Microscopic Observations on Secreting Structures: Insights from Goodsir

As Presented to the University of Edinburgh and the Anatomical Museum

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Microscopic anatomy has significantly advanced our understanding of biological processes, particularly secretion. Early observations by Malpighi, Müller, Schwann, and others laid the groundwork for our knowledge of glandular structures and their functions. However, it was Goodsir's meticulous microscopic observations that brought about a more nuanced understanding of the primary secreting cells and their roles in various glands. This compilation delves into Goodsir's detailed findings on secreting structures, emphasising his contributions to the study of nucleated cells in different glandular tissues and their secretion processes.

Historical Context and Early Contributions

The study of glandular structures has a rich history, with Marcello Malpighi being the first to propose that secreting glands are composed of tubular structures with blind extremities. Johannes Muller's extensive research further refined this concept, bringing it to a relatively advanced state. The hypothesis that the epithelium of mucous membranes might act as secreting organs, suggested by Theodor Schwann, and Friedrich Gustav Jakob Henle's detailed descriptions of epithelial cells lining glandular ducts, laid the groundwork for Goodsir's pioneering work. However, Goodsir's observations went beyond merely describing structures; he identified the role of nucleated cells in secretion, providing a clearer picture of how secretions are formed and released.

Goodsir's Observations on Secreting Structures

The Ink-Bag of Loligo Sagittata

In the ink-bag of Loligo sagittata, Goodsir noted that the membrane lining the secreting portion is composed almost entirely of nucleated cells filled with a dark fluid resembling ink. These cells were spherical or ovoidal, with composite nuclei and a dark-brown fluid between the nuclei and the cell walls. Goodsir's careful documentation of these cells illustrated that the secretion process involves the accumulation of ink-like fluid within the cells, making them turgid and giving them their characteristic colour.

The Liver of *Helix Aspersa*

Goodsir's examination of the liver of *Helix aspersa* revealed a similar structure, with the terminal extremities of the liver ducts containing nucleated cells. Each cell had a nucleus with smaller cells inside, surrounded by a fluid similar to bile. This fluid contained oil-globules, demonstrating the presence of a secretion process within the nucleated cells. This observation was significant in establishing that bile production occurs within these cells before being released into the ducts.

Other Glandular Structures

Goodsir extended his observations to various other species and glandular structures, including the hepatic organs of mollusks and echinoderms. In each case, he found that nucleated cells play a crucial role in the secretion process. For instance, in the gastric glands of *Uraster rubens*, Goodsir identified nucleated cells with a dark-brown fluid, presumed to be bile. Similarly, in the liver of *Modiola vulgaris* and the gastrohepatic pouches of *Pecten opercularis*, he observed nucleated cells filled with bile-like fluids. These consistent findings across different species underscored the universality of the secretion process within nucleated cells.

The Role of Primary Secreting Cells

Goodsir proposed that the primary secreting cell is the ultimate secreting structure, consisting of a nucleus, cell-wall, and cavity. The nucleus acts as the generative organ, possibly developing into young cells, while the cavity retains the secretion until it is discharged. He further suggested that these cells are endowed with specific properties according to the gland in which they are situated, explaining why different cells produce different substances such as bile or milk.

Functional Insights and Physiological Implications

Goodsir's work provided significant insights into the functional aspects of secretion. He demonstrated that growth and secretion are not distinct processes but are regulated by the same laws. Secretion occurs when the primary secreting cell, distended with its specific secretion, bursts or dissolves, releasing its contents into the ducts or onto gland surfaces. This understanding resolved longstanding physiological puzzles, such as why secretions are only released on the free surfaces of gland ducts or membranes. Goodsir's explanation that secretion is formed and released by the superficial bursting of nucleated cells removed the mystery surrounding this selective process.

