so derived might possibly blight the fœtus and blanch the mother; and, if frequently repeated, might even cause abortion.[1]

But it is at least equally probable that the discharges to which Hippocrates alludes had the same pathological cause as those which occurred in the above case. Accepting this explanation, the strict accuracy of the statements contained in these passages, from the Hippocratic Writings, will be readily admitted. For, at every period, part of the ovum would be detached from the uterine walls, and injury to the fœtus from diminution of its maternal connections would ensue; and, as it is not likely that these connections could be re-established by any subsequent process, it is evident that, if a fresh partial separation took place every month, the fœtus would perish by asphyxia, and abortion would be the result.

The periodicity with which spurious menstruation sometimes occurs might appear inconsistent with this explanation, but it is not really so; for it seems to be established that, during pregnancy, at what would otherwise be the menstrual periods, there occurs a congestive state of the uterus and appendages, predisposing to partial separations of the membranes or placenta. And it is well known that women are most liable to abort at these times.[2]

Article III.—*Starch as a Constituent of the Animal Organism.* By T. A. Carter, M.D.

It may be remembered that in the August number of this Journal for 1855 I called attention to the "extensive diffusion and frequency of starch corpuscles in the tissues of the human body," by means of a number of observations made upon the solids and fluids of thirteen different individuals who had died of various disorders. I also examined the tissues of some of the lower animals which were perfectly healthy, and found that these also contained what I considered to be grains of starch, in greater or less abundance. From a consideration of these facts, I was led to conclude that starch is a physiological product of the animal organism, and then proceeded to assign to it the possible function which it performs in the economy.

Since that time, nothing has, in this country, so far as I am aware, been written corroborative either of the facts or theories contained in that communication; and as some authorities have expressed strong doubts, if they have not actually denied, that the corpuscles found in animals, and described as starch, are identical with that substance, I consider it a duty to incite, as far as lies within my power, those interested in the advancement of science, and the establishment of truth, to institute a practical examination of the subject.

[1] Bennet, *On Ulceration and Induration of the Neck of the Uterus*, second edition, pp. 212 to 221.
Tyler Smith *On the Theory and Practice of Obstetrics*, *Lancet* for March 8, 1856, p. 251. Whitehead *On Abortion*, p. 223.

[2] Tyler Smith, *Op cit.*, *Lancet* for March, 1856, pp. 251, 276.

It is not at all surprising that persons who have not devoted particular attention to this matter, should be somewhat incredulous as to the accuracy of the novel, and perhaps somewhat startling, statements made in my former paper; for it must be confessed that, at the commencement of the investigation, upon discovering the granules in every organ which was examined, I was induced to think that the materials had in some unknown way become contaminated with vegetable substances; and it was not until I had taken measures to avoid every conceivable source of error,—until I had changed the place of examination, and employed the instruments and re-agents of others, that I became fully persuaded of their correctness. Although on a previous occasion it did not appear to me desirable to enter into a detailed exposure of the properties of the corpuscles, and of the means and methods employed in demonstrating them, I have since become convinced that, in making statements which are capable of being verified by experiment, the practice should invariably be observed, so as to place the investigator on an equal footing with the author, and thus allow him with the least amount of labour to arrive at a true estimate of the recorded observations. I shall now, therefore, without further preamble, proceed to the description of certain bodies discoverable in the textures of animals; leaving the reader to judge whether the evidence is sufficient to support the opinion, which I entertain in common with Mr Busk and some others, as to their being corpuscles of starch.

The corpuscles to which allusion has just been made, are solid, colourless, transparent, and highly refractile, possessing an external wall or envelope of variable thickness,—this being comparatively greater in some of the small than in the large bodies. In shape, as in some other points to be presently noticed, there are differences such as to justify a division into two varieties. In the one, the ovoidal, or nearly spherical, appears to be the typical form; in the other, the oblate spheroid, or extremely compressed ovoid,—although some belonging to this class are so irregular in outline as entirely to baffle description.

The former possess either a punctate, linear, or stellate hilum, situated near one extremity (if ovoidal), surrounded by a series of concentric ellipsoidal markings. These corpuscles exhibit, under polarized light, four equidistant black radii diverging from the hilum, around which point, as an axis, they rotate, when rotatory motion is communicated to the polarizing apparatus.

The latter, and more common variety, seldom exhibits the concentric markings; but in the centre of the corpuscles is occasionally to be seen the shadowy outline of something resembling a nucleus: I say resembling, because I do not believe it to be such in reality, seeing that, when this pseudo-body is present, no sharp limitation of its wall can in most instances be made out, and because it, together with the other corpuscular contents, dissolve and disappear when acted upon by dilute sulphuric acid,—this indicating, in all probability, their

uniformity of composition, and consequently an incompatibility with the properties of a nucleus. A large number of these bodies do not appear to possess any hilum, unless the appearance just described be considered as such; in some, however, it is indicated by a minute superficial spot, or a linear fold situated on their margins.

Polarized light affects this variety, but not in so striking a manner as the other. Many corpuscles will, however, exhibit the black cross, if care be taken to render the field of the microscope perfectly black, and to exclude from the eye all rays of light which have not passed through the body of the instrument.

At times corpuscles are to be met with whose contents are of a more or less granular aspect, and whose exterior surface is undulated and irregular, looking flaccid, and as if partially emptied of their originally included matters.

