule, because they form in the in-
terlobular septa as well.   The Mesoblastic covering
of the ureter branches is a structure of great im-
portance.   In the third month it forms a fairly even
surface under the capsule, but portions of it are con-
tinuous between the first branches of the Ureter.
As the collecting tubules grow and become arranged
in groups, each group giving rise subsequently to
one lobule, the covering remains at the peripheral
ends of the tubules.   Lobules are gradually formed,
the cellular covering being still at the periphery
of each.   With further growth the lobules coalesce
from the pelvis outwards, the capsule becomes con-
tinuous at the point of junction of one lobule with
the other, but the cellular covering or "Anlage" of
the German writers remains between the lobules, and
dips down from the capsule to the pelvis.   Figs
(/.+2.) show the lobulation.   In Fig (/.), which is
a section of a human kidney at the 4th month, lobul-
ation is not marked on the surface, but the division
by septa internally can be seen.   Fig (2.) from a
human kidney at the 6th month shows a single lobule

which is made up of cortex and medulla.   The capsule
on the surface bridges from one lobule on to the next,
leaving a wedge shaped space between their surfaces,
which is filled with loose connective tissue.   There
is a distinct line of separation between each lobule
extending from the capsule to near the pelvis.   This
line of separation is composed of a dense mass of
mesoblastic cells, and is really a double layer of the
same nature as the layer under the capsule.   Each
lobule has its own layer, and they can be seen to
blend where the two surfaces come together at the
point of the wedge shaped space between the lobules.
In this mesoblastic septum the central cells have a
longitudinal direction as under the capsule, but on
either side they become larger with round deeply
staining nuclei, and among them appear the cells
mantles or caps in relation to the Ampulla just as under
the capsule.   Malpighian bodies and convoluted
tubules therefore develope in the periphery of each
lobule on either side of the septum.

In addition to glandular elements, there is a
large amount of embryonic connective tissue in the
foetal kidney.   It is more abundant and cellular at
first, and gradually decreases towards the time of
birth.   The largest amount is found in the cortex,
where it is difficult to distinguish it from the cells

which give rise to the tubules. The connective tis-
sue of the kidney is recognised by all to be formed
from the mesoblastic covering of the ureter branches.
Remak, Kölliker and others considered that the
branches of the ureter grew into the connective tis-
sue, and that there was a constant proliferation of
connective tissue and tubules under the capsule.
The connective tissue certainly appears to be formed
under the capsule, and the question arises, "Are both
connective tissue cells and epithelial cells devel-
oped from the same layer?" This is a difficult
matter to decide. The superficial layers under the
capsule consist of flattened cells with a longitudin-
al arrangement, these appear to be definitely part
of the capsule. But below them the cells are very
thickly massed together and resemble one another in
appearance. Collecting tubules reach the periphery
of the lobule at numerous points with small inter-
vals between. Over the Ampullae the cells take up
the arrangements already noticed, but in the inter-
vals the cells become less numerous, their nuclei
elongate, and many take up an arrangement with their
long axes parallel to the collecting tubules. This
flattening of cells is sometimes marked round the

outer side of what becomes Bowman's capsule. The
majority of the cells between the tubules develope
into mucoid tissue, they become less numerous from
the cortex to the pelvis, and in the deepest layers
consist of large branching cells, with small nuclei.
They are most numerous in the young kidney, and are
very plentiful at the 3rd and 4th months, but with
the further growth of the kidney they gradually dis-
appear but not entirely. Hortoles (Bb *37.*) comment-
ing on the large amount of connective tissue in the
foetal kidney, said, that though it for the most part
disappeared it still existed "en puissance" through-
out life, and was rendered evident by pathological
processes. Connective tissue is always evident in
the papillae between the collecting tubes, and remains
so in adult life. Most of it disappears from the
cortex, but some remains under the capsule, and to a
less extent in the positions of the interlobular sep-
ta. Delicate connective tissue can often be found
around the larger blood vessels, and surrounding the
Malpighian bodies. The presence of a definite ar-
rangement of connective tissue in the adult kidney
was first pointed out by Goodsir in 1842 (Bb *25*).
Goodsir described a fibro-cellular framework pervad-
ing the whole gland, and compared it to Glisson's cap-

sule in the liver. This framework is not very evident in the healthy adult kidney, but becomes a great feature in some of the chronic inflammatory lesions· Goodsir's description is especially true of the foetal kidney, in which the framework is cellular and large, forming separate compartments for each tubule.

Among the connective tissue of the cortex of the developing kidney numerous capillaries are formed· These appear to me to be developed in situ, and not as outgrowths from the larger vessels. Some of the mesoblastic cells become more and more elongated and their nuclei flattened. They become very numerous among the tubules, and appear to replace the connective tissue cells in the cortex. By proliferation and anastomosis they gradually form the complex network which is found in the fully developed kidney.

The origin of the Mesoblastic envelope has already been mentioned, there are two main views.

I.   Peritoneal Epithelium. Braun after examining the development in Lacertilia arrived at the conclusion that the tissue, out of which the tubules of the Metanephros were formed, was derived from irregular solid ingrowths of Peritoneal epithelium. "Peritoneal Zellstränge."

II.   The Intermediate Cell Mass. This was the view enunciated by Sedgwick (Bb 76.) in the develop-

ment of the chick.   Sedgwick believed Braun's view
to be **erroneous**.   He showed that in the chick part
of the Intermediate cell mass was at first continu-
ous with the peritoneal epithelium, and had a continu-
ation of the body cavity into it, but subsequently
it became detached, and lay between the peritoneum
and protovertebrae, and formed the Wolffian blastema.
Sedgwick allowed that part of the blastema was form-
ed from peritoneal epithelium, not as solid ingrowths
in the way described by Braun, but as a continual
process of budding of cells, which travelled inwards
and united with the cells of the blastema.   From
the Wolffian blastema thus formed, Sedgwick believed
the tubules of the Wolffian body arose as far back
as the 30th segment.

But the blastema from the 30th to 34th segment
in the chick remained for a long time passive, and was
called by Sedgwick the kidney blastema.   It is from
this that he believed the tubules of the permanent
kidney arose.   With the appearance of the ureter
the kidney blastema altered its position further from
the peritoneum, so as to lie to the inner side of the
ureter.   After a time it broke away from the Wolffian
body, and invested the anterior end of the ureter, col-
lecting especially round the dilatations.

From the cellular investment, tubules and Malpighian
bodies were formed in connection with branches of the
ureter.   The manner in which this came about was only
imperfectly described.

Wolffian tubules and kidney tubules have a simi-
lar origin then according to Sedgwick.   Schäfer takes
the same view as regards the development of the human
kidney, and it seems probable that the history of dev-
elopment is much the same in all ∧higher Vertebrates.
                                      the
The views of Braun and Sedgwick are not really very
different, and we must regard the envelope of the
ureter branches as composed of mesoblastic cells dev-
eloped from the Intermediate cell mass and peritoneal
epithelium.   The envelope produces Malpighian bodies,
tubules, connective tissue, and blood vessels, and forms
a layer at the periphery of the ureter branches, which
may be compared to the periosteum surrounding bone.
Unlike periosteum its functions cease at an early date,
the portions of the interlobular septa which lie near-
est the pelvis disappear first, the layer under the
capsule persists the longest, but no more tubules are
formed after the 8th month or early part of the 9th.
In connection with the tubules last developed Malpigh-
ian bodies form, but do not reach full development till
the time of normal birth, and in some cases later.
The Subcapsular layer gives rise to the ordinary kid-
ney cortex, while the interlobular septa form the

inter-pyramidal cortex.   As mentioned above the pro-
cess ceases in the latter, while it is still going on
under the capsule.   The oldest Malpighian bodies in
the kidney are those which lie nearest the apex of
the papilla in each lobule, the more recently formed
are further from it, and the last are developed under
the capsule, but as will be shown later never next the
capsule, a zone containing convoluted tubules being
interposed between them and the capsule.

Let us now return to the Cap or Cell mantle
which forms in the kidney "Anlage."   A mass of cells
has been shown to develope in relation to the peri-
pheral end of a collecting tube as in Fig. (4.).
The Ampulla continues to grow, not as a solid mass
of cells but as a hollow tube, the cells under the
capsule proliferate at the same time.   Meanwhile
the cap extends and is found reaching down some dis-
tance on either side of the collecting tube.   The
cap begins to thin over the extremity and the two
sides become detached.   Fig. (4.) shows the thin-
ning in the centre of the cap.   The Ampulla then
begins to divide into two branches, each of which
remains in close association with one of the divis-
ions of the cap.   Fig. (5.) shows a still later
stage. The end of the collecting tubule is cut ob-
liquely, and does not show the dichotomous budding

of the Ampulla.   Over its end is forming another cap,
and to one side is seen one of the divisions of the
first cap.   Owing to the elongation of the collecting
tubule this division is now no longer immediately
under the capsule, but lies deeper in the cortex.
While this alteration in their relative positions
is going on through elongation and division of the
collecting tube, the cells composing the cap alter
in shape and appearance.

The cells become greatly elongated, and narrow,
and their nuclei large, and deeply staining.   In
this they offer$_\wedge$contrast to the cells of the collect-
ing tubule, which are more cubical, and stain less
deeply.   The cells become arranged with their long
axes radiating out from the centre in which a lumen
appears.   Fig. (5) shows the character of this
hollow vesicle, the "vesicule renale"of Emery.   It
is composed of long thin columnar cells with central
lumen, and is sharply defined from the surrounding
connective tissue, and close to, but also separated
from, the collecting tubule.   By active proliferation
of cells the vesicle grows in length, but not as a
straight tube, it becomes comma shaped as in the next
Fig. (6.).   The bend of the comma is always away
from the collecting tubule with which it eventually
joins .   Here we see one of the divisions of the
Ampulla, which now curves a little under the capsule,

but never completely round in the way described by
Ribbert.   Over its end is another cap forming, and
just under its extremity is the comma shaped body.
The cells now are even more cylindrical than before,
and form a single layer.   The tail of the comma is
directed away from the collecting tube.   In it a
differentiation of cells is already taking place,
the ones forming the convex bend of the tail are less
cylindrical than the others, it is this portion that
forms part of Bowman's Capsule, and these cells con-
stitute its earliest lining.   The comma is now in
close contact with the Ampulla, but the lumens are not
continuous.   As the comma shaped body grows it el-
ongates, but the tail remains in the same position,
further growth is upwards towards the capsule along
with the end of the collecting tube.   It grows more
quickly than the latter, and takes on another curve
at its upper end, this time towards the Ampulla.
The result is an S shaped body with a central lumen.
Fig. (7.). When the S is well developed its lumen
becomes continuous with the lumen of the collecting
tube.   Fig. (10). The S shaped tubule is well known
since Golgi's description of it, but Golgi considered
it to be a structure continuous with the collecting
tubule from the very first.   One can often find the
two in continuation as in Golgi's diagram, but these
are late stages.   They are well shown in Figs. (10+11.)

The two structures are intimately associated, but
are not in continuity from the beginning.   Golgi
showed that the lowermost limb of the S surrounds
the glomerulus, and forms the Malpighian body, the
middle one developes into the proximal convoluted
tube and Henle's loop, while the upper limb forms
the distal convoluted tube and the junctional tube.
Figs. (//&73) show that this is the case, and being
photo-micrographs of actual sections demonstrate
it in a way no diagram could.

The origin of the Malpighian bodies cannot
then be considered by themselves alone, they are
part of a structure which forms several of the most
important parts of the kidney.   Their origin is a
complex one , and involves at the same time the or-
igin of convoluted tubules, and connective tissue,
and their further development is closely associated
with the growth of the entire organ.

There has been even more difference of opinion
on the origin and development of the Malpighian bod-
ies than on the origin and development of the convol-
uted tubules.   In the first place there have been
two opposite views .

                                    were formed
    I.   That the Malpighian bodies ⁀at the peripheral
ends of ureter branches, and that their epithelium
was developed by proliferation of cells, which orig-

inally sprung from the Wolffian duct by way of the
ureter.   This was the view of Remak, Waldeyer, Toldt,
Kölliker, Lieberkühn, Pye, Ribbert, Hortolès, Golgi,
Nagel, and Berry Haycraft.

11.   That the Malpighian bodies arose in the kid-
ney cortex independent of the Ureter branches, and
united with them secondarily.   Their epithelium was
not developed from the Wolffian duct, but from masses
of mesoblastic cells which surrounded the anterior
end of the ureter.   With this view agreed Thayssen,
Riedel, Kupffer, Bornhaupt, Braun, Fürbringer,
Balfour, Sedgwick, Emery, Hamburger, and Schäfer.

My own observations as already indicated lead me
to believe that the second view is the correct one.

Colberg   (Bb /3.) described two systems of tub-
ules, one forming the looped canals and developing
from the periphery, the other the ureter branches
and growing from the pelvis.   He further believed
that Malpighian bodies developed in both systems,
some being formed in connection with the loop forming
canals, and others at the end of the ureter branches.
This description is incorrect, Malpighian bodies
certainly develope after the tubules have become
continuous; but the part of the tubule they develope
in is not an outgrowth from the ureter.

Löwe (Bb *57.*) believed that the epithelium of the Malpighian bodies was derived from the Ureter branches, and that the mesoblastic cells formed the vascular part of the glomerulus.   With this I cannot agree. The vessels are certainly formed from mesoblast, but do not play the active part they are generally credited with.

The mode of formation of Malpighian bodies has also been very differently described.   They have been regarded as made up of two structures, Vascular and epithelial, each of which has been considered by different observers to take an active or passive part.

Remak (Bb *64.*) in 1855 was the first to describe the formation of the Malpighian bodies.   He believed that the end of a column of cells surrounded a glomerular tuft, and by degrees enclosed it.   The epithelium played the active part at first, but by the further growth of the capillaries a basin shaped invagination of the tube came about.   The cells lining the end of the tube were cylindrical, but gradually became flattened, the tuft pressing inwards so as to narrow but not quite obliterate the lumen. Remak said the process took place either at the end, or in the side wall near the end of the tubule.   The value of his description lay in the fact that he established the presence of a layer of cells over the glomerular tuft.

Toldt (Bb *84.*) confirmed Remak's observations and described the process more fully. He stated that the tubules ended blindly in spherical dilata-ions, and that in their further development capill-aries appeared, which pushed in one side of the wall gradually invaginating it. He compared the process to the driving in of one side of a hollow india rubber ball till the two sides came into contact. This description has been followed in some modern text books, it is delightfully simple and wholly in-accurate.

Kölliker was of the same opinion as Toldt, that the wall of a tubule was invaginated by blood vessels.

Bornhaupt (Bb *5.*) described the Malpighian bodies as arising from solid spherical masses of cells in the cortex, which became hollow and by a thicken-ing of their wall at one side formed a glomerulus, and gradually assumed their later appearance. Bornhaupt believed the epithelial portion to be chiefly concerned in their development, and the glom-erulus was formed, not by an ingrowth of capillaries, but by a thickening of the epithelium in that part of the wall which became the glomerulus.