Observations on Specific Glands

The Testicle of *Squalus Cornubicus*

In his detailed study of the testicle of *Squalus cornubicus*, Goodsir observed the development stages of the vesicles within the gland. Starting from a single nucleated cell, the vesicles undergo several stages of development, ultimately leading to the formation of spermatozoa. Goodsir's observations highlighted the progressive nature of these changes, from simple nucleated cells to complex spiral filaments, illustrating the intricate processes underlying sperm production.

Hepatic Structures in Various Species

Goodsir's observations extended to the hepatic structures of various species, including the caeca of Crustacea and the follicles of other marine organisms. He noted that each follicle or caecum contains nucleated cells at different stages of development, from primitive nucleated cells to primary secreting cells filled with bile or other secretions. These findings supported his hypothesis that secretion is an integral part of the growth process, governed by the same developmental laws as other cellular structures.

The following is Goodsir's work viz.

"Secreting Structures

Malpighi was the first to announce that all secreting glands are essentially composed of tubes, with blind extremities.[1] Muller, by his laborious researches, has brought this department of the anatomy of glands to its present comparatively perfect condition.[2] Schwann suggested that the epithelium of the mucous membranes might be the secreting organ of these surfaces.[3] Henle described minutely the epithelium-cells which line the ducts of the principal glands and follicles, but did not prove that these are the secreting organs. The same anatomist has stated that the terminal extremities of certain gland-ducts are closed vesicles, within which the secretion is formed, and which contain nucleated cells. Henle has not, therefore, verified the hypothesis of Purkinje, although he is correct in stating that the terminal vesicles of certain gland-ducts are closed.[4] It will be shown, that the secretion is not formed, as Henle has asserted, in the closed vesicles, but in the nucleated cells themselves.

The discrepant observation of Boehm[5] and Krause[6] on the glands of Peyer, were in some measure reconciled by Henle, who referred them to the same class of structures as the closed vesicular extremities of the ducts of compound glands. Dr. Allen Thomson has observed, that the primitive condition of the gastric and intestinal gland is a closed vesicle.[7] Wasmann described the structure of the gastric glands in the pig; and his description will be fully explained by the following observations and views.[8] Hallman has given a detailed account of the testicle of the ray.[9] which closely resembles that of the *Squalus cornubicus*, as described in another part of this chapter. None of the recent observations on the development of the spermatozoa have proved that the vesicles, in which they are formed, are the epithelium-cells of the ducts of the testicle. I am indebted to Dr. Allen Thomson for directing my attention to a notice in Valentin's *Repertorium*, 1841, of a Dissertation by Erdl,[10] in which he describes, in the kidney of that mollusc, cells, the nuclei of which pass out by the duct of the gland. It does not appear, however, that Erdl had discovered the uric acid within the cell.[11]

If the membrane which lines the secreting portion of the internal surface of the ink-bag of *Loligo sagittata* (Lamark) be carefully freed from adhering secretion by washing, it will be found to consist almost entirely of nucleated cells, of a dark-brown or black colour. These cells are spherical or ovoidal. Their nuclei consist of cells, grouped together in a mass. Between these composite nuclei, and the walls of their containing cells, is a fluid of a dark-brown colour. This fluid resembles, in every respect, the secretion of the ink-bag itself. It renders each cell prominent and turgid, and is the cause of its dark colour.

The dilated terminal extremities of the ducts in the liver of *Helix aspersa* (Muller) contain a mass of cells. If one of these cells be isolated and examined, it presents a nucleus consisting of one or more cells. Between the nucleus and the wall of the containing cell is a fluid of an amber tint, and floating in this fluid are a few oil-globules. This fluid differs in no respect from the bile, as found in the ducts of the gland.

If a portion of the ramified glandular organ which opens into the fundus of the stomach of *Uraster rubens* (Agassiz) be examined, its internal surface is found to be lined with cells; between the nucleus of each of which and the wall of the cell itself a dark-brown fluid is situated. The organ secretes a fluid, supposed to be of the nature of bile.

The dark-brown ramified caeca of the same animal exhibit on their internal surfaces an arrangement of nucleated cells, the cavities of which contain a brown fluid. These caeca are also supposed to perform, or to assist in the performance of, the function of the liver.

The liver of *Modiola vulgaris* (Fleming) contains masses of spherical cells. Between the nucleus and the wall of each of these cells a light-brown fluid is situated, bearing a close resemblance to the bile in the gastro-hepatic pouches.

The nucleated cells which are arranged around the gastrohepatic pouches of the *Pecten opercularis* are irregular in shape, and distended with a fluid resembling the bile.

The hepatic organ, which is situated in the loop of intestine of *Pirena prunum* (Fleming), consists of a mass of nucleated cells. These cells are collected in groups, in the interior of larger cells or vesicles. These nucleated cells are filled with a light-brown bilious fluid.

The hepatic organ, situated in the midst of the reproductive apparatus, and in the loop of the intestine of *Phallmia vulgaris* (Forbes and Goodsir), consists of a number of vesicles, and each vesicle contains a mass of nucleated cells. These cells contain a dark-brown bilious fluid.

The hepatic organ in the neighbourhood of the stomach, in each of the individuals of the compound mollusc, the *Alpidium ficus* (Linnaeus), consists of nucleated cells, which contain in their cavities a reddish-brown fluid.

The liver of *Loligo sagittata* (Lamark) contains a number of nucleated cells, ovoidal and kidney-shaped. These cells are distended with a brown bilious fluid.

The nucleated cells in the liver of *Aplysia punctata* (Cuvier) are full of a dark-brown fluid.

The ultimate vesicular caeca of the liver of *Buccinum undatum* contain ovoidal vesicles of various sizes. These vesicles contain more or less numerous nucleated cells. The cells are full of a dark-brown fluid.

The hepatic caeca in the liver of *Patella vulgata*. Each of these vesicles encloses a body, which consists of a number of nucleated cells, full of a dark fluid resembling the bile.

The simple biliary apparatus which surrounds the gastric portion of the intestinal tube of *Nereis* contains nucleated cells, full of a light-brown fluid.

The hepatic caeca of *Carcinus moenas* contains cells full of a fluid of an ochrey colour, along with numerous oil-globules.

The hepatic caeca of *Carabus catenulatus* (Fabricius) contain cells attached to their internal surfaces. Between the nuclei and the cell-walls a brown liquid containing numerous granules is situated.

The kidney of *Helix aspersa* (Muller) is principally composed of numerous transparent vesicles. In the centre of each vesicle is situated a cell full of a dead white granular mass. This gland secretes pure uric acid.

The ultimate elements of the human liver are nucleated cells. Between the nucleus and the cell-wall is a light-brown fluid, with one or two oil-globules floating in it.

The vesicular caeca in the testicle of *Squalus cornubicus* contain nucleated cells, which ultimately exhibit in their interior bundles of spermatozoa.

The generative caeca of *Echiurus vulgaris* (Lamark) contain cells full of minute spermatozoa.

Aplysia punctata secretes from the edge and internal surface of its mantle a quantity of purple fluid. The secreting surface of the mantle consists of an arrangement of spherical nucleated cells. These cells are distended with a dark purple matter.

The edge and internal surface of the mantle of *Janthina fragilis* (Lamark), the animal which supplied the Tyrian dye, secretes a deep bluish-purple fluid. The secreting surface consists of a layer of nucleated cells, distended with a dark purple matter.

If an ultimate acinus of the mammary gland of the bitch be examined during lactation, it is seen to contain a mass of nucleated cells. These cells are generally ovoidal, and rather transparent. Between the nucleus and the cell-wall of each a quantity of fluid is contained, and in this fluid float one, two, three, or more oil-like globules, exactly resembling those of the milk.