Thayssen (Bb *83.*) stated that the Malpighian body arose from a solid clump of cells in which a split like lumen appeared, but he did not describe it any further.

Riedel (Bb *67.*) showed that solid masses of cells in the cortex became hollow, and gradually formed Malpighian bodies. He compared each corpuscle to a deeply hollowed spoon, of which the handle formed the tubule, and the hollow contained the glomerulus, while the convex back of the spoon represented Bowman's capsule.

Previous to the last three observers Colberg (Bb *13.*) had described the development of Glomeruli in the kidney. He injected the blood vessels and found that some of the Glomeruli showed the injection, but others did not. He described the urinary tubes as ending in the cortex partly as club-shaped swollen ends, partly as betufted ends, and partly as injected Glomeruli. The non-injected ones he called "Pseudo-glomeruli", though what he meant by that term is not quite clear. Hamburger (Bb *29*) interprets it as meaning that Colberg **did** not recognise their nature, but the assumption is not quite warranted from Colberg's description. The name "Pseudo-glomeruli" given by Colberg to certain structures in the cortex of the kidney has been **retained** probably on account of so little being known about them. The name was clearly given to Malpighian bodies in an early stage of development and need not be retained. It is useless and misleading.

Pye (Bb *61.*) expressed views very similar to those of Remak's. He stated that the end of a tubule curved round the glomerulus so as to embrace it and become its capsule.

Ribbert (Bb *65.*) described it similarly. He compared each urinary tubule to a man's arm, the end of the tubule being represented by the hand. The tubule curved round in a way represented by flexion of the wrist and fingers. The hand with fingers flexed on the palm represented the early stage of a Malpighian body, the skin of the dorsal aspect of the hand being equivalent to Bowman's capsule, and the skin of the palmar aspect to the covering of the glomerulus. Capillaries grew into the space between fingers and palm, which was at first wide, but gradually closed to form the neck of the glomerulus.

All the foregoing observers described the flattening of the epithelium lining Bowman's capsule and covering the glomerulus. Schweigger Seidel (Bb *75.*) in addition pointed out that there was a great difference for some time between the kinds of cells in the two places. The cells covering the tuft remained cylindrical for a considerable period of time after the cells of Bowman's capsule had become flattened. Ribbert recognised this when he described the

Malpighian body as a sickle shaped structure with two
different layers of cells uniting at the end of the
sickle.   The cells of the outer layer were flat,
those of the inner cubical, and opposite the middle of
the sickle cylindrical, a split like lumen appearing
between the two layers.   Hortolès (Bb 37.) admitted a
cellular covering to the glomerulus during develop-
ment, but believed that the cells fused together later
to form one endothelial cell with multiple nuclei.
This is very unlikely.

Nagel (Bb 57.) in 1889 described each urinary
tubule as ending somewhat widened, with its epithel-
ium passing over a prominence of connective tissue,
which became the glomerulus by formation in it of cap-
illaries.   The cells which became the lining of Bow-
man's membrane were flat at an early stage, while the
cells over the glomerulus were cylindrical, and re-
sembled those of the convoluted tubule.

Nagel agreed with Toldt that the capillaries were
the active agents in the formation of the Malpighian
bodies.

Hamburger (Eb 29.) in 1890 found that the Mal-
pighian bodies arose in the manner described by Born-
haupt and Riedel.   A shell like structure was formed
with its concavity towards the capsule of the kidney,
consisting of two layers of cells, an inner and an

outer separated by a split like lumen.   The cells
of the inner layer were cylindrical, those of the
parietal layer were flat.   The inner layer covered
the glomerulus, the outer formed the lining of Bow-
man's capsule.

None of the foregoing observers have described
the development of the Malpighian body fully, nor do
their descriptions all agree.   The process described
by Remak and Toldt differs very considerably from
that described by Bornhaupt and Riedel.   As far as
I am aware none of their papers have been illustrated
by photographs of actual specimens, and the diagrams
employed instead cannot but be misleading when one
wishes to enquire into detail, such as the character
and shape of the epithelial cells in different situ-
ations.   The photographs illustrating this part of
the paper are taken from sections of Human kidneys
of from 4 to 6 months old.

Mode of Formation of the Malpighian Bodies.

The origin of the Malpighian bodies from the
mesoblastic envelope of the kidney has already been
described.   There are usually two developing sim-
ultaneously, one on either side of the extremity of
each collecting tube.   The cells from which they

are formed are at first situated as a Cap on the end

of the Ampulla, and are therefore to be found immed-

iately under the capsule, or in an interlobular sept-

um; but with the further growth and bifurcation

of the end of the collecting tube, the Cap divides,

and each half is pushed aside. The cells meanwhile

go on proliferating, and form a group on either side

of the collecting tube now some distance from the

capsule. The cells are irregularly arranged in sev-

eral layers at first, Fig. (4.), but gradually elong-

ate with their long axes radiating outwards, and a

lumen appears in their centre. Fig. (5.). A tend-

ency to spiral arrangement soon shows itself, and the

end of the vesicle nearest the medulla grows out-

wards away from the collecting tube. In this way a

"Comma" shaped body is formed, the lumen being con-

tinued into the tail, which is always directed away

from the collecting tubule, and ends in a fine point

always turned towards the periphery of the lobule.

The cells lining the vesicle are cylindrical and

narrow, with long deeply staining nuclei; compared

with the cells of the Ampulla they are longer, more

irregular, and their nuclei take on a much deeper

stain. Fig. (5). With the formation of the Comma

shaped body the cells begin to differentiate; 'in the

part next the Ampulla they go on elongating, but in
the tail there is a marked contrast between the cells
on either side of the lumen. On the concave side,
which is the side towards the periphery of the lobule,
the cells become elongated, their nuclei large, and
even more darkly staining; on the convex side, the
cells are smaller and more cubical, while towards the
point they appear drawn out so that their long axes
are almost parallel to the lumen. Fig. $(6-8.)$.

The tail of the Comma shaped structure is the
beginning of a Malpighian body. The concave side
with the elongated cells is the first appearance of
the glomerulus; the convex side becomes the outer
layer of Bowman's capsule, and the lumen is the cav-
ity of the Malpighian body.

It is this early stage of the Malpighian body
that has been known as a "Pseudo-glomerulus" Fig.
$(9-11.)$. Riedel's comparison of it to a deeply hollowed
spoon is a very suitable one, the developing glomer-
ulus occupies the hollow, and Bowman's capsule is
represented by the convex back of the spoon.

The remaining portion of the Comma developes
into the convoluted tubules and Henles loop. The
lumen of the tube is continuous with the cavity of
the Malpighian body from the very first, and the tube
does not begin opposite the glomerulus as in the

adult, but to one side of its base.   The first ap-
pearance of the cavity of Bowman's capsule is a
narrow slit, and never a vesicle in the Human Kid-
ney.   Toldt's description of the driving in of one
wall by capillaries is not an accurate one.   At
this stage there are no capillaries in the glomer-
ulus.   The glomerulus appears rather to be as Born-
haupt described, a thickening of the cells on one
side.

The Malpighian bodies during development have
always the same relation to their surroundings at
each stage.   The glomerulus always developes on
the side of the lumen next the periphery of the lob-
ule, and Bowman's capsule is to the medulla side.
The origin of the tubule is always to the side of
the cavity next the collecting tube with which it
eventually joins, and consequently the tubule leaves
the Malpighian body close to the base of the glom-
erulus, and is always directed outwards towards the
periphery of the lobule, e. g. towards the capsule
or interlobular septum, and is parallel in the first
part of its course to the collecting tube.   These
relative positions are maintained for a long time,
and I have never seen an exception.   The photo-

micrographs have all been arranged so that the cap-
sule of the kidney is above and parallel to the upper
margin of the plate. It will be noticed that in all
the glomerulus hangs downwards, and this is always the
arrangement in the foetal kidney, every glomerulus has
its base towards the periphery of the lobule. The
Malpighian bodies seem to be fixed structures at an
early period, and do not move their position as do the
tubules during further growth. This is an important
fact, and is not explained altogether by the vascular
arrangements. The early fixation seems to be due to
the density of connective tissue round the Malpighian
body, and it is likely that a certain part of it
always remains constituting the frame work. The con-
voluted tubules and Henle's loop especially appear to
be free, and alter their relative positions enormously
during growth, but the extremity, the Malpighian body,
remains fixed throughout life, and is so from its first
appearance.

A noticeable feature about the early Malpighian
body is the large size of its cavity, this is probably
due to contraction of the part which forms the glom-
erulus. With the further development the cells
lining the two sides become more and more different in

character.   Those which form the Glomerulus prolif-
erate rapidly, and are large and cylindrical with
deeply staining nuclei.   Instead of being one layer
deep they are usually several.   Fig. (8.). The cells
on the opposite side of the lumen, which form the cells
lining Bowman's capsule, are fewer in number, and are
spread out instead of being closely packed together.
They gradually become flattened, and this flattening
takes place very early; by the time the tubule joins
with the collecting tubule, they have become quite
flat, and can scarcely be distinguished from the cells
of the surrounding connective tissue.   This is shown
in Figs. (20 - 22.) which are cross sections, and not
parallel to the line of the tubule, and are more
highly magnified.   In the other Figs. (7 & 12.) the
process can be traced, the cells which are first
altered are those at the far extremity from the tub-
ule, as a rule there is a gradual transition from
that point to the cylindrical cells of the tubule.
At the far extremity the transition is sudden where
Bowman's capsule becomes continuous with the glomer-
ulus, the flat cells in single layer become cylind-
rical as soon as they turn the point.   On the tub-
ule side of the glomerulus the cells also flatten a
little, but not as markedly , they mark the position
of the neck of the Malpighian body.   At this stage

the neck is represented by a fairly wide lumen, and is lined by cubical cells which rapidly become cylindrical as they pass into the tubule, while on the capsule side of the neck they differ on either side of the lumen, those forming the glomerulus again becoming cylindrical as described, and those lining Bowman's capsule gradually flattening till they resemble endothelium.

The Glomerulus.

The Glomerulus is at first formed by a thickening of cells in the position indicated, and is not vascular.   If the surrounding connective tissue be carefully examined no capillaries can be seen, but there are some connective tissue cells close to the base of the glomerulus.   When the S shaped tubule is formed, the space between the lower and middle limbs is occupied by these cells, they are few in number, and resemble the other cells which are found in the Matrix of the cortex.   From these cells I believe the capillaries of the glomerulus are formed in situ, and not as ingrowths.   Capillaries and the cellular covering develope together, and are joined by a branch from the renal artery at an early period, but the connection is not established until the lumens of collecting and convoluted tubules have become

continuous. The cells covering the glomerulus go on proliferating, and form a basin shaped swelling, in the hollow of which the capillaries develope. The cells are cylindrical with large nuclei, and little protoplasm, and take on a very deep stain. Figs. (20 & 22.) show this very well. The further growth in size of the glomerulus may be described as an invagin- ation, but it is not an invagination of the kind usu- ally supposed. None of it takes place at the ex- pense of the other side as occurs in Toldt's illus- tration of the India Rubber ball. It is rather an increase in size by proliferation of its own constit- uents; the base remains in the same position, and is wide at first, but gradually narrows, the narrowing being brought about by the formative action of the large cells in the covering. In a simple invagin- ation, as of one side of an India Rubber ball, the base becomes larger as more of the wall is pushed in. The cells covering the glomerulus seem to have a special function in shaping it , and they afterwards grow into its interior and split it into lobules. The charact- er of these large cells is well shown in Fig. (22.), a high power view of a glomerulus in which capillaries have begun to form. A single layer of almost cylind-

rical cells with large nuclei cover the glomerulus, and at intervals there are seen similar cells dipping into the interior.   In Fig. (21.) these cells are further in, and have divided the glomerulus partially into lobules.   The contrast between these cells and those lining Bowman's capsule is very marked at this stage.

The cells contained in the interior of the glomerulus Fig. (22)   also proliferate, their nuclei are smaller and rounder than those of the cells covering them.   Spaces are soon formed which are the lumens of capillaries, and with the increase in size of the tuft these multiply, and are arranged into lobules by the ingrowth of the surrounding cells.   The cells forming the capillaries elongate, and their nuclei flatten and become less evident.   After the glomerulus has been divided into lobules, and the capillaries have assumed their shape, the cells of the membrane covering them also flatten, Fig. (23.), their nuclei grow smaller, and they gradually take the appearance characteristic of the fully developed glomerulus.

The cells of the membrane covering the glomerulus take the important part in its development.   They are responsible for its first appearance, and after-

wards regulate its shape, and divide it into lobules.
It is not till the glomerulus has been fully formed,
and the capillaries definitely arranged, that the
cells of the membrane lose their shape, and flatten
out.   It would seem that this part of their funct-
ion over, they have a tendency to behave in the same
manner as the cells lining Bowman's capsule.   Both
have been shown to arise from the same cell mass,
and to resemble one another at first.   They are
mesoblastic structures, but assume the character of
epithelium; the cells lining Bowman's capsule ap-
parently having no further function than to form
the lining of a space rapidly reassume the characters
of the mesoblastic cells which line other body cav-
ities; the cells covering the glomerulus have a
further function to perform and develope accordingly,
but when the glomerulus is fully formed, they also
assume the shape of endothelial cells.   Owing to
their position the cells covering the glomerular
capillaries must have some function, and no doubt
they are modified accordingly.   Whether they play
an active or a passive part in urinary secretion is
not yet determined.

The presence of connective tissue in the glomerulus
at an early period is quite evident, and from the
mode of development it is not impossible that some
remains when the Malpighian body is fully formed .
Its place seems to be taken by capillaries, but there
is no reason why some cells should not remain.   There
may also be nerves and lymphatics.   Certain it is
that in some adult kidneys spaces may be found in
the glomerulus which are not capillaries.   Professor
Greenfield has pointed them out to me, they may be
lymphatics but it is a difficult matter to prove them
to be such.   The presence of lymphatic rootlets in
the kidney has usually been taken for granted since
Ludwig and Zawarykins' researches (Bb 53.), but when
one studies the methods employed, and the results ob-
tained by these and other observers, one is inclined to
doubt the value of their observations.   Any method
of injection by employing pressure is bound to be
fallacious, artificial spaces are readily produced,
and rupture into the capillaries may also occur.
The injection of fine particles into the kidney of
living animals might give more reliable results.   My
own observations have been of negative value.

The neck of Bowman's capsule.