In addition to the series of examples already given, I might adduce many others to prove that secretion is a function of the nucleated cell. Some secretions, indeed, are so transparent and colourless, as to render ocular proof of their original formation within cells impossible; and we are not yet in possession of chemical tests sufficiently delicate for the detection of such minute quantities. The examples I have selected, however, show that the most important and most striking secretions are formed in this manner. The proof of the universality of the fact, in reference to the glandular structures which produce colourless secretions, can only rest at present on the identity of the anatomical changes which occur in their cellular elements. This part of the proof I shall enter upon in another part of this chapter.

The secretion within a primitive cell is always situated between the nucleus and the cell-wall, and would appear to be a product of the nucleus.[12]

The ultimate secreting structure, then, is the primitive cell, endowed with a peculiar organic agency, according to the secretion it is destined to produce. I shall henceforward name it the primary secreting cell. It consists, like other primitive cells, of three parts the nucleus, the cell-wall, and the cavity. The nucleus is its generative organ, and may or may not, according to circumstances, become developed into young cells. The cavity is the receptacle in which the secretion is retained till the quantity has reached its proper limit, and till the period has arrived for its discharge.

Each primary secreting cell is endowed with its own peculiar property, according to the organ in which it is situated. In the liver it secretes bile in the mamma, milk, etc.

The primary secreting cells of some glands have merely to separate from the nutritive medium a greater or less number of matters already existing in it. Other primary secreting cells are endowed with the more exalted property of elaborating from the nutritive medium matters which do not exist in it.

The discovery of the secreting agency of the primitive cell does not remove the principal mystery in which this function has always been involved. One cell secretes bile, another milk; yet the one cell does not differ more in structure from the other than the lining membrane of the duct of one gland from the lining membrane of the duct of another. The general fact, however, that the primitive cell is the ultimate secreting structure, is of great value in physiological science, inasmuch as it connects secretion with growth, as phenomena regulated by the same laws. The force, of whatever kind it may be, which enables one primary formative cell to produce nerve and another muscle, by an arrangement within itself of the common materials of nutrition, is identical with that force which enables one primary secreting cell to distend itself with bile, and another with milk.

Instead of growth being a species of imbibing force, and secretion on the contrary a repulsive the one centripetal, the other centrifugal they are both centripetal. Even in their later stages the two processes, growth and secretion, do not differ. The primary formative cell, after becoming distended with its peculiar nutritive matter, in some instances changes its form according to certain laws, and then, after a longer or shorter period, dissolves and disappears in the intercellular space in which it is situated, its materials passing into the circulating system if it be an internal, and being merely thrown off if it be an external cell. The primary secreting cell, again, after distension with its secretion, does not change its form so much as certain of the formative cells, but the subsequent stages are identical with those of the latter. It bursts or dissolves, and throws out its contents either into ducts or gland-cavities, both of which, as I shall afterwards show, are intercellular spaces, or from the free surface of the body.

The general fact of every secretion being formed within cells, explains a difficulty which has hitherto puzzled physiologists viz. why a secretion should only be poured out on the free surface of a gland-duct or secreting membrane.

'Why,' says Professor Muller, 'does not the mucus collect as readily between the coats of the intestine as exude from the inner surface? Why does not the bile permeate the walls of the biliary ducts, and escape on the surface of the liver, as readily as it forces its way outwards in the course of the ducts? Why does the semen collect on the inner surface only of the tubuli seminiferi, and not on their exterior, in their interstices? The elimination of the secreted fluid on one side only of the secreting membrane viz. on the interior of the canals is one of the greatest enigmas in physiology.'

Muller proceeds to explain this enigma by certain hypotheses; but the difficulty disappears, the mystery is removed, when we know that the secretion only exists in the interior of the ripe cells of the free surface of the ducts or membrane, and is poured out or eliminated simply by the bursting and solution of these superficial cells.

I have hitherto confined my observations to the structure and function of the ultimate secreting element, the primary secreting cell. I now proceed to state the laws which I have observed to regulate the original formation, the development, and the disappearance of the primary organ. This subject necessarily involves the description of the various minute arrangements of glands and other secreting structures.