In the adult kidney the neck of the tubule is usually

opposite the base of the glomerulus.   In the Mal-
pighian body undergoing development the tubule always
leaves the cavity next the base of the glomerulus, and
to that side of it which is towards the collecting
tube.   The process of alteration from this to its
position in the adult I have not seen described, but
it is very well shown in the Figs. (*13-19*).   At first
the cells covering the glomerulus are continuous in an
unbroken curve from the glomerulus into the convoluted
tube,   Figs. (*11-12*), and the lumen is wide.   The cells
at the future neck however soon begin to thin and be-
come cubical in shape, while the lumen narrows. Fig.
(*12.*) shows a condition which is not quite so common,
the neck is very long and has a wide lumen;   the
greater part of it afterwards becomes convoluted tub-
ule.   An indentation usually appears at the base of
the glomerulus at the same level as the apex of the
lumen on its other side.   Fig. (*13.*) .   In the next
Fig. (*14.*) a further stage is shown, there is now a
definite recess between the base of the glomerulus and
the origin of the tubule.   The succeeding Figs.(*16 to
19.*) show the further development of this recess.   It
is lined internally from the very first by flat cells
similar to those of Bowman's capsule already formed.

The wall between this, the later developed portion
of Bowman's capsule is well seen in Fig. (/7.) to
consist of the wall of the first part of the convol-
uted tubule.   This arrangement persists for a long
time.   At the apex of the dividing wall where the
cavity of the capsule becomes continuous with the
lumen of the tube, there is always a sudden transition
between the characters of the cells; those lining
the capsule are flat, those lining the tubules are
cubical.   On the other side of the lumen there is
not this sudden transition, but the cubical cells in
the neck become less cubical as they pass over the
capsule until they are opposite the middle of the
glomerulus, when they become flat.   Bowman's cap-
sule contains cubical cells for a considerable time,
and they are always in this situation, e.g., the
half of the capsule that is on the side of the origin
of the tube.   When the Malpighian body is fully dev-
eloped, these cells form part of the convoluted tube.
It follows therefore that part of what seems to be
originally Bowman's capsule is not so in the fully
formed Malpighian body.   Nearly one half of Bowman's
capsule is a later formation, and grows outwards from
the base of the glomerulus, until the neck of the tub-
ule is in a position opposite the entrance of the ves-
sels.   That this is the mode of formation is easily

seen, it is not a rotation of the glomerulus.   The
base of the glomerulus is fixed, and remains in the
same position relative to the collecting tubes and
periphery of the lobule.   The tubule at first leaves
the capsule nearest the periphery of the lobule, but
eventually comes to leave it at the furthest point
from the periphery.   Part of the process comes about
by the gradual constriction of the base of the glom-
erulus, the cavity extending inwards, but I believe
that the immense and rapid growth of the convoluted
tube is the chief factor.   The tube by its growth
descends towards the medulla, and carries with it the
neck, until that has reached the lowest point it can
get to.   The process can be easily followed in the
plates.

The neck of Bowman's capsule then varies in
position during development, its lumen is at first
wide but when fully developed is slightly constricted.
Cubical cells are found continuous from the tubule
into the capsule at the side of the lumen opposite
the glomerulus, but they do not extend as a rule be-
yond a point opposite the entrance of the vessels.
In the fully developed Malpighian body the cubical
cells are not as a rule continued beyond the neck,
Bowman's capsule being lined by the flattened cells

alone.   Exceptions to this rule are found.   In
some Mammalia, e.g. the mouse, the cubical cells
often line a third or even more of the capsule.

Bowman's Capsule.

This has been for the most part described al-
ready, but some points in its formation need emphasis.
It has been shown to consist of two parts, one of
which is formed considerably later than the other.
Bowman originally described the capsule as consist-
ing of a basement membrane lined with cells.   In
the developing kidney the cells alone appear to con-
stitute the wall of the capsule, the basement mem-
brane is a later formation still.   The cells arise
in common with the origin of the rest of the Malpigh-
ian body from the mesoblastic kidney envelope.   They
become elongated and are situated in the tail of the
comma shaped body opposite the cells that form the
glomerulus, a split like lumen separating them.
Though almost cylindrical at first, they rapidly
become cubical, and at the extremity of the lumen
are quite flat at a very early stage, forming a
single layer.   Fig. (8.). At the middle of the cap-
sule opposite the base of the glomerulus, they grad-
ually become more and more cubical till they join
the cells of the convoluted tubule.   The greater

part of the capsule becomes convoluted tubule at a
later stage, the septum being formed by the downward
growth of the tube in the manner already described.
The cells lining the later portion of the capsule
are flat from the very first, and apparently grow by
proliferation of the existing cells, which line the
capsule around the base of the glomerulus.   In every
section of foetal kidney one finds numbers of Mal-
pighian bodies where the cells lining Bowman's cap-
sule are cubical, and it is easily seen how this
comes about.   The section has passed through that
part which forms the capsule for the time, but which
is not really true capsule as found in the fully
developed Malpighian body.   Fig. (23.) shows this,
the cells lining Bowman's capsule are here close
to the neck of the tubule.

Though no basement membrane can be distinguished
outside the cells, there are often several layers of
cells of similar character closely applied to them.
Figs. (20-22) show them.   The cells are long and
flat, with thin drawn out, and deeply staining nuclei
arranged parallel to one another.   All bear a strik-
ing resemblance to endothelial cells.   They might
be regarded as going to form the basement membrane
if we accept Ludwig's view that the basement membrane

is a mosaic of flattened cells, and Roth's that it
is composed of endothelium. The homogenous membrane
met with in the adult kidney is absent. How it is
formed, and what it is composed of, is still unsettled.

It is probable that from the mesoblastic origin
of Bowman's capsule the cells may be regarded as
endothelial, and the space contained by them as a
small body cavity, specially adapted for excretory
purposes. This view is supported by the history
of the Malpighian body in comparative Embryology.
Its origin also in Man from the Intermediate Cell
mass and Peritoneal epithelium, if Sedgwick's descript-
ion is right, is an additional fact in favour of this
view.

The Origin of the Convoluted Tubes.

The Convoluted tubes arise in the manner already
described, in common with the Malpighian bodies, from
solid cell masses in the Mesoblastic covering of the
Ureter branches. The cells become cylindrical, and
arrange themselves round a central lumen, forming
the body of the Comma. Their subsequent develop-
ment is shown in the Figs. (7 6 13.). In place of
a vesicle a tubule is formed by its elongation,
which takes on a curve in its upper part towards the
Ampulla. The lumen of the tubule is now S shaped,
the upper and middle limbs of the S being the parts
from which the convoluted tubes develope. The cells
which line them are at first cylindrical with long
and deeply staining nuclei, and offer a great con-
trast to the cells of the collecting tubule. Fig.
(7.). There often seems to be several layers of
cells at first, but eventually there is only **one**.
The lumen is narrow, but widens out considerably
at the lower bend of the S, where tube joins Mal-
pighian body. The S is closely applied to the under
surface of the Ampulla, but their lumens are not
continuous at this stage. With further growth a
thin process from the under side of the Ampulla

unites with the thinned extremity of the upper limb,
and the two structures become continuous, a narrow
lumen forming between them.

Fig. (*10.*) shows the thin portion of tubule con-
necting them, the section here passing through its
widest part.   The cells of the narrow connecting
tube are small, and their lumen joins the Ampulla
at right angles to the collecting tube.   It is
this small tube which connects the two independently
developed structures that is known in the fully
formed kidney as the Junctional tubule.   Here the
tubules of the Kidney blastema unite with the ex-
tremities of the ureter branches, and Mesoblast
joins Epiblast, if we are to regard the Wolffian
duct as Epiblastic.

It is seen that the tubule which forms the con-
voluted tubes is very early divided into two limbs,
the upper two of the S.   This distinction is main-
tained and increased.   The cells which form them
multiply very rapidly, and form a single layer with
central lumen.   Owing to the rapid increase in
length of the tubule, the convolutions become great-
er, the middle bend, or rather the one which is be-
tween the two upper limbs soon shows a tendency to
growth downwards towards the medulla.   Figs. (*9 & 13*)

illustrate this.   In Fig. (*12.*) the bend has reach-
ed to the level of the Malpighian body, and it con-
tinues to descend parallel to the collecting tube.
It is this bend which afterwards constitutes Henle's
Loop, and the parts of the tubule on either side of
the bend formed the ascending and the descending
limbs of the loop.   The limbs of Henle's loop pur-
sue a parallel course, and are straight.   They
gradually descend during further development, and
eventually reach the peripheral part of the medulla.
The cells lining them also flatten, but not to such
an extent as the cells lining Bowman's capsule.

The portion of the tubule between Henle's loop
and the Malpighian body forms the proximal convolut-
ed tubule; the portion beyond Henle's loop, and be-
tween it and the junctional tubule, becomes the dis-
tal convoluted tubule.

From their mode of development it is clearly
seen that, as Golgi described, both proximal and
distal convoluted tubes closely surround the Mal-
pighian body with which they are associated; and
further, that the limbs of Henle's loop in their upper
part are also in close proximity to the Malpighian
body.   One often sees in a section one narrow tub-
ule, and sometimes two, in close relation to the base

of the glomerulus.   Fig. (*19.*). These are the limbs
of Henle's loop belonging to it.

The convoluted tubules go on growing in length,
and as they are not fixed in the way the Malpighian
body is, they form many convolutions in the cortex.
As already shown it is by this increase in length
that the neck of the tubule comes to occupy a posit-
ion opposite the base of the glomerulus.

During their growth the cells undergo a change
in character, they are larger and broader; Fig. (*19.*)
The nucleus is relatively smaller, round, and more
deeply placed in the cell.   The protoplasm is large
in amount, and granular, and stains well with rubin
and orange.   I have not seen the rodded character
described by Heidenhain.

The Ampulla.

The Ampulla is a structure of great importance.
It is always to be found in the periphery of the lob-
ule, either under the capsule, or the interlobular
septa.   It is therefore in the formative area, where
everything is in active growth.   The Ampulla like
its surroundings is constantly growing, but not in
the way described by Toldt.   My own observations
lead me to believe that it does not send out solid
branches, but hollow buds.   Each Ampulla is the

dilated end of a collecting tube, and forms the ex-
tremity of one ureter branch.   It is lined by a
single layer of cells, and has a large lumen.   Fig.
(7.). Growth occurs at the peripheral end, and in
this way the straight character of the collecting tube
is produced.   After division of the cap of cells
over it, the Ampulla usually begins to bifurcate, two
hollow buds being gradually pushed out from the ex-
tremity.   Each bud enlarges and forms a new Ampulla,
with which the S shaped tube joins on that side.   The
two branches separate from one another, and each bends
to a certain amount under the capsule or septum.
Fig. (8.) shows this bending, which in this instance
has reached what appears to be the furthest extent
usual.

After junction has been established between it
and the convoluted tubules, the Ampulla still goes on
growing.   Figs. (9 - 10.). A new cap of cell appears
above it, and the process is repeated.   After the
8th month the growth of the Ampulla ceases, and in
the interlobular septa it appears to cease before
that time.   The last Ampulla formed merely unites
with the convoluted tubule, and a simple bend under

the capsule results.

In this way every collecting tube branches, and is joined by convoluted tubules, and the oldest being the nearest to the medulla, and the latest at the periphery of the lobule.

In every section of developing kidney there are therefore Malpighian bodies and tubules at different stages. The oldest are fully formed, and lie deepest in the cortex. A narrow zone at the periphery of the lobule is the formative area, in which Malpighian bodies, convoluted tubules, junctional tubules, and Ampullae are gradually produced, and all except the Ampullae are left behind to perfect their structure from the material which has been constructed there.

Connective Tissue.

Connective tissue is large in amount in the foetal kidney, but diminishes with the growth of the glandular element, and by the time of normal birth there is remarkably little left. In the cortex of the developing kidney the matrix is very abundant and cellular, in the deeper parts the cells become myxomatous, and their place is eventually taken by the tubules, and blood vessels. Each primitive cone is surrounded by connective tissue, and may be said to occupy a special compartment. The septa between the compartments are well marked, and cellular, not fibrous; there is in

fact a framework, which may be compared to Glisson's
capsule in the liver.   It does not appear to devel-
ope further, and is greatly thinned owing to the great
increase in size of the compartments by the enormous
growth of the convoluted tubules.   It is probable
that vestiges of the septa persist, and form the
fibro-cellular framework described by Goodsir.   More
connective tissue is found in some places than in
others.   In the Papillary region there is a consid-
erable amount between the collecting tubes, and this
is easily explained.   The collecting tubes do not in-
crease the breadth of the papilla by forming convolut-
ions, they are developed early, and always remain sep-
arated by connective tissue, the septa are not ex-
panded and thinned, as they are in the cortex.   The
great increase in breadth of the pyramids comes about
by the descent of Henle's loop between the collecting
tubes, but as Henle's loops do not descend to the apex
there are left below them wedge-shaped spaces between
the large tubules or Ducts of Bellini, in which the
connective tissue persists.

There always remains a certain amount too round
the Malpighian bodies, and especially at the bases of
the glomeruli.   It helps to keep them fixed struct-

ures, a provision which is rendered necessary by the enormous growth in length of the convoluted tubules.

Connective tissue is also found under the capsule, and round the branches of the renal artery.

Blood vessels of the Kidney.

The development of the larger branches I have not studied.   It seems probable that the branches of the Renal Artery lie at first between the first branches of the ureter, i. e. the branches which go to form the pyramids, and **the mesoblastic** envelope. From these arteries vessels are given off at right angles which follow the collecting tubules in their peripheral growth.   Though called Interlobular Arteries they are not strictly interlobular, but each lies in a septum between two adjacents primitive cones, and gives off single branches, the afferent-arterioles to the glomeruli of those cones.   The interlobular arteries give off as many branches as there are origins of tubules in the cortex, and it is very probable that they do not exceed this number, Ludwig (Bb 52.).

The capillaries of the glomerulus seem to form in situ from mesoblastic cells which are embraced by the lower limb of the S shaped tubule.

The capillaries of the network round the convoluted tubes continue developing by branching and anas-

tomosis as the tubes increase in length and complexity.

Mode of Growth of the Kidney.

The individual structures which make up the kidney have already been studied separately, but it is necessary to consider them as a whole.

Malpighian bodies begin to form at the end of the second month, and new ones are continually being added up to the end of the 8th, or beginning of the 9th month.

The collecting tubes on the other hand are formed early, a certain number of branches are given off and these multiply by frequent branching towards the cortex. There is no evidence that new tubes grow out from the pelvis.

The branches of the ureter which correspond to the papillae each form a lobule by repeated branching. The lobules are almost completely separated from one-another by the mesoblastic envelope, which forms a double septum. After the 7th month the cells constituting the septa begin to disappear, from the pelvis outwards, and in the 9th month scarcely any of the mesoblastic envelope is left.

In all sections of foetal kidney one notices the much larger number of Malpighian bodies relative to the adult kidney. Convoluted tubules which make

up the greater part of the cortex in the adult are almost absent at the 4th month. Fig. (/.). At the time of birth there are as many Malpighian bodies in the kidney as there will ever be. Some of these are certainly not fully developed, and occasionally one finds imperfectly formed ones some time after birth, but no new ones develope. At birth all the structures in the kidney are already formed, and further growth is but a finishing and enlargement of existing structures.

This has been recognised for some time, and Schweigger Seidel (Bb 75.) has divided the growth of the kidney into two periods. "An Embryonal", and a "Post Embryonal". In the first period growth takes place in two ways. One by an Apposition or formation of new material in the periphery. The other by increase in size of material already formed. In the Post embryonal, the formation of new material has ceased, and growth now takes place by an increase in size only.

Riedel found that the first periods did not always correspond to the period of Intra-uterine life. In mice and in other blind born animals the formative process continued for as long as 14 days, while in other animals the process ceased before birth.

During the first period the structures that lie
the deepest increase in size, the Malpighian bodies
become very large, some more so than they are in the
adult kidney.   The convoluted tubules increase in
length and diameter.   In the 4th month there is
very little division between cortex and medulla.

During the second period growth of the cortex
chiefly takes place by increase in the length and
the convolutions of the convoluted tubes.   Growth
of the medulla comes about by increase in length of
the collecting tubes, and by the descent of Henles
loops.   As the result of these processes a definite
arrangement of structures comes about.   There is
the broad division of kidney into cortex and medulla.
Malpighian bodies and convoluted tubes are confined
to the cortex, while the medulla is made of the dis-
tal ends of the collecting tubes and the limbs of
Henle's loop.   Part of the cortex is inter-pyramidal,
and its mode of development has been described;
                    are
these portions also known as the Septula Renum or
Columnae Bertini.

A Zone of the cortex, the subcapsular zone, con-
tains ordinarily no Malpighian bodies, and the reason
is evident, the convoluted tubes are developed peri-

pherally to the Malpighian bodies, and some of their
convolutions remain in that position.   In the same
way there is a deep zone in the cortex, where there
are no Malpighian bodies, this may be explained by
the manner in which the convoluted tubules tend to
descend towards the papillae, so that the origin of
the tube from Bowman's capsule is at the nearest
point to the medulla, as a consequence there is al-
ways a certain amount of tube below the Malpighian
body.   These layers are not always perfect, one
sometimes meets with Malpighian bodies next the cap-
sule, but this is not the ordinary arrangement.   In
the same way though the base of every glomerulus orig-
inally is towards the periphery of the lobule, it does
not always persist thus, and Malpighian bodies may be
found which have rotated.

GENERAL CONCLUSIONS.

Origin of the Kidney.

The kidney has a double origin, each of which is quite distinct from the other, but the two come together at an early period, and remain intimately associated during further development.

1. The Kidney Blastema.

This consists of a mass of cells closely related to the Blastema of the Wolffian body, and apparently formed from the Intermediate Cell Mass, or the Peritoneal epithelium.   It is therefore Mesoblastic. It forms an envelope round the ends of the Ureter branches, and persists as a thin cellular investment under the capsule, and between the lobules, until the end of the 8th month, after which it almost entirely disappears.

11. The Ureter.

This structure is an outgrowth from the Wolffian duct.   It appears at the end of the 1st month, and grows forwards as a solid column of cells to reach and imbed its peripheral branches in the Kidney Blastema.   It is not settled whether the Ureter is Mesoblastic or Epiblastic, but the balance of recent opinion is in favour of its being Epiblastic.

At the middle of the 2nd month the Ureter has

come into apposition with the kidney Blastema, and
the result is the beginning of the formation of a
definite kidney.

The Ureter branches early, and its lumen dilates
anteriorly to form the future pelvis and calyces.
The primary branches are of a definite number, and at
their extremities masses of cells appear constituting
the "Nierenbecken of the German writers.   From these
masses of Cells in the kidney pelvis, are developed
the Collecting tubes of each lobule.   From each cell
mass, the tubules grow outwards in a radiating manner,
and terminate in the Mesoblastic envelope immediately
under the capsule.   Ureter, pelvis, calyces, and coll-
ecting tubules, are therefore formed from the Wolffian
duct, and these are the only parts of the kidney
which are formed from the Wolffian duct, unless we
include part of the Junctional tubule.

From the kidney Blastema arise the Malpighian
bodies, convoluted tubules, Henle's loops, and the
Junctional tubules, the connective tissue frame work,
and capsule.   Blood vessels appear to be partly of
the same origin, and partly branches from the renal
artery.   The Blastema or "Nierenanlage" of the
Germans forms a peripheral envelope from which the
above structures are developed in succession.   Owing

to its surrounding the primary Ureter branches, part
remains close to the pelvis between the lobules, where
it constitutes double septa, which give rise to the
Interpyramidal cortex.   The septa disappear before
the subcapsular layer, and no more glandular elements
are formed after the end of the 8th month.

Malpighian bodies appear at the end of the 2nd
month, together with tubules, which become the convol-
uted tubes belonging to them.   They unite at an early
stage with the Ureter branches, the point of junction
always being situated at the periphery of the lobule.

Each Malpighian body and its tubule arise as a
solid mass of cells at the periphery of a lobule,
either under the capsule, or in the interlobular septa,
in close relation to the dilated extremity of a Ure-
ter branch or collecting tubule.   The solid cell mass
acquires a lumen, and takes on the shape of an S. The
lower limb of the S becomes a Malpighian body, the
upper and middle limbs form convoluted tubules, the
bend between them constituting Henle's loop, while the
extremity of the upper limb joins the collecting tub-
ule, and forms the greater part of the junctional
tubule.   As a rule this process takes place on two
sides of a collecting tube, the dilated extremity or
Ampulla of which divides into two, each branch being

joined by the junctional tubule of its side. The
S shaped tubule has always the same relation to the
collecting tubule, its long axis is parallel to, and
its lower limb turned away from, the collecting tube.
Malpighian bodies.

The Malpighian body forms in the lower limb of
the S shaped tubule, and is the first part to show
differentiation. A split like lumen appears early,
and attains considerable size. The convex side of
the limb is formed by the epithelium which lines
Bowman's capsule, the concave side by the epithelium
which covers what becomes the glomerulus. The epith-
elium on both sides is similar at first, but only for
a very short time, the cells lining the capsule thin-
and become flattened, though not all over.

The Glomerulus is formed, not by an invagination,
but by a thickening of the epithelium. The capill-
aries of the glomerulus develope in situ, and are
covered by the epithelium. Further growth takes
place by an enlargement of the capillaries, and pro-
liferation of the cellular covering. Its shape is
influenced by these cells, which are almost cylind-
rical in form, and arranged in s single layer. The
division of the glomerulus into lobes comes about by
the penetration of the epithelial cells between the

capillary loops. When the glomerulus is fully form-
ed the cells diminish in size, and become flattened,
like the cells lining the true capsule.

Bowman's capsule is lined by cells which show a
difference in two situations. From a point opposite
the middle of the base of the glomerulus to the ex-
tremity of the capsule opposite the neck of the tub-
ule the cells are long and flat from an early stage.
The remainder of the capsule is lined by cells which
become more and more cubical as they pass into the
neck of the tubule, this part eventually becomes the
first part of the convoluted tubule. It is completed
by the development of a septum, which grows from the
base of the glomerulus between it and the origin of the
tube. The septum consists of a double layer of cells,
that on the side next the glomerulus is of flattened
epithelium, that on the convoluted tubule side is of
large cubical cells. The neck of the tubule is at
first wide, and situated close to the base of the glo-
merulus, but with the growth of the septum it passes
to a point opposite the base of the glomerulus. Thus
part of Bowman's capsule is a later formation than the
other, and both are lined with flat cells. There is
no basement membrane round the developing capsule.

The cavity of Bowman's capsule may be regarded as
a body cavity specially differentiated for urinary ex-
cretion. Its lining consists of flattened cells,

which are developed from cells closely allied to
those which form the lining of the general peritoneal
cavity; in Bowman's capsule they seem to have no
further function than to form the wall of the cavity,
and they assume at a very early period the character
of the cells lining other body cavities; and this
character is maintained under normal conditions
throughout life.   It is not therefore surprising
that in certain inflammatory conditions these cells
should proliferate, and form organised connective
tissue.   Professor Greenfield was quite justified in
classing them as Endothelial from their pathological
reactions; the history of their development lends
additional support to his view.

The cells of the convoluted tubules attain a
much higher stage of development, and once arrived at
this stage it is doubtful how much retrogression can
take place without dissolution of the cell.   They
are elaborated for the performance of special, and pro-
bably complex functions, and are more highly organ-
ised.   Their reactions in disease are likely to be
altered accordingly.

Malpighian bodies begin to form in the 2nd month,
and continue appearing till the end of the 8th month.
The new Malpighian bodies are always found at the

periphery of each lobule.

Connective tissue exists in large amounts in the foetal kidney, but most disappears by the 9th month. It forms a septum between the primitive cones, and fixes the glomerulus in a definite position, but allows the tubules to elongate, and alter their relative positions.

Henle's loop is formed by the downward growth of the upper angle of the S shaped tubule.

Up to the end of the 8th month growth of the kidney takes place in a two fold manner, partly by apposition of new material in the periphery of the lobules, and partly by growth of already formed material. After the 8th month growth is due to increase in length of tubules, especially the convoluted tubules, no new Malpighian bodies or tubules are formed.

The arrangement of the different structures into the definite zones of the fully developed kidney is chiefly due to the arrangement of the connective tissue frame work, which allows the tubules to move freely in their growth, but holds the Malpighian bodies and large collecting tubes in fixed positions.

A short sketch of the Comparative Anatomy

and Embryology of Malpighian bodies

with special reference to a few Types.

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The Comparative Anatomy of the Malpighian Bodies.

Malpighian bodies are peculiar to the excretory or-
gans of the members of the great Phylum of "Craniata"
Each Malpighian body contains a space into which pro-
-jects a vascular tuft, the glomerulus, and from which
a tubule leads to the exterior of the body.   The wall
of the space, known as Bowman's capsule in the more
highly differentiated Malpighian bodies, is not al-
ways complete in the lower forms, but often includes
several other structures, and allows access to the
cavity from other cavities.   In the highest forms
however, Bowman's capsule completely shuts off the
space from everything but the urinary tube which
leads from it.   Malpighian bodies therefore show a
great variety in structure in the different Classes
of the Phylum.

One would expect to find a gradual transition
from the one to the other, the more primitive in the
lowest types, and the more highly differentiated in
the highest classes.   But this does not exactly
occur, there are missing links in the system, and
the degree of development of the Malpighian bodies,
does not always correspond to the degree of devel-
opment of the organism as a whole.   A more perfect

series is found in Comparative embryology, and in
some it would appear that their history of develop-
ment is truly a recapitulation of the history of the
race.

Definite excretory organs are found first in
the Plathelminthes.   In Taenia Solium, Distomum
Hepaticum, and others of the flat worms, there exist
a number of small tubes opening into larger canals,
which open externally by pores.   The fine branches
end blindly, some of them in peculiar cells which
have been called Flame cells, from the fact that
they project one or more flame shaped cilia into
the lumen of the tube.   Parker (Bb 59.).   There
being no vascular system there cannot be anything
of the nature of a glomerulus.

In Mollusca, Polyzoa, and Brachiopoda, the ex-
cretory organs are simple tubules often ciliated,
and opening by one end into the general body cavity,
and by the other on the exterior.   These may be re-
-garded as the simplest form of excretory apparatus.

In the Peripatus we meet with a segmental ar-
rangement of tubes, a pair connecting body cavity
with the exterior in each segment.

In the Amphioxus there are ninety pairs of tubes,
each consisting of two limbs, which open by several
apertures into the general   body cavity, and by a
single ciliated opening externally into the Atrium.
The Amphioxus may be regarded as a prototype of the
Vertebrata, and the history of development of the
excretory organs of some of the higher Craniata, the
chick for instance, as described by Sedgwick (Bb 76.),
shows that the first stages have a great resemblance
to the condition found in the adult Amphioxus.   In
the chick the cells which give rise to the tubules
are found in a great number of segments, and form
a long strip of tissue on either side of the body,
extending throughout the greater part of its length.

In none of the Craniata are the adult urinary
tubes formed from the whole length of this strip.
In most, the cells which rise in a few special seg-
ments, give origin to the adult kidney.   In many
Teleosts; the Cod for instance, the urinary tub-
ules are found throughout the greater length of the
body, opening into a common longitudinal duct, but
the anterior portion close to the head is more dev-
eloped than the rest, and constitutes the larger part
part of the kidney.   In the higher Classes the an-
terior tubules do not persist, though present in
nearly all for a short period at a very early stage.

According as the anterior, middle, or posterior tubes develope, the structure which they form is called the Pronephros, Mesonephros, or Metanephros.   As a rule the kidney represents the Pronephros in the lowest classes, the Mesonephros in the more highly developed, and the Metanephros in the highest.   Development takes place from before backwards.

In none of the Craniata is the Pronephros sufficient for excretory purposes, and where it persists there is also to be found some Mesonephros.   In Cyclostomata and Teleostei both are found co-existing.   In Elasmobranchii the Mesonephros forms the functional kidney, as it also does in Amphibia. The rest of the Craniata including Reptilia, Aves, and Mammalia, often classified together as Amniota, derive their kidneys from the Metanephros.   In all three divisions Malpighian bodies are found, but they differ in each; those of the Pronephros are the most primitive, those of the Mesonephros are modified by close relation with the development of the male generative organs, while the Malpighian bodies of the Metanephros are the highest differentiations.

The Malpighian bodies of the Pronephros.

In the Cod fish (Gadus morrhua) the Pronephros, or Head Kidney, is a large irregularly shaped red body situated in front of the Air bladder, and close to the Gills.

On section it appears to be largely composed of round nucleated cells resembling lymphoid tissue lying around the glandular tubules. The Malpighian bodies are not numerous, and are difficult to find. They are very small. Fig. (24) a photomicrograph ✕ 700 diameters shows one of the largest. As a rule a number are grouped together round a septum of a thick fibrous nature, and they become more numerous towards the posterior end of the gland. Each is an oval body, and measures about ·06 m.m. from side to side. A glomerulus hangs inside the cavity attached by a rather broad base, which is of a fibrous nature, and continued into the fibrous septum around. The glomerulus always seems to be a dense structure, but this may be partly due to its retraction; it con-sists of a few capillaries, though these seem very small for the large size of the blood corpuscles. Round its margin can be seen small round cells with

round faintly staining nuclei, offering a great con-
trast to the cells lining Bowman's capsule.   The
tubule begins opposite the neck of the glomerulus,
and its cells are not continued into the capsule,
which is lined by a single layer of very flat cells
scarcely visible.   Between the flat cells and the
fibrous tissue surrounding the capsule is a semi-
lunar space, which is generally filled with cells re-
sembling those of the tubules.