If the testicle of *Squalus cornubicus* (Gmelin) be examined when the animal is in a state of sexual vigour, the following arrangements of structure present themselves: -

The gland consists of a number of lobes separated, and at the same time connected, by a web of filamentous texture, in which ramify the principal blood-vessels.

The lobes, when freed from this tunic, present on their surface a number of vesicles. When the gland is dissected under water, and one of the lobes is raised out of its capsule, an extremely delicate duct is observed to pass from it into the substance of the capsule, to join the ducts of the other lobes.

When a section is made through one of the lobes, it becomes evident that the vesicles are situated principally on its exterior.

If a small portion be macerated in water for a few hours, and dissected with a couple of needles, there are observed attached to the delicate ducts which ramify through the lobe vesicles in all stages of development. These stages are the following: *1st*, A single nucleated cell attached to the side of the duct, and protruding, as it were, its outer membrane.

2d, A cell containing a few young cells grouped in a mass within it; the parent cell presenting itself more prominently on the side of the duct.

3d, A cell attached by a pedicle to the duct, the pedicle being tubular, and communicating with the duct; the cell itself being pyriform, but closed and full of nucleated cells.

4th, Cells larger than the last, assuming more of a globular form, still closed, full of nucleated cells, and situated more towards the surface of the lobe.

5th, The full-sized vesicles already described as situated at the surface of the lobe. These vesicles are spherical, perfectly closed; that part of the wall of each which is attached to the hollow pedicle forms a diaphragm across the passage, so that the vesicle has no communication with the ducts of the gland. The contents of the vesicles are in various stages of development. Those least advanced are full of simple nucleated cells; in others, the included cells contain young cells in their interior, so that they appear granular under low powers; in others, the included cells have begun at a certain part of the vesicle to elongate into cylinders, with slightly rounded extremities. In others the cylindrical elongation has taken place in all the included cells, with the exception of a few, which still retain the rounded form, at a spot opposite to that part of the vesicle in which the change commenced; and at the same time, it may be observed, that the cylindrical cells have become arranged in a spiral direction within the parent vesicle. *Lastly*, Vesicles exist in which all the cells are cylindrical, and are arranged within its cavity in a spiral direction.

The changes which occur in the included nucleated cells of the vesicle are highly interesting. After the nucleus of each has become developed into a mass of cells, the parent cell becomes, as has been stated, cylindrical. The change in the shape of the cell is contemporaneous with the appearance of a spiral arrangement of the included mass of cells. This spiral arrangement is also contemporaneous with an elongation of each cell in the mass, in the direction of the axis of the parent cell. When the elongation has reached its maximum, the original mass of included cells has assumed the appearance of a bunch of spirals, like corkscrews arranged one with another, spiral to spiral. In particular lights the cylindrical cell presents alternate spots of light and shade, but by management of the illumination, the included spiral filaments become evident; the light and shade are seen to arise from the alternate convexities and concavities of the spiral filaments, combined in a spiral bundle.

In vesicles more advanced, the wall of the cylindrical cells has become attenuated.

In other vesicles the diaphragms across their necks have dissolved or burst, the bundles of spiral filaments float along the ducts of the gland, or separate into individual spiral filaments. These filaments are completely developed spermatozoa, pointed and filamentous at both extremities, thicker and spiral in the middle.

In the centre of the lobe, where the smaller ducts meet to form the principal duct, there is a mass of grey gelatinous matter through which the ducts pass. This gelatinous matter consists of a number of cells lying between the converging ducts, and from their peculiar appearance not presenting the usual nuclei. I am inclined to believe that they are either vesicles which have never become developed on account of the pressure of the surrounding parts, or that they are old vesicles in a state of atrophy after the expulsion of their contents.

Having now described the changes which are constantly taking place in the testicle of this shark when the organ is in a state of functional activity, I must defer till a future occasion an account of similar changes which occur in the parenchyma of an order of glands, of which the one already described may be considered as a type. I may state, however, that I have ascertained the following general facts in reference to glands of this order: -

1st, The glandular parenchyma is in a constant state of change, passing through stages of development, maturity, and atrophy.

2d, The state of change is contemporaneous with, and proportional to, the formation of the secretion, being rapid when the latter is profuse, and *vice versa*.

3d, There are not, as has hitherto been supposed, two vital processes going on at the same time in the gland, growth and secretion, but only one viz. growth. The only difference between this kind of growth and that which occurs in other organs being, that a portion of the product is, from the anatomical condition of the part, thrown out of the system.

4th, The vital formative process which goes on in a gland is regulated by the anatomical laws of other primitive cellular parts.

5th, An acinus is at first a single nucleated cell. From the nucleus of this cell others are produced. From these, again, others rise in the same manner. The parent cell, however, does not dissolve away, but remains as a covering to the whole mass, and is appended to the extremity of the duct. Its cavity, therefore, as a consequence of its mode of development, has no communication with the duct.

The original parent cell now begins to dissolve away, or to burst into the duct at a period when its contents have attained their full maturity. This period varies in different glands, according to a law or laws peculiar to each of them.

6th, In the gland there are a number of points from which acini are developed, as from so many centres. These I name the germinal spots of the gland.

7th, The secretion of a gland is not the product of the parent cell of the acinus, but of its included mass of cells. The parent cell or vesicle may be denominated the primary cell; its included nucleated cells, after they have become primary secreting cells, may be named secondary cells of the acinus.

8th, There are three orders of secretions: (1.) A true secretion that is, matter formed in the primary secreting cell-cavities; or, (2.) A mixture of a fluid formed in these cell-cavities with the developed or undeveloped nuclei of the cells themselves; and, (3.) It may be a number of secondary cells passing out entire.

In the liver of *Carcinus moenas*, and other Crustacea, it may be observed, that each of the follicles of which it consists presents the following structure: The blind extremity of the follicle is slightly pointed, and contains in its interior a mass of perfectly transparent nucleated cells. From the blind extremity downwards, these cells appear in progressive states of development. At first they are mere primitive nucleated cells; further on they contain young cells; and beyond this they assume the characters of primary secreting cells, being distended with yellow bile, in which float oil-globules, the oil in some instances occupying the whole cell. Near the attached extremity of the follicle an irregular passage exists in the midst of the cells, and allows the contents of the cells which bound it to pass on to the branches of the hepatic duct.

This arrangement of the secreting apparatus may be taken as the type of an order of glands, which consist of follicles more or less elongated. Growth in glands of this kind is regulated by the following laws: -

1st, Each follicle is virtually permanent, but actually in a constant state of development and growth.

2d This growth is contemporaneous with the function of the gland, that function being merely a part of the growth, and a consequence of the circumstances under which it occurs.

3d, Each follicle possesses a germinal spot situated at its blind extremity.

4th, The vital action of some follicles is continuous, the germinal spot in each never ceasing to develope nucleated cells, which take on the action of and become primary secreting cells, as they advance along the follicle. The action of other follicles is periodical.

5th, The wall, or germinal membrane of the follicle, is also in a state of progressive growth, acquiring additions to its length at its blind extremity, and becoming absorbed at its attached extremity. My brother, in a paper on the 'Development and Metamorphoses of *Caligus*' read in the Wernerian Society, April 1842, has stated that the wall of the elongated and convoluted follicle, which constitutes the ovary in that genus, grows from its blind to its free extremity, at the same rate as the eggs advance in development and position. A progressive growth of this kind would account for the steady advance of its attached contents, and would also place the wall of the follicle in the same category with the primary vesicle, germinal membrane, or wall, of the acinus in the vesicular glands.

6th, The primary secreting cells of the follicle are not always isolated. They are sometimes arranged in groups, and when they are so each group is enclosed within its parent cell, the group of cells advancing in development according to its position in the follicle, but never exceeding a particular size in each follicle.