Malpighian bodies similar to these are found
throughout the kidneys of the cod.   Those too of
the Haddock (Gadus aeglefinus) are almost identical
in structure.   One of their chief features is their
mode of arrangement in thick fibrous septa.   It is
also interesting to note the flattened character of
the cells of Bowman's capsule, and the rounder cells
which cover the tuft.

While the above affords an example from an adult
Pronephros, the Malpighian bodies of the Pronephros
of early embryos of some of the higher animals are
of more importance, as indicating their earliest mode
of formation.   The "Glomerulus of the Head Kidney"
of the chick has been a familiar figure in text books
of Embryology since Sedgwick's description, (Bb 77.).
I have not succeeded in obtaining a preparation to
show it, but will mention a few of its characters as
described by Sedgwic

described by Sedgwick.   In the chick he found that
the Head Kidney was a transitory structure, only pres-
ent between the 90th & 120th hours of incubation.
It consisted of three grooved openings into the
peritoneum, but slightly before their formation vas-
cular outgrowths appeared projecting into the body
cavity on each side at the root of the Mesentery.
Sedgwick at first believed that these formed a vas-
cular ridge, but at a later date he described them
as separate structures or glomeruli, and compared
them to the glomeruli of the Head Kidneys of the
Icthyopsida.   Each glomerulus was covered by perit-
oneal epithelium, and attached by a narrow neck
through which passed capillaries from the aorta.
The External glomeruli were to be found in front of
the peritoneal openings of the tubules of the Pro-
nephros.   During further development the peritoneal
funnels widened considerably, and eventually formed
bays, narrow behind, but wide in front, and continu-
ous with the general peritoneal cavity.   In these
bays other glomeruli developed, and Malpighian bodies
thus formed, their cavities being at first part of
the peritoneal cavity, but at a later period shut
off from it.   The epithelium covering the External

and Internal glomeruli was continuous at first, and was part of the peritoneal epithelium, but with the closure of the cavity the two were separated, and the External glomerulus disappeared.   Sedgwick concluded that the External glomeruli belonged to primary segmental tubes which never developed.

Sedgwick's description was of special interest in that it showed a close resemblance to the mode of development of the Pronephros in the Cyclostomata, Teleostei, and Amphibia.   In the Cyclostomata Balfour (Bb 2.) described the Pronephros as formed from ciliated funnels, which connected the peritoneal cavity with the Segmental duct.   On the inner side of the peritoneal openings vascular glomeruli formed, which projected into the body cavity, and were covered with peritoneal epithelium.   In Myxine the Pronephros was highly developed, and consisted of ciliated funnels opening into the body cavity, and containing diverticula in which glomeruli formed.

In Teleostei Balfour believed the Pronephros to be formed as a groove in the peritoneal epithelium, which eventually became a funnel.   Glomeruli appeared in the funnel, projecting at first into the body cavity, but during further growth the groove deepened, and a partition formed which shut off the cavity.

round the glomerulus from the rest of the body cav-
ity.   In this case the cavity of Bowman's capsule
was clearly part of the peritoneal cavity, which
afterwards became specially shut off for excretory
purposes, and both the cells covering the glomerulus,
and those lining the capsule were peritoneal in orig-
in.

In Amphibia Balfour described a similar condit-
ion, but considered that the formation of a special
compartment was incomplete, the cavity round the
glomerulus remaining continuous with the body cavity,
though partially separated from it.

The structures that have been described are prob-
-ably homologous, and may be looked upon as rudiment-
ary Malpighian bodies.   Most of them are merely
transitory, and found only at an early stage of em-
bryonic life.   It is doubtful if those of the Head
Kidney of the Cod are really part of the true Pro-
nephros.   They are probably secondary, and resemble
the Malpighian bodies of the Mesonephros.   We may
consider that the Pronephros in its development af-
fords an example of the most primitive form of what
afterwards becomes a definite Malpighian body.   It
is therefore interesting to note that the glomerulus

projects into a cavity, which is part of the general body cavity, its covering is peritoneal epithelium, Bowman's capsule is undeveloped, and its place is occupied by the general lining of the body cavity. In Amphibians a partition appears, but is imperfect; in Teleostei it is complete, and we have the development of Bowman's capsule as a specially enclosed portion of the body cavity, lined with what was actually part of the peritoneal lining.

The Malpighian Bodies of the Mesonephros.

In the Mesonephros the Malpighian bodies reach a high degree of perfection; but show a great variety in the detail of their structure. In some of the lower forms Bowman's capsule still communicates with the body cavity, in others with the ducts of the Testis in the male, in the more highly developed there is no connection with the body cavity, and the Malpighian body resembles that of the Metanephros.

The kidney of the Skate (Raja Batis) is a good example of the Mesonephros. The Malpighian bodies are not numerous, but are very large, varying from .2 to .3 mm in length, about five times as large as those of the Cod. Fig. (25.) shows a typical example from the Skate. In shape there is an immense

variety, most are very irregular, narrow portions
often running some distance between the neighbouring
tubules: as a rule the base or attachment of the
glomerulus is very broad, in some breadth greatly
exceeds length, in others length greatly exceeds bread-
th. The glomerulus is large and varies in shape in
a similar way. In Fig.(*25.*) it is spread out, and
individual capillaries can be seen, there is also a
distinct *inct* membrane of flat cells with small round nuclei
covering the capillaries. Bowman's capsule often
shows a definite basement membrane lined with flatt-
ened cells; there are usually two openings, but I
cannot say if this is always the case, and the cells
lining the tubules are prolonged for a short distance
into the capsule. One opening is situated opposite
the base of the glomerulus, and the other at one side
of the base. The tubules are at first narrow, but
widen out, and become very large. The cells lining
the necks of the tubules are cubical and ciliated.
Fig.(*26.*) shows an opening at the base of the glomer-
ulus. Cilia are found in great numbers in many of
the tubules, and appear to be of two kinds. One
kind is made up of numerous short cilia, the other of
fewer long cilia, or flagella, which look as if a

number of the short had united to form a long thick
flagellum. Those in the neck of the tubules are
more like flagella. In Fig. (*25.*) a few are seen
opposite the base of the glomerulus, where tubule be-
gins, the section not showing the lumen of the tube
in this case. I have not been able to satisfy my-
self as to the nature of the second tubule, but acc-
ording to Balfour it is part of the generative duct
from the Testis, or an open canal from the peritoneal
cavity in the male; in the female it is from the per-
itoneal cavity. It would appear therefore that the
products from the generative organs of the male pass
through some of the Malpighian bodies, while others
are in relation to the body cavity. The researches
of Balfour on the development of the urinogenital
organs of Elasmobranchii are of great interest in
showing how these relations have been established.
Balfour described the tubules as being formed from
mesoblast, and having ciliated funnels opening into
the peritoneum, at the deep end of each funnel a
Malpighian body appeared. Each primary Malpighian
body was connected with peritoneal cavity by a cili-
ated funnel, and by another tube with the segmental
duct at first, the Wolffian duct later. From the

primary Malpighian body other secondary Malpighian bodies were formed. He considered that each segment was isolated from the others, and had only one peritoneal funnel, and one communication with the Wolffian duct.

In the kidney of the Skate the Malpighian bodies are grouped together, and some appear almost continuous, but I have not seen a direct connection between their cavities.

In Amphibia the Malpighian bodies are well developed, Bowman showed that the capsule was partly lined by ciliated cells from the neck of the tubule, the presence of flat cells lining the rest of the capsule has long been known. In the kidney of the frog there are also a number of ciliated canals which open into the peritoneal cavity. Balfour believed that these were outgrowths from the neck of the Malpighian body. Nussbaum (Bb $58.$) showed that in the adult they opened into the Inferior Vena Cava.

In the male Amphibians part of the urinary canals act as ducts for the Testicular products, the junction of generative ducts with the kidney tubules varying in position in different species. Heidenhain (Bb $34.$) found that in Rana esculenta they

opened into the collecting tubes, Nussbaum (Bb 58.)
showed that in Rana temporaria they opened into the
necks of the Malpighian bodies.   According to Balfour
the testicular network of ducts is developed by out-
growths from the primary Malpighian bodies, they do
not correspond to the peritoneal funnels.   The ex-
istence together in the adult kidney of testicular
network and peritoneal funnels tends to prove this.

The Mesonephros is well developed in the embryos
of some of the Amniota.   In the chick it is a large
structure, and contains numerous Malpighian bodies.
The origin of the tubules has been a matter of dis-
pute.   Fürbringer believed them to be formed from
peritoneal epithelium, so did Braun.   Sedgwick des-
cribed their origin from the cells of the Intermed-
iate Cell Mass.

The persistence of peritoneal connections with
the Malpighian bodies in the Elasmobranches, and
their mode of development as shown by Balfour, point
strongly to a close resemblance between the Malpigh-
ian bodies of the Pro- and Mesonephros.   Though
never a part of the peritoneal cavity in the Mesone-
phros, Bowman's capsule is still in communication
with it.   In Amphibia the communication is interrup-

ted, and the peritoneal funnels, though at first in
communication with Bowman's capsule (Balfour), be-
come detached, and open into the Inferior Vena Cava.

The Malpighian bodies of the Metanephros.

The Metanephros forms the permanent kidney of
Aves and Mammalia. It arises in the posterior seg-
ments of the body behind those of the Mesonephros,
and becomes the most highly differentiated of the ex-
cretory organs.

The Malpighian bodies vary a great deal in size
and appearance, though all are constructed on the
same plan. Not only do they vary in different ani-
mals, but they show a difference in size in different
parts of the kidney of the same animal. Bowman
pointed out that the Malpighian bodies which were
found nearest the medulla were as a rule larger than
those found near the surface of the cortex. The
deepest Malpighian bodies are the oldest, and they
seem to maintain throughout life the greater size
which they acquired during development. Their size
however is not altogether dependent on developmental
reasons, in most animals they undergo a diminution
in size after foetal life is over. This is espec-
ially noticeable in Aves, where the Malpighian bodies

are very large during development, while in the adult
they are much smaller.   The alteration in size is
probably largely associated with function, and may be
regarded as a true Hypertrophy or Atrophy, according
as they increase or decrease.   In the Human kidney
it is not uncommon to meet with both processes.   Some
of the deep Malpighian bodies in the foetus are larger
than any found in the adult kidney, other of the later
formed and superficial Malpighian bodies are small,
and imperfectly developed at birth, and may remain so
for some time in the child, but with increase of func-
tion they appear capable of enlargement.   These im-
perfectly formed Malpighian bodies are usually found
in positions corresponding to the interlobular septa,
their appearance, and the persistence of fibrous tissue
around them, led to the belief at one time that they
were infarctions.

Bowman's capsule consists of a thin homogenous
basement membrane, which is lined by a single layer
of cells.   The basement membrane is apparently struc-
tureless.   Rühle (Bb 7/.), who has recently examined it
very carefully, considers that it is composed of a
number of minute fibrils.   Ludwig (Bb 52.) believed
it to be a mosaic of flattened cells, and other ob-
servers by the use of Silver nitrate have come to
this conclusion.   In the human foetus there is

nothing at an early stage to correspond to the stru-
-cture which is so noticeable in the adult.   The
cavity of the capsule is separated from the surround-
ing connective tissue merely by a layer of cells.
In the adult Human kidney the basement membrane bears
some resemblance to the elastic lamina of an artery
Fig. (*28.*).   Bowman described it as ending round the
afferent and efferent arterioles.   Rühle considers
that it is reflected near them into the glomerulus,
where it forms an exceedingly delicate mesh work of
fine fibrils.   I have often seen it apparently re-
flected but then disappearing.   If the basement mem-
brane is a secretion by the lining membrane, it is
most probable that it is continued into the glomer-
ulus, but its development must be influenced by the
continual excretion taking place there.

The cells lining Bowman's capsule vary in appear-
ance.   The greater part of them are long and flat,
and resemble endothelium.   In the Human, and most
Mammalian kidneys, the whole of the capsule is thus
lined.   In Birds, and some Mammals e.g. the Mouse,
a portion of the capsule is lined by cubical cells,
in direct continuation with the flat cells.   The
transition between the two is sometimes sudden, and at

other times more gradual, so that there are cells of

an intermediate character present.   Where there are

cubical cells in Bowman's capsule they are always to

be found at the neck of the tubule, and are contin-

uous with the cells lining the convoluted tubule.

The cells nearer the base of the glomerulus, i.e.,

that part of the capsule furthest from the neck of

the tubule are always flat.   In the Mouse the cubi-

cal cells extend over a third or more of Bowman's

capsule;   they closely resemble the cells of the con-

voluted tubule, and are probably the same in function.

It looks as if this were to be regarded as a Hyper-

trophy of the convoluted tubule at the expense of

Bowman's capsule.   In Birds a similar appearance is

met with.   Fig. (27.) is from the kidney of an adult

Sparrow.   In the Sparrow the Malpighian bodies are

very small having a diameter of about ·04 MM.   In Fig.

(27) which is magnified 1,000 diameters, the capsule

is for the most part lined with cubical cells almost

identical with the cells of the convoluted tubules.

The glomerulus is very small.   In this case it app-

-ears as if the Malpighian body had undergone changes

due to atrophy of its usual function, and had been

invaded by the cells of the convoluted tubule con-

verting its function, partly into that of a convoluted

tubule. This supposition, if we assume Bowman's theory as true, that the glomerulus excretes fluid, and the cells of the tubules solids, is rendered more likely by the fact that the urine of birds is semi-solid. The cubical cells lining the neck of the capsule in the Mouse have been stated by Klein to be ciliated. I have not seen anything that could be undoubtedly called cilia, appearances something like very fine cilia are sometimes seen, especially in specimens fixed in Corrosive sublimate, whether they are cilia or not I am not prepared to say. Other observers have described cilia in various Mammalian kidneys. Dr. Carlier has recently shown them in the Cat, Sheep, and other Mammals. In the Mesonephric kidney, where the tubules are also the generative ducts, the cilia are well marked, Fig (26), and their presence is easily explained. In the Metanephros it is not so easy to understand why cilia should be present, and they are certainly not very obvious. I have not seen anything resembling cilia in the human foetal kidney.

The convoluted tubule usually leaves Bowman's capsule opposite the base of the glomerulus, but variations occur; and it is often found nearer one side than the other, but never next the base as in the

early stages of development, or as in the kidney of the Skate.

The glomerulus is attached by a narrow base consisting chiefly of the afferent and efferent arterioles and the membrane covering them. The capillary loops form lobes, and differ in number and arrangement in different animals. The epithelium covering the glomerulus consists of flat nucleated cells in a single layer, and it dips down between the lobes covering each capillary loop. The relation of the capillaries to the cells covering them is not quite clear; there seems often to be a space between which is exaggerated in some pathological conditions. Fine connective tissue cells and lymphatics have been described, and the mode of development of the glomerulus indicates the possibility of such being present.

The Malpighian body of the Metanephros is surrounded by convoluted tubules. A small amount of connective tissue is also present especially at the base of the glomerulus, but it does not form so prominent a structure as in the Cod, where each Malpighian body is fixed round the periphery of a thick fibrous septum.