In my original memoir, I stated my opinion that there is an order of glands namely, those with very much elongated ducts which do not possess germinal spots in particular situations, but in which these spots are diffused more uniformly over the whole internal surface of the ducts. The human kidney is a gland of this order.[13]

We require renewed observations on the original development of glands in the embryo. From the information we possess, however, it appears that the process is identical in its nature with the growth of a gland during its state of functional activity.

The blastema, which announces the approaching formation of a gland in the embryo, in some instances precedes, and is in other instances contemporaneous with, the conical blind protrusion of the membrane upon the surface of which the future gland is to pour its secretion.

In certain instances, it has been observed that the smaller branches of the duct are not formed by continued protrusion of the original blind sac, but are hollowed out independently in the substance of the blastema, and subsequently communicate with the ducts.

It appears to be highly probable, therefore, that a gland is originally a mass of nucleated cells, the progeny of one or more parent cells; that the membrane in connection with the embryo gland may or may not, according to the case, send a portion of the membrane, in the form of a hollow cone, into the mass; but whether this happens or not, the extremities of the ducts are formed as closed vesicles, and then nucleated cells are formed within them, and are the parents of the epithelium cells of the perfect organ.

Dr. Allen Thomson has ascertained that the follicles of the stomach and large intestine are originally closed vesicles.

This would appear to show that a nucleated cell is the original form of a follicle, and the source of the germinal spot which plays so important a part in its future actions. The ducts of glands are, therefore, intercellular passages. This is an important consideration, inasmuch as it ranges them in the same category with the intercellular passages and secreting receptacles of vegetables.[14]

Since the publication of my paper on the secreting structures, in the *Transactions of the Royal Society of Edinburgh* in 1842, I have satisfied myself that I was in error in attributing to the cell-wall the important function of separating and preparing the secretion contained in the cell-cavity. The nucleus is the part which effects this. The secretion contained in the cavity of the cell appears to be the product of the solution of successive developments of the nucleus, which in some instances contains in its component vesicles the peculiar secretion, as in the bile-cells of certain Mollusca, and in others becomes developed into the secretion itself, as in seminal cells. In every instance, the nucleus is directed towards the source of nutritive matter, the cell-wall is opposed to the cavity into which the secretion is cast. This accords with that most important observation of Dr. Martin Barry, on the function of the nucleus in cellular development.

I have also had an opportunity of verifying, and to an extent which I did not at the time fully anticipate, the remarkable vital properties of the third order of secretions, referred to in the memoir to which I have just alluded. The distinctive character of secretions of the third order is, that when thrown into the cavity of the gland, they consist of entire cells, instead of being the result of the partial or entire dissolution of the secreting cells. It is the most remarkable peculiarity of this order of secretions that, after the secreting cells have been separated from the gland, and cast into the duct or cavity, and therefore no longer a component part of the organism, they retain so much individuality of life, as to proceed in their development to a greater or less extent in their course along the canal or duct, before they arrive at their full extent of elimination.

The most remarkable instance of this peculiarity of secretions of this order, is that discovered by my brother, and recorded by him in a succeeding chapter.[15] He has observed that the seminal secretion of the decapodous crustaceans undergoes successive developments in its progress down the duct of the testis, but that it only becomes developed into spermatozoa after coitus, and in the spermatheca of the female. He has also ascertained that, apparently for the nourishment of the component cells of a secretion of this kind, a quantity of albuminous matter floats among them, by absorbing which they derive materials for development after separation from the walls of the gland.

This albuminous matter he compares to the substance which, according to Dr. Martin Barry's researches, results from the solution of certain cells of a brood, and affords nourishment to their survivors. It is one of other instances in which cells do not derive their nourishment from the blood, but from parts in their neighbourhood which have undergone solution; and it involves a principle which serves to explain many processes in health and disease, some of which have been referred to in other parts of this work.