Conclusions.

There exists an analogy between most of the

animal organs of excretion.   The essential parts
consist of

1.   A cavity in the body.

2.   A tube leading from it to the exterior.
In the simplest forms the cavity which is drained by
the tube is the coelome or general body cavity.   Such
an arrangement is found in the Amphioxus.   With the
greater development of the vascular system a special
structure,the glomerulus is formed.   The glomerulus
at first appears in the general body cavity near the
exit of the tubule.   This condition is only seen in
a short stage of the development of the Pronephros,
and no adults remain to show it.   In the next stage
the glomerulus forms in the mouth of the tubule,which
is still in connection with the body cavity.   This
is found in the Pronephros of the chick, the glomer-
ulus being known as the Internal glomerulus.   The
condition persists throughout life in the Myxine or
Hag Fish.

In Elasmobranchs the cavity in which the glom-
erulus hangs remains in connection with the body cav-
ity by a tube of more or less length, but some be-
come connected with the Testis, and the urinary tubes
take on the action of Vasa deferentia.   In Amphibia

the kidney is also associated with genital functions,
and acts as a Vas deferens.   In some Species the
testicular canals open into the neck of Bowman's cap-
sule, in others they open into the collecting tubes.
In Amphibia the peritoneal connections with the Mal-
pighian bodies become broken off.   In Reptiles, Birds,
and Mammals Bowman's capsule has no communication
with the general body cavity.   Its cavity in fact is
a specially differentiated one, closely related to, but
now distinct from, the general body cavity.

The association of the Urinary with the Genital
organs is an interesting one, and increases the com-
plexity of the Mesonephric kidney.   In the male the
ducts from the Testis open into the general body cav-
ity in the lowest forms, then they open into the spec-
ially differentiated cavities the Malpighian bodies,
then into the collecting tubes, and in Mammalia their
openings have descended to the urethra.

In the kidney of Man it seems only natural to
suppose that the cavity of each Malpighian body is a
small body cavity specially differentiated for excre-
tory purposes.   Its structure supports the assumption.
The lining of Bowman's capsule corresponds to the lin-
ing of other true body cavities.   The cells lining

Bowman's capsule have probably no other function than
to form the lining of such a cavity, the thick base-
ment round them in the adult precludes the possibility
of their having an excretory function, and gives to
the capsule a character more like that of an artery,
the basement membrane corresponding to the elastic
lamina of the latter.   The cells of the tubules
though closely allied to the cells lining the capsule
are much more highly developed, and take on quite a
different structure and function.   The epithelium
covering the glomerulus is also closely related to the
other two, but assumes a different and special char-
acter at an early stage.   It is further modified to
allow of the performance of the excretion of water
and some solids, and has no basement membrane, or at
least a very fine one with numerous perforations.

The cells lining Bowman's capsule, the cells of
the convoluted tubules, and the cells covering the
glomerulus, must therefore be regarded as differentia-
ted, and specialised, for the performance of three diff-
erent functions.   Their pathological reactions should
also differ, and it is found that they do so. The cells
lining Bowman's capsule are the least highly differ-
entiated, and in inflammatory conditions they behave

like the endothelium of an artery in Endarteritis.
This was long ago taught by Professor Greenfield from
a pathological basis; and the embryology, and compar-
ative anatomy of the Malpighian body, give a feasible
explanation of what seemed contrary to views generally
accepted.

Pathology.

A short consideration of some of the

Pathological Changes in the

Malpighian bodies of the Kidney.

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General Considerations.

In the Kidney there are three important struct-
ures which have to be considered in its Pathology.
These are

     1.   The Blood Vessels.

     2.   The Glandular elements.

     3.   The Connective Tissue framework.

The Blood Vessels. The Kidney is extremely vas-
cular. Bowman first pointed out that there was a
double system of capillaries in the Cortex. The first
consisted of the capillary loops forming the Glomer-
ulus, these united to form the efferent arteriole,
usually a single thin walled vessel, which almost im-
mediately after leaving the Glomerulus, broke up into
the second system, a number of fine capillaries surr-
ounding the convoluted tubes. Ludwig (Bb 52.) showed
that the Interlobular arteries each gave off one, and
only one, afferent arteriole to each Malpighian body,
and that the second system of capillaries, resulting
from the breaking up of the efferent arteriole, were
distributed among the different portions of the con-
voluted tubule belonging to that Malpighian body.
In other words that each Malpighian body, together with
its convoluted tubule, was supplied by a single branch
from the Interlobular artery. The development of

the kidney gives support to this, in that it shows that
the Malpighian body is surrounded by the convolutions
of its own tubule, among which the second capillary
network is distributed.   This fact has a most import-
ant bearing in Pathology.   It shows that the blood
supply to the convoluted tubules is largely dependent
on the condition of the capillaries in the glomerulus.
Any hindrance to the stream there will bring about a
diminution of the blood supply to the convoluted tub-
ules.   The diminution will not be quite proportional
to the amount of obstruction in the glomerulus, for
there exists a certain amount of anastomosis between the
capillaries of adjacent convoluted tubules;   but if
the circulation of a number of neighbouring glomeruli
be impaired, there is necessarily an impairment of the
blood supply to their convoluted tubes;   and as a re-
sult of this diminished blood supply, there must be
secondary charges produced.   The consequences of this
vascular arrangement are seen in the frequency with
which Infarction occurs in the kidney. They have also
been shown experimentally by Professor Greenfield in
the production of Infarctions in the dogs' kidney by
the injection of Tobacco seeds into the Renal artery.
Embolism readily occurs in the afferent arteriole, and
in the capillaries of the Glomerulus, and these vessels

are also extremely liable to impairment in disease.
The glomerulus therefore is a very important factor,
changes in its vessels not only inpair its own funct-
ions, but they have wider and more general effects,
since they interfere with the nutrition and functions
of the tubules. Circulation through the vessels of
the glomerulus may be hindered by changes inside the
vessels, or in their walls, but there may be an add-
itional factor.   It is probable that there is a cer-
tain amount of connective tissue between the capillary
loops of the glomerulus, and in certain inflammatory
conditions these cells proliferate, and by their grow-
th compress the vessels.   Compression and obliter-
ation of the vessels may also occur in another way, by
proliferation of the epithelium lining Bowman's cap-
sule.   The results of such obliteration must have, and
are found to have, a great influence on the parts of
the kidney, that normally receive their blood supply
through these glomeruli.

The double capillary system has also another bear-
ing, the importance of which is difficult to estimate.
The blood in the second system of capillaries is nor-
mally more concentrated owing to the loss of part of
its watery element during its passage through the
glomerulus.   In the nephritis following Scarlatina,

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and Diptheria, there are probably injurious chemical
materials in the blood.   These are brought into close
relation with the glandular elements in both sets
of capillaries.   Whether they are excreted through
the glomeruli, or pass in a more concentrated form to
the convoluted tubules, is undetermined.   The chang-
es in Scarlatinal Nephritis would lead one to infer
that they acted more especially on the glomeruli at
first.

Glomeruli in different parts of the Cortex also
appear to be differently affected sometimes; those
in the interpyramidal cortex reacting differently
to those in the ordinary cortex.   The reason of this
is not clear.

2.   The Glandular elements.   These include the
epithelial lining of Bowman's capsule, and the cover-
ing of the glomerulus, as well as the tubules.   In
the Development of the kidney it has been shown that
all the glandular elements, with the exception of the
collecting tubes, are Mesoblastic structures.   The
collecting tubes are probably Epiblastic.   The for-
mer constitute the greater part of the cortex, and
the Epiblastic tubules the medulla.   The Mesoblast
or cortex is far more prone to disease than the Med-

-ulla.   Sir T. Grainger Stewart (Bb *80.*) in his work
on "Bright's diseases of the Kidneys" published in
1868 speaking of Cirrhotic kidney said "It is however
singular that even when the disease is furthest ad-
vanced the cones are comparatively little affected,
the cortical substance may be reduced to a very thin
layer perhaps one sixth of its natural size, and yet
the cones be but slightly wasted."   The glandular
elements of the cortex are more highly organised, and
vascular, and therefore liable to greater changes in
disease; but their origin from Mesoblast is probably
of importance, such structures showing less power of
existence than epiblastic structures when invaded by
connective tissue.

In the Malpighian body there are two kinds of
epithelium to be noticed, that covering the glomerulus
being a more highly differentiated form than that
lining Bowman's capsule, and showing a difference in
reaction in disease.   A third form of epithelium,
that lining the neck of the convoluted tubule is also
found at times inside Bowman's capsule.

The basement membrane is closely related to the
glandular elements, but its exact nature is not clear.
It has been supposed to be a homogenous membrane,
formed by some process of secretion by the epithelial

cells it borders.   Others have considered it to be a
cellular structure acquiring a fibrous nature, with
nuclei imbedded at intervals between the fibres.
This view is supported by some common pathological
changes, in which the basement membrane appears to be
split, and often separated by fibrous tissue, the cells
being produced by the proliferation of its nuclei, and
the splitting being caused by their further growth.
The basement membrane which forms Bowman's capsule of-
ten acts in this manner.   It shows a remarkable per-
sistence at times, even when the glomerulus has been
almost obliterated by cell proliferation inside it.
At other times there are appearances suggesting the
formation of a new capsule inside the old one, the
interval between them being filled with connective
tissue, or the one may join the other, and in this way
appear as if it had been split up into two or more
strands.

There are no pathological changes to support
Rühle's view, that the capsule is continued into the
glomerulus over the capillary tufts.

3.   The Connective Tissue framework.   The im-
portance of this has been shown in **development**; and
it is of even more importance in Pathology.   The con-
nective tissue is small in amount in the cortex, and

scarcely visible in the normal adult kidney.   Some
persists round the larger blood vessels, and round
the Malpighian bodies, especially at the base of the
glomerulus; it is probably continued into the glom-
erulus itself, and binds together the capillaries.
The development of the Malpighian body supports such
a view.   In fact all the structures that form a
glomerulus, are so closely related in their origin,
that they might be looked as differentiations of the
same tissue.   Proliferation of connective tissue is
soon brought into evidence by the appearance of cells
round Bowman's capsule, which have a tendency to arr-
ange themselves in laminae round it.   Proliferation
inside the glomerulus itself had been described as
an evidence of the presence of such cells in that
situation.   Their proliferation leads to interfer-
ence with the passage of the blood through the cap-
illaries by pressure on them.

Connective tissue is also found under the cap-
sule, and is more plentiful in the medulla between
the large collecting tubes.   In all long continued
inflammatory changes in the kidney, and especially
in Cirrhosis, there is a great increase especially
in the cortex of connective tissue, an exaggerated

framework of fibrous tissue developes replacing the glandular elements. In the foetal kidney the framework is large in amount and cellular, in the normal adult kidney it is almost non-existent, in Cirrhosis it is large, dense, and fibrous,and constitutes the greater part of the cortex of the kidney.

All three structures, Vascular, Glandular, and Connective tissue have therefore to be considered in the Pathology of the Malpighian body, and from the foregoing remarks it will be seen that alterations in any of these structures will bring about changes of the greatest importance not only in the Malpighian body itself but in the rest of its tubule. The Pathology of the Malpighian body therefore occupies a most important position in the Pathology of the kidney.

Hypertrophy and Atrophy.

It is difficult to determine of some of the changes, which are Pathological and which are Physiological. Since the experiments of Rose Bradford (Bb 7.) it has been recognised that very little healthy kidney substance is required to fulfil the necessary excretory functions of an animal. Bradford found that a quarter of the total amount of kidney was

sufficient for ordinary purposes, and he showed the
remarkable circumstance that when more than three
quarters of the whole kidney substance was removed
by operation the excretion of both water and solids
was so much increased by the small portion remaining
that the animal rapidly emaciated and died.   In
Pathological conditions of the kidney there are often
the most extensive changes with destruction of a
great many Malpighian bodies and tubules, yet the
out-put of water may be above the normal, and the
solid constituents may or may not be decreased.

From a consideration of the development of the
kidney it seems extremely improbable that any new
Malpighian bodies or tubules should form.   The mat-
erial from which they arise is exhausted at the end
of the 8th month of foetal life, and disappears en-
tirely.   The subsequent growth of the kidney is
essentially a hypertrophy of already formed struct-
ures.   The hypertrophy or growth appears to be in
excess of physiological needs, as if making provision
for future contingencies, or for the increased de-
mands on the function occasionally required in
health.

In Congenital Cystic kidney it has been alleged
that the healthy portion hypertrophies to compensate

for the smaller number of functional Malpighian
bodies and tubules, and the history of development
and mode of subsequent growth of, the kidney favour
this view.   Some Malpighian bodies again in the peri-
phery of the lobules of the normal kidney appear to
remain small for some time after birth, such are not
found in the adult kidney, and it is very likely that
they grow larger with increase of function.

When the kidney is fully formed it is question-
able whether Hypertrophy can take place as in the
growing kidney.   Numerous experiments have been per-
formed.   Rosenstein (Bb 68.) in 1871 removed one
kidney from an animal, allowed the wound to heal,
and after some time killed the animal and compared
the two kidneys.   He found that there was a slight
increase in the epithelium of the tubules, and in
the connective tissue.   Ribbert (Bb   ), and Barth
(Bb 3.), each came to the conclusion that after re-
moval of one kidney compensatory Hypertrophy occurred
in the remaining kidney, the Malpighian bodies increas-
ed in size, Bowman's capsule became wider, and the
glomerular tufts longer and broader.   Ribbert experi-
mented on a large number of animals, and found that in
all there was both proliferation of cells, and in-
crease in size of the Malpighian bodies and convol-
uted tubes.   Golgi (Bb 24.) and Sacerdotti (Bb 73.)

performed Nephrectomy on animals, and found that
there was active Karyokinesis in the cells of the
tubules of the remaining kidney several days after
the operation.   Golgi (Bb 24) further stated that
a similar proliferation of cells took place in some
forms of Bright's disease, regeneration by Kary-
okinesis occurring.

It is not uncommon to find in the Human kidney
that part of Bowman's capsule is lined with cubical
cells.   Fig. (28.) is from a cystic kidney, and
shows a well marked basement membrane with cells
lining it almost cubical, and gradually enlarging
towards the convoluted tube.   The same appearance
is often met with in some forms of chronic Bright's
disease.   The question arises.   Is this an attempt
at Hypertrophy, an attempt to utilise the interior
of Bowman's capsule by an ingrowth of cells from
the convoluted tubule? · In Fig. (28) the enlarge-
ment of the cells appears to be more of a swelling
of the flattened cells, and the nuclei still preserve
some of their flattened character.   In other cases
one finds well marked cubical cells inside Bowman's
capsule as in the normal kidney of the Mouse.   The
changes which take place in the Malpighian body of
birds seem to be of the nature of hypertrophy and

atrophy, hypertrophy of the tubule and atrophy of
the glomerulus with the result that the Malpighian
body in many cases becomes a portion of tubule with
scarcely any glomerulus. Fig. (27.).