I conclude, therefore, from the observations which I have made *1st*, That all the true secretions are formed or selected by a vital action of the nucleated cell, and that they are first contained in the cavity of that cell; *2d*, That growth and secretion are identical the same vital process, under different circumstances.[16] [17]

Conclusion

Goodsir's microscopic observations profoundly advanced our understanding of glandular structures and their functions. By establishing the role of nucleated cells in secretion, he provided a unifying explanation for the formation and release of various secretions across different species and glandular tissues. The work bridged the gap between growth and secretion, demonstrating that both processes are regulated by similar laws of cellular development. Goodsir's findings continue to influence modern physiology, highlighting the importance of detailed microscopic examination in uncovering the fundamental mechanisms of biological processes.

[1] *Exercitationes de Structura Viscerum*, 1665.
[2] J. Muller, *De Gland. Struct. Penit*. 1830.
[3] *Froriep. Notiz*. 1838.
[4] Muller's *Archiv*, 1838, 1839.
[5] *De Gland. Intestin. Struct. Penit*. 1835.
[6] Muller's *Archiv*, 1837.
[7] *Proceedings of the British Association*, 1840.
[8] *De Digestions Nonnulla*, Diss. manq. Berol. 1839.
[9] Muller's *Archiv*, 1840.
[10] *De Helicis Algirae vasis sanguiferis*, 1840.
[11] Mr. Bowman has shown that the fat in the fatty liver is contained in the secreting cells. *Observations on the Minute Structure of the Fatty Degeneration of the Liver*, January 1842.
[12] In the original Memoir the cell-wall is stated to be the probable secreting structure. "Now, as we know that the nucleus is the reproductive organ of the cell that it is from it, as from a germinal spot, that new cells are formed. I am inclined to believe that it has nothing to do with the formation of the secretion. I believe that the cell-wall itself is the structure, by the organic action of which each cell becomes distended with its peculiar secretion, at the expense of the ordinary nutritive medium which surrounds it." *Trans. Roy. Soc. Edin*. 1842.
[13] "I am the more inclined to believe this, from what I have observed in certain secreting membranes. Thus, the membranes which secrete the purple in *Aplysia* and *Janthina* are not covered with a continuous layer of purple secreting cells; but over the whole surface, and at regular distances, there are spots, consisting of transparent, colourless, nucleated cells, around which the neighbouring cells become coloured. Are these transparent cells the germinal spots of these secreting membranes? And may not the walls of the elongated tubes, and the surfaces of the laminae within certain glands, have a similar arrangement of germinal spots?" *Trans. Roy. Soc. Edin*. 1842.
[14] Henle, in his *General Anatomy*, has made a similar statement.
[15] See page 429.
[16] In Mr. Bowman's elaborate Paper "On the Structure and Use of the Malpighian Bodies of the Kidney," read in the Koyal Society of London, 17th February 1842, and in his Article "Mucous Membrane," in the *Cydopaedia of Anatomy*, written in December 1841, certain parts of the theory of secretion are well elucidated by a reference to human structure. In my own Memoir, read in the Royal Society of Edinburgh, 30th March 1842, I endeavoured, by an appeal to facts in comparative anatomy, to establish secretion as a function of the nucleated cell, and to show that glandular phenomena are only the changes which the cellular elements of these organs undergo. Mr. Bowman's own observation on the secretion of fat by the cells of the human liver in a state of disease was an important and positive result; and Professor John Reid, with whom I had frequent conversations on the subject of secretion, and to whom I had communicated my views on the subject a year before the publication of my Paper, was in the habit of supporting Purkinje and Schwann's hypothesis, by an appeal to the structure of *Molluscum contagiosum*, as described by Professor Henderson and Dr. Paterson in the *Edinburgh Medical and Surgical Journal*, 1841.
[17] Turner, William (ed.) and Lonsdale, Henry (contrib.). *The Anatomical Memoirs Of John Goodsir F.R.S. Late Professor Of Anatomy In The University Of Edinburgh, Volume II* (Edinburgh: Adam and Charles Black, 1868): 412-428.