Mechanical hindrance of the escape of urine
from the kidney produces in itself remarkably little
alteration in the structure and appearance of the
Malpighian bodies.   In Hydronephrosis following
obstruction of the ureter the Malpighian bodies re-
main very little altered for a long time.   Eventually
many become obliterated by fibrous growth.   Griffiths
(Bb 28.) has recently described the changes as due to
a proliferation of the cells lining Bowman's capsule,
but he denies that the accompanying interstitial
change is the result of interference with the circul-
ation through the capillaries of the glomerulus, a
view which he says was advocated by Newman.

Rose Bradford (Bb 8.) has performed a number of
experiments on dogs with the object of ascertaining
whether obstruction of the Ureter would cause atrophy
of the kidney.   He ligatured a ureter, and after
various periods of from 11 to 40 days removed the
ligature, and established a urinary fistula.   Some
time subsequently he killed the animal, and examined

the kidney. As a result of the ligature Hydrone-
phrosis occurred, but after removal of the ligature
urine was again excreted, and the kidney rapidly
diminished in size, but regained its normal shape
though considerably smaller than originally. Very
little alteration took place in the Malpighian bodies,
the glomerulus was a little shrunken, and the cavity
of the capsule wider, but there was no increase of
fibrous tissue except round the larger blood vessels,
and no proliferation of the cells lining Bowman's
capsule. The chief change was in the cells of the
convoluted tubules, which had lost their granules,
and were smaller and transparent.

In the beginning of December 1898, I removed a
wedge shaped portion equal to half the kidney from
a cat in the manner described by Bradford (Bb 7.);
at the same time one of the stitches in bringing the
two ends of the kidney together included the ureter.
The animal soon recovered, and the wound healed.
In March 1899. a little over three months after the
first operation I killed the cat and examined the
kidney. The wound had healed with very few surround-
ing adhesions, and the kidney was less than half the
size of the sound kidney. On opening the small
kidney a quantity of urine escaped, and the pelvis

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was found to be dilated.   On microscopic examination
and comparison with a section of the wedge shaped
piece that had been previously removed there was
little difference to be seen in the Malpighian bodies.
Bowman's capsule was unaltered but the glomerulus
was smaller in the hydronephrotic kidney and occupied
less of the space.   The cells lining the capsule
were unaltered.   I could not detect any increase of
fibrous tissue.

Urinary pressure is a low one, and it seems to
produce little effect on the Malpighian bodies;
circulation apparently goes on through the glomeruli,
and is sufficient to supply the cells of the convol-
uted tubes.   Some additional factor is necessary
for the production of the gross forms of atrophy met
with in many diseased conditions.   This is probably
an irritant, and the changes that result are Inflam-
matory.

Inflammatory Changes.

The Inflammatory lesions of the Malpighian
bodies have been classified as Acute, Subacute, and
Chronic.   Cornil and Brault (Bb /4.) applied the name
"Glomerulitis" to all these conditions.   The name is
misleading for the part taken by Bowman's capsule is

no less important in its ultimate effects.   Pro-

fessor Greenfield (Bb *26.*) divided the changes into

those occurring in the capsule itself, those exter-

nal to it, and those in its interior.   These

practically resolve themselves into affections of

the Blood vessels, epithelium and connective tissue.

In acute inflammatory affections of the Kidney the

vessels of the glomerulus are soon concerned.

Congestion and swelling of the tuft occur very read-

ily.   The changes are more marked in some conditions

than in others.   In the acute infectious diseases

especially Scarlatina there are early and important

alterations in the vessels.   Klein (Bb *44*) describ-

ed these as consisting in a hyaline degeneration of

the elastic intima of the minute arteries, especially

those of the afferent arterioles of the Malpighian

bodies.   By swelling of the intima of the capill-

aries of the glomerulus the circulation through

them was greatly interfered with.   Klein also

described an increase in the nuclei of the muscle

cells of the afferent arterioles especially at

their points of entrance into the glomeruli.

Besides changes in the walls of the vessels there

is a diapedesis of leucocytes which accumulate

round the base of the glomerulus in many cases of Scarlatinal Nephritis Cornil mentions that the emigration of leucocytes and haemorrhage from the glomerular capillaries is very marked in animals poisoned by Cantharides. The blockage of the capillaries by hyaline thrombi was described by Klein.

Owing to the close relationship between capillaries and the epithelial covering of the glomerulus the changes in them have been much confused, and are not yet quite clear. In most acute inflammatory affections of the glomerulus, and particularly in Scarlatina, there is a great proliferation of nuclei in the tuft. These have been considered to be the nuclei of the capillaries, or of the epithelial covering, or of connective tissue cells lying between the capillaries. Klebs (Bb 43.) was the first to draw general attention to the condition. He gave the name "Glomerulo-nephritis" to the lesions of the Malpighian bodies met with in Scarlatina. Klebs described a great increase in the number of nuclei in the glomerulus and believed that they were the results of the proliferation of connective tissue cells lying between the capill-

aries.   Their increase was to such an extent as to
press on the capillaries and prevent circulation
through them.   Klein (Bb 44.) questioned the accuracy
of Klebs's observation; he found that such a pro-
liferation of nuclei was very rare, and was inclined
to look on the chief change as a degeneration of the
vessels.   Hansemann (Bb 31.) adopted Klebs's view,
and described proliferation of connective tissue
cells in the glomerulus.   Kelsch and Kiener (Bb 42.)
considered that the proliferation was one of the
epithelial envelope covering the glomerulus.   Cornil
and Brault (Bb 14.) described the change as a prolif-
eration and desquamation of the epithelial cells.
According to these authors the nuclei of the epithel-
ial cells dipping between the loops enlarge, the
flattened cells become swollen, and a pedicle forms
between each one and its attachment, which ultimately
becomes separated.   Cells are formed in this manner
which lie loose inside Bowman's capsule.   Langhans
(Bb 49.) described the glomerular lesion as a prolif-
eration of the endothelial cells of the capillaries
leading to their obliteration.   Welch (Bb 88) came
to the same conclusion as Langhans and called the
condition "Intracapillary Glomerulitis".

Councilman (Bb /5.) has recently described the cap-
illary lesions very fully.   He found that the
majority of the nuclei were those of the capillaries
as described by Langhans and Welch, but that some
were the result of proliferation of definite conn-
ective tissue cells in the glomerulus, there were
also a few leucocytes, rarely many, which might be
seem in the act of emigration from the vessels into
the capsular space.   There was a remarkable absence
of red cells in all the cases he examined.   Hyaline
thrombi and partial necrosis of capillaries were
found in a few.

There are therefore three opinions on the
origin of the nuclei which are so marked a feature
of the glomeruli in the early stages of Scarlatinal
nephritis.   Kelsch and Kiener, Cornil and Brault
believe them to be epithelial, Klebs and Hansemann
that they are connective tissue, and Langhans, Welch
and Councilman that they are endothelial in the main,
but a few are connective tissue.   In some cases
leucocytes are numerous but their nuclei differ from
the small round deeply staining nuclei which are
characteristic of the condition.   The proliferation
of these nuclei varies in amount in different cases

but is a marked feature of the Nephritis due to
acute infectious diseases, and poisoning by various
irritants.   They are shown in Fig. (*29.*) a glomerulus
from a cat poisoned by Corrosive Sublimate.   In
other instances it is not so marked a feature, and
it is questionable how much of the change is primary,
and how much is a result secondary to alterations in
Bowman's capsule.

   All the authors above mentioned have described
the proliferation of the cells lining Bowman's
capsule, but only a few have attached much importance
to it.   Klebs found a number of angular nuclei
lying free in the interior of the capsule in the
condition he called Glomerulo-Nephritis.   These
angular nuclei were usually surrounded by amorphous
granular masses which he believed to be the result
of the proliferation and degeneration of the capsular
epithelium.   Klein found a proliferation of nuclei,
and the presence of granular material and blood in-
side the capsule, the thickening of Bowman's capsule
and obliteration of glomeruli he ascribed to a general
interstitial change.   Kelsch (Bb *41.*) considered
that the change was essentially an interstitial one,
and that the thickening of Bowman's capsule was a

secondary result.   Professor Greenfield (Bb 26.) in
1879 was the first to point out the importance and
extent of the cellular proliferation inside the cap-
sule.   He showed that the proliferation of these cells
was a constant phenomenon not only in Scarlatinal
nephritis, but in almost every form.   It was more
rapid in Scarlatina and led to many important results.
The capsule itself sometimes became swollen, but the
most common process was a multiplication of the en-
dothelial cells lining it.   Similar changes were
found by him in the early cirrhotic kidney, the pro-
cess affecting the more peripheral Malpighian bodies
at first, and extending towards the medulla, the
glomeruli of certain interlobular arteries being more
implicated than those of others.   The proliferating
cells formed laminae inside the capsule, and event-
ually became organised tissue;   in many cases the
opening of the tubule was blocked at an early stage,
but in others it remained open, but with the con-
traction of the fibrous layers the glomerulus atroph-
ied, and in time disappeared, its place being taken
by a knot of fibrous tissue.   The cells inside the
capsule did not always proliferate uniformly, some-
times the growth occurred very rapidly near the base

of the glomerulus mechanically interfering with the
circulation.   Bowman's capsule itself often split
up by proliferation of nuclei between its layers,and
a concentric pericapsular growth of fibrous tissue
was a common accompaniment.   The interference with
the circulation through the glomeruli led to a loss
of part of the function of their convoluted tubes,
and at the same time decreased their blood supply.
As a consequence the tubules belonging to the affected
glomeruli atrophied, and owing to the process affect-
ing those supplied by particular interlobular arter-
ies the kidney showed strips of corresponding atroph-
ied tissue running in from cortex to medulla.   In
Scarlatinal nephritis proliferation of the cells
lining the capsule was often very rapid and early.
The capsular epithelium therefore acted very differ-
ently to the glomerular epithelium.   In the glomer-
ulus there was a proliferation of nuclei as already
mentioned, but instead of persisting and increasing
the glomerulus gradually shrank and atrophied, the
cells of the capsule forming concentric rings and
gradually obliterating it.

Langhans (Bb 49.) in the same year described the
proliferation of the capsular epithelium as the first

change in the Malpighian body, and showed that this
growth compressed the vessels.

Cornil and Brault (Bb /4) found that prolifera-
tion and desquamation of the cells occurred in
Cantharides poisoning, but that it was more marked
and important in the subacute inflammations.

Welch (Bb 88.) proposed the name "Desquamitive
glomerulitis" for this lesion as against the "Intra-
capillary glomerulitis" already mentioned. Council-
man found it present in all his cases and emphasised
its importance.

Friedländer (Bb /9) found that Bowman's capsule
was constantly thickened but rarely markedly.   In
its interior it was common to find sickle shaped
masses of flat cells which formed stratified layers
round the glomerulus.   The epithelial covering of
the glomerulus on the other hand rarely increased to
any extent.   He considered that in the early stages
the hindrance to the glomerulur circulation was due,
not to outside pressure, but to internal changes in
the capillaries.

Proliferation of the cells lining Bowman's
capsule is now recognised to be of very common occ-
urrence.   It occurs in many cases of irritant pois-

oning such as by Corrosive Sublimate, in many of the
infectious fevers, Cholera, Yellow fever, and espec-
ially Scarlatina, in other such as Diptheria it is
less marked.   The cells for the most part preserve
their flattened shape, and form concentric rings
inside the capsule.   Some of them are free, and show
their pointed extremities and flattened nuclei, but
the majority remain in apposition, and after a time
become organised connective tissue.   Bowman's
capsule itself shows a remarkable persistence, and is
very little altered in many.   Fig. (*30.*) from a sect-
ion of Human kidney shows the persistence of the
basement membrane round the Malpighian bodies with
accumulation of cells inside.   The kidney was a
good example of Subacute Nephritis, non Scarlatinal,
but had been too long in Muller's fluid to show de-
tail under high power, the stain by Heidenhain's
method has picked out the basement membranes very
clearly.   The cells are clearly inside the capsule,
and are not derived from basement membrane.   It is
often found that their nuclei have lost the power of
staining.   Fig. (*31.*) under a high power shows a
similar change, some of the cells are detached, and
their characters are very typical.   This specimen is
from a case of subacute nephritis in which the

Malpighian bodies show all changes from slight thick-
ening to complete obliteration of the glomerulus.
Some of the cells have been believed to be derived
from the epithelium covering the glomerulus as de-
scribed by Cornil and Brault.   A few may be so de-
rived, but the concentric arrangement and position of
the cells indicate that they are capsular in origin.
They are often found growing between the lobes of
the glomerulus, but they grow in peripherally.   Ad-
hesions are of frequent occurrence between the new
cells and the capillary tufts.   The glomerulus swol-
len at first, and often showing marked hyaline degen-
eration, gradually atrophies.   The changes can be
easily studied in subacute conditions such as seen
in Fig. (*31.*) where the process is slower.   Organ-
isation of the newly formed cells takes place and
small capillaries appear inside the basement mem-
brane.   This latter appears to be often split into
layers, some of which enclose numerous cells and cap-
illaries, in many, however, it remains single, and
not much thickened.   At the same time there is a
pericapsular growth of connective tissue, the cells
of which become arranged in parallel layers, Fig. (*31.*),
and help to bring about the ultimate atrophy of the
Malpighian body.

Another condition is sometimes present in Bowman's capsule in acute forms of Nephritis.   It is the presence of degenerated cells from the convoluted tubule.   This was found by Councilman in one of his cases, and he gives a diagram illustrating it.   Large masses of granular cells were present inside the periglomerular space, and continuous with the cells of the convoluted tubule.   I have found the same present in the kidneys of two cats poisoned by Corrosive Sublimate, in both it was a marked feature, some of the spaces being almost filled and the glomerulus flattened against its base.   Fig. (29.) shows one of these Malpighian bodies, the indentation of the glomerulus by the cell mass is also seen.   It is not the usual lesion described in Corrosive Sublimate poisoning, and appears to be the result of great swelling and detachment of the cells in the neck. The cells lining Bowman's capsule remain in position, and in these instances were little affected.   Necrosis of tubular epithelium was very marked in places. Welch (Bb 88.) described the same appearance in Bowman's capsule in the kidneys of rats poisoned by Cantharidin.   The cells present no resemblance to the masses which result from proliferation of the cells lining Bowman's capsule, and the lesion probably only occurs in very acute conditions.

The exact relation of changes in the Malpighian
bodies to changes in the rest of the kidney is diff-
icult to estimate.   As every tubule depends on its
Malpighian body for the proper performance of its
function, and for much of its blood supply, any lesion
in the Malpighian bodies must affect the function
and nutrition of the tubules.   On the other hand
the same cause that effects the capsular lesion will
probably produce results directly in other parts of
the kidney.   Professor Greenfield has shown that in
some forms of Cirrhotic Kidney the lesion is one
beginning in the most distal Malpighian bodies of
certain of the Interlobular arteries, and has ad-
vanced as a possible explanation the view that some
irritant circulating in the blood has been eliminated
by the glomerulus, but remained in a stagnant con-
dition for some time in the distal Bowman's capsule,
with the result that the cells have proliferated
under irritation.

Once organised tissue has formed inside Bowman's
capsule it seems likely that the glomerulus is doomed,
contraction gradually occurs, the excretion of urine
may continue some time, but eventually the cavity
becomes closed and obliterated.   In this as in many

other kidney changes there is a great variety in the

mode of onset and course of the lesion.   Some

Malpighian bodies are affected early, and ~~some~~ *soon* dis-

appear, others persist unaltered.   In acute condit-

ions too some kidneys show marked changes in the

Malpighian bodies, in others they are less evident.

The condition termed Glomerulo-nephritis by Klebs

while occurring typically in Scarlatinal nephritis

appears to be merely an exaggeration of a pathological

change which is very common in the kidney in all in-

flammatory affections.

In these lesions it is seen that the cells

lining Bowman's capsule behave, not like the cells of

a glandular epithelium, but rather as an endothelium.

The changes were aptly compared by Professor Greenfield

(Bb *26*) to the changes occurring in the inner lining

of an artery in endarteritis deformans.   The cells

covering the glomerulus though possessing a similar

anatomical appearance do not act thus, but more after

the manner of the tubular cells.   I think the reason

for this is explained by their development, and by

their Comparative anatomy.   The cells which line

Bowman's capsule, and the convoluted tubules, and

cover the glomerulus, arise from Mesoblastic cells

closely related to the peritoneal epithelium. The
cavity of Bowman's capsule is a specially different-
iated body cavity, which in a low form of kidney such
as that of the Myxine is a part of the general body
cavity, and in the higher forms presents certain
close analogies at an early stage of development.
The epithelium which lines the cavity flattens very
early, and assumes the character of a lining membrane,
while the epithelium covering the tuft attains a far
higher degree of development, and performs important,
and special functions. Though it flattens later on,
and resembles the lining cells of the capsule, it is
probably a more highly organised structure, different-
iated like the cells of the convoluted tubules but
in a different manner for excretory purposes. The
highly organised structures react to irritation in a
different way to endothelium. Their cells easily
degenerate and necrose and in catarrhal conditions
form different and less persistent masses. On the
other hand endothelium proliferates and becomes or-
ganised connective tissue. I think we are warranted
in regarding the cavity of Bowman's capsule as a
specially differentiated body cavity lined by en-
dothelium, and containing a glomerulus of capillaries

covered by a special and more highly organised

epithelium;   the whole structure arising from

Mesoblast.

BIBLIOGRAPHY.

1.   Adami J. G............On the nature of glomerular
                           activity in the kidney,
                           Jour. of Physiol, Vol. 3.
                           1886.

2.   Balfour................Comparative Embryology 1885.

3.   Barth. .... Mercredi Medical, 1892.

4.   Bidder.............. Ueber die Malpighi'schen
                           Körperchen der Niere.
                           Arch. f. Anat, Phys. u
                           wissen Med. Berlin 1845.

5.   Bornhaupt............ Untersuchungen über die
                           Entwickelung des Urogenital-
                           systems beim Hühnchen.
                           Dorpat. 1867.

6.   Bowman............... On the structure and use of
                           the Malpighian bodies of
                           the Kidney, with observa-
                           tions on the circulation
                           through that gland.
                           Trans. Roy. Soc. Lond. 1842.

7.   Bradford J. Rose ..... The influence of the Kidney
                           on Metabolism.   Trans.
                           Roy. Soc. Lond. 1892.

8.   Bradford J. Rose...... Observations on dogs to
                           determine whether obstruct-
                           ion of the ureter would
                           cause atrophy of the kidney.
                           Brit. Med. Jour. Vol 2.
                           1897.
                           Trans. Path. Soc. Lond.
                           Vol. 49. 1898.

9.   Braun Max............. Das Urogenitalsystem der
                           einheimischen Reptilien.
                           Arbeit aus dem Zool-Zoot
                           Instit. Wurzburg Bd. 4.
                           1877-78.

10. Burdach............... Die Physiologie als
                           Erfahrungswissenschaft.
                           Leipzig. Bd 2. 1828.

11. Chievitz J. H.........,... Beobachtungen und
                             Bemerkungen über
                             Saügerthiernieren.
                             Arch. f. Anat. u Phys.
                             Suppl. Bd. 1897.

12. Chrzonszczewsky......... Zur Anatomie der Niere.
                             Centralblatt. f. med.
                             Wissen. 1863.

13. Colberg................ Zur Anatomie der Niere.
                             Centralblatt. f. med.
                             Wissen. 1863.

14. Cornil et Brault....... Etudes sur la Pathologie
                             du Rein. Paris. 1884.

15. Councilman W. T........ Forty-nine cases of
                             acute and subacute
                             nephritis with especial
                             reference to the glom-
                             erular lesions.
                             Boston. 1897.

16. Drasch C. .... Über das Vorkommen
                             Zweierlei verschiedener
                             Gefässknauel in der
                             Nière.
                             Wien Sitzungsb. 1878.

17. Emery. .... Recherches embryologiques
                             sur le rein des Mammi-
                             fères.
                             Arch. Italienne de
                             Biologie 1883.

18. Forster. .... Pathologische Anatomie.
                             1863.

19. Friedländer. .... Ueber Nephritis scar-
                             latinosa. Fortschritte
                             der Medicin. 1883.

20. Fürbringer............. Zur vergleichenden
                             Anatomie und Entwick-
                             elungs-geschichte der
                             Vertebraten.
                             Morphol Jahrbuch.
                             Bd 4. 1874.

21. Gerlach................. Beitrage zur Struktur-
lehre der Niere.
Arch. f. Anat. Phys. u
wissen Med. Berlin. 1845.

22. Götte.................. Untersuchungen über die
Entwickelung des Bom-
binator igneus.
Arch. f. mikr. Anat.
Bd.5. 1869.

23. Golgi................. Annotaziona intorno all
'istologia dei Reni dell'
Uomo e di altri Mammiferi.
Rend. del. Acad. dei.
Lincei. Rome. 1895.

24. Golgi................. Sulla ipertrofia compen-
satoria du rein. Archivio
per le scienze mediche:
V. 6. 1883.

25. Goodsir............... Lond. and Edin. Month.
J. Med. Sc. 1842.

26. Greenfield W. S. .... Resumé of Renal Pathol-
ogy.   New Sydenham
Soc. Atlas, 1879.

27. Greenfield W. S. „„„.... Granular contracted
kidney.   Trans. Path.
Soc. Lond. 1880.

28. Griffiths J. „„......... The histological changes
in the kidney in
Hydronephrosis.
Trans. Path. Soc. Lond.
1881.

29. Hamburger O. „„„........ Ueber die Entwickelung
der Saügethierniere.
Arch. f. Anat. u Phys.
Suppl. Bd. 1890.

30. Hamilton............... Text book of Pathology.

31. Hansemann................Zur pathologischen
                             Anatomie der Malpighi'
                             schen Körperchen der
                             Niere.
                             Virchow's Archives.
                             Bd. 110. 1887.

32. Haycraft Berry. ....Development of the
                             kidney of the rabbit.
                             Internat Monatschrift.
                             Leipzig 1895.

33. Hedinger................Ueber den Bau der Mal-
                             pighi'schen Gefäss-
                             knauels der Niere.
                             Inaug Diss. Breslau.
                             1888.

34. Heidenhain R. ....Mikroscopische Beitrage
                             zur Anatomie und Physiol-
                             ogie der Nieren.
                             Arch. f. mikr. Anat.
                             Bd. 10. 1874.

35. Hertwig O. ....Lehrbuch der Entwick-
                             elungsgeschichte des
                             Menschen und der
                             Wirbelthiere.

36. His. W. ....Anatomie menschlicher
                             Embryonen. Leipzig. 1885.

37. Hortoles C. ....Recherches histologiques
                             sur le glomerule et les
                             epitheliums du rein.
                             Arch de Phys. norm et
                             path. Paris. Tom 8. 1881.

38. Huschke................Ueber die Textur der
                             Nieren. 1828.

39. Isaacs..................Researches into the
                             structure and physiology
                             of the kidneys.
                             Trans. New York Acad.
                             of Med. 1857.

40. Janosik................. Histologisch-embryolog-
                              ischen Untersuchungen
                              über das Urogenitalsystem.
                              Wien Sitzungsb. Bd. 91.
                              1886.

41. Kelsch................. Revue critique et recher-
                              ches Anatomo-patholog-
                              iques sur la Maladie de
                              Bright. Arch der Phys.
                              norm et path. 1874.

42. Kelsch et Kiener........ Arch de Phys. n. et. p.
                              1882.

43. Klebs.................. Handbuch der patholog-
                              ischen Anatomie. 1876.

44. Klein E. .... The anatomical changes
                              of the kidney, liver,
                              spleen and lymphatic
                              glands in Scarlatina of
                              man.   Trans. Path. Soc.
                              Lond. Vol.28. 1877.

45. Kölliker............... Entwickelungsgeschichte
                              des Menschen und der
                              höheren Thiere. 1879.

46. Kölliker............... Ueber Flimmerbewegungen
                              in den Primordialnieren.
                              Arch. f. Anat. Phys. und
                              wissen Med. 1845.

47. Kollmann J. .... Ueber die Verbindung
                              zwischen Cölom und
                              Nephridium.
                              Festschrift. Basel. 1882.

48. Kupffer................ Untersuchungen über die
                              Entwickelung der Harn
                              und Geschlechtsorgane.
                              Arch. f. mikr. Anat.
                              Bd. 1. 11. 1865-66.

49. Langhans T. .... Ueber die Veranderungen
                              der Glomeruli bei der
                              Nephritis. Virchow's
                              Archives Bd. 76. & 99.
                              1879.

50. Lieberkühn.............. Ueber die Allantois und
die Niere von Saügeth-
ierembryonen.
Sitz der Gesellschaft.
Marburg 1875.

51. Löwe.................... Zur Entwickelungsgesch-
ichte der Saügethierniere.
Arch. f. mikr. Anat. Bd.
16. 1879.

52. Ludwig................. Stricker's Handbuch der
Histologie.

53. Ludwig & Zawarykin...... Zur Anatomie der Niere.
Wiener med Jahrbucher
1862.

54. Malpighi............... De Renibus.   Omnia
opera 1686.

55. Marshall............... Vertebrate Embryology.
1893.

56. Müller Johannes........ De glandularum secernent
ium structura penitiori.
Leipzig. 1830.

57. Nagel.................. Ueber die Entwickelung
des urogenitalsystem
des Menschen.
Arch. f. mikr. Anat.
Bd. 34. 1889.

58. Nussbaum............... Zur Kenntnis der Nieren-
organe.   Arch. f. mikr
Anat. Bd. 27. 1886.

59. Parker & Haswell....... Text book of Zoology.
1896.

60. Phisalix.............. Sur l' Anatomie d' un
embryo humain de trente
deux jours.   Comp. rend.
d'accad. d. Sci. Paris
Tom 104.   1887.

61. Pye...................Observations on the
development and structure
of the kidney.
Journal of Anat. and
Physiology. London.
Vol. 9. 1875.

62. Rathke................ Abhandlungen zur Bildungs
und Entwickelungsgesch-
ichte des Menschen und
der Thiere.
Leipzig. 1833.

63. Reger................. Ueber die Malpighi'
schen Knauel der Niere
und ihre sogennanten
Kapseln.
Arch. f. Anat. Phys. u
wissen. Med. 1864.

64. Remak................. Untersuchungen uber die
Entwickelung der Wirbel-
thiere Berlin. 1855.

65.Ribbert.................. Ueber die Entwickelung
der Glomeruli.
Arch. f. mikr. Anat.
Bd. 17. 1880.

66. Ribbert............... Beitrag zur pathologi-
schen Anatomie der
Glomeruli. Fortschritte
der Med. Berlin. 1888.

67. Riedel............... Entwickelung der Saüg-
ethierniere.
Rostock. 1874.

68. Rosenstein S. .... Ueber complementäre
Hypertrophie der Niere.
Virchow's Archives.
Bd. 53. 1871.

69. Roth................. Untersuchungen über die
Drusensubstanz der Niere.
Schweiz. Zeitschrift.
f. Heilk. Bern. 1864.

70. Rothstein T. .... Zur Kenntnis der
Nierenepithels.
Biol. Foren. Forhandl.
Stockholm. 1891.

71. Rühle.................. Ueber die Membrana
propria der Harnkanal-
chen.
Arch. f. Anat. u. Phys.
1897.

72. Ryndowsky.............. Die Lymphgefässe der
Niere. Centralblatt.
f. d. med. Wissen.
Berlin. 1869.

73. Sacerdotti............. Ueber die compensator-
ische Hypertrophie der
Nieren.
Virchow's Archives.
Bd. 146. 147. 1896-97.

74. Schäfer................ Quain's Text Book of
Anatomy. Vol.1. pt.1.
1890.

75. Schweigger-Seidel....... Die Niere des Menschen
und der Saügethiere.
Halle. 1865.

76. Sedgwick............... Development of the kid-
ney in its relation to
the Wolffian body in
the chick.
Quart. J. Micr. Sc.
Vol.20. 1880.

77. Sedgwick............... On the structure known
as the glomerulus of
the Head Kidney of the
chick.
Quart. J. Micr. Sc.
Vol.20. 1880.

78. Seng.................. Wien Sitzungsberichte.
Bd. 64. 1873.

79. Spengel.............. Das Urogenitalsystem der
                         Amphibien. Arbeiten
                         aus dem Zool-Zoot.
                         Institut. Wurzburg.
                         Bd. 3. 1876-77.

80. Stewart Sir T. Grainger. Bright's diseases of the
                         Kidney 1868-71.

81. Stewart Sir T. Grainger Bright's Disease.
                         Quains dict. Med.

82. Still.................Congenital cystic liver
                         with cystic kidneys.
                         Trans. Path. Soc. Lond.
                         Vol. 49. 1898.

83. Thayssen..............Die Entwickelung der
                         Niere. Centralblatt
                         f. d. med. Wissen. 1873.

84. Toldt................ Untersuchungen über das
                         Wachsthum der Niere des
                         Menschen und der
                         Saugethiere.
                         Wien Sitzungsb. 1874.

85. Valentin............. Handbuch der Entwickel-
                         ungsgeschichte des
                         Menschen. Leipzig. 1835.

86. Virchow R. .... Gesammelte Abhandlungen.

87. Waldeyer..............Eierstock und Ei.
                         Leipzig. 1870.

88. Welch................ Trans. Assoc. Amer.
                         Phys. 1886.