The subjoined remarks are of equal applicability to either kind. The variation in their dimensions is very considerable, as observed in the same, or in different subjects; some descending to less than the 1-12,000th of an inch, while others attain to a size discernible by unassisted vision, reaching to the 1-195th of an inch in diameter. Those, however, usually encountered are of a size intermediate between the 1-500th and the 1-1000th of an inch in diameter. A large number, when subjected to pressure, fissure readily without undergoing any lateral expansion; others are evidently elastic to some extent, and capable of being very much flattened and extended before laceration takes place. In contact with an aqueous solution of iodine, they assume either a blue, blue-purple, purple, or sometimes even a reddish purple, or lilac colour,—the tints varying, from some unknown cause, as in the vegetable starches. When iodized and allowed to dry, their colour passes from those just mentioned to reddish brown. Sulphuric acid causes them to swell up to several times their original bulk,—their envelopes remaining entire for some time, unless the acid be too concentrated. By the continued action of it, however, they are at length entirely dissolved.

It is almost unnecessary to mention that the two kinds of corpuscles, which I have attempted to describe, correspond with two varieties met with in vegetables;—the one being identical with potato-starch, the other having the same characters as the starch of the ordinary cereals.[1] Now, notwithstanding very similar evidence

[1] I find that it is here necessary, in self-defence, to state what I consider to be the essential, as distinguished from the non-essential characters of a starch corpuscle, whether vegetable or animal; for the prevalent notions regarding them are perhaps somewhat more than vague, and appear to be derived from observations made exclusively upon the fecula of the potato.

Every starch corpuscle possesses the following essential and, taken in combination, diagnostic characters:—Solidity, transparency or translucency, absence of colour, the property of becoming blue or purple when acted on by simple aqueous solutions of iodine, and of being, in contact with dilute sulphuric acid, transformed into large, thin-walled, flaccid vesicles, which ultimately undergo complete solution. The non-essential characters are: the

to the preceding, which was brought forward by Busk, in order to prove that certain bodies found in the brain, and termed "amyloid," were nothing more than starch corpuscles, some authorities seem still unwilling to admit either the truth of his statements, or the legitimacy of his deductions. Thus Professor Virchow, in his paper on the Cellulose question,[1] says, "The corpora amylacea of the nerve substance exhibit a bluish, and those of the spleen, liver, and kidney, a yellowish red colour;" and then proceeds to remark, "Were this not the case, it would have been inconceivable how Donders and Busk should ever have thought of such a thing, as at once to declare them to be of the nature of starch." It would certainly have been a circumstance difficult of comprehension, had Mr Busk pronounced the splenic, hepatic, or renic "corpora amylacea" of Virchow (which give a yellowish red with iodine) to be starch corpuscles, as it would have been totally inconceivable how he could have arrived at any other conclusion, than that those which, in general appearance, resembled starch grains, which became blue on the simple addition of a solution of iodine, swelled up and dissolved when sulphuric acid was added, and gave with polarized light[2] a black cross, were any other than those of starch. In speaking of the corpora amylacea of the nervous centres (those of Virchow, which we are alone justified in considering as starch), this author says, "They have the concentrically striated structure, the comparatively strongly reflecting surface, the bluish colour on the simple addition of iodine, and lastly, their swelling in hot, and ultimate solution, although with chemical change, in boiling water,"—properties which I am inclined to suppose more characteristic of starch than of any other substance. The only apparent objection which has been raised, so far as I can discover, against such corpora amylacea of the brain being grains of starch, is comprised in the following sentence:—"Busk even says, what Donders and myself have been unable to perceive, that some of the smaller corpora amylacea exhibit, in polarized light, a sharply defined dark cross."[3] Those who have examined carefully, by means of the polariscope, the fecula of wheat, will at once perceive that this objection, if considered valid, carries with it not the slightest degree of force, from the fact, that many of these grains will not display the phenomenon under the circumstances intimated; and, indeed, according to the observations of Pereira, the starch of the common oat is totally devoid of this peculiarity. With all due deference to the observations of Professors Virchow and Donders, I must state as my conviction, that had there been instituted a more extended or differently conducted series of experiments upon this matter, they would have met with many corpuscles, not in the brain

form, the hilum, the concentric markings, and the exhibition of a black cross under polarized light.

[1] *Microscopic Journal*, July 1855, p. 285.

[2] *Microscopic Journal*, January 1854, p. 107.

[3] *Microscopic Journal*, July 1855, p. 288.

alone, but elsewhere, whose properties coincided with those mentioned by Busk. I have in my possession at the present time preparations of corpuscles presenting this optical peculiarity, which, owing to their great abundance in one human pancreas, were capable of being collected by a process of elutriation.

It now remains to be decided whether bodies endowed with the chemical and physical qualities attributed to them by Busk, can be reasonably supposed to consist of cellulose, as Professor Virchow seems to imagine. Although it is within the limits of possibility that this substance may, in the animal body, simulate very closely, or even assume the precise form of the starch granule,—although it may polarize light in the same manner, and strike a purple tint with iodine alone, as that found in certain fungi does,—these things, when taken separately, are not probable—still less so when taken in combination: then it is absolutely incredible that solid masses of cellulose are capable of being rapidly expanded into thin flaccid vesicles, when subjected to the influence of cold and dilute sulphuric acid. This phenomenon, we know, is determined partly by chemical, and partly by physical agency, immediately attributable to the acid penetrating the envelopes of the corpuscles, which for some time are scarcely affected by it, except in being perhaps rendered more distensible, and reducing their previously insoluble contents to a state of solubility,—thus rendering them amenable to the law of endosmose. It is remarkable that the sulphuric acid test, mentioned by Busk, should have been entirely overlooked by Professor Virchow,—a test of all the least susceptible of misinterpretation, and one which is, I believe, of itself sufficient to distinguish starch in a corpuscular form from any other bodies which are at present known.

Some remarks occur in the "Cellulose Question," with reference to the discrimination of cellulose and starch by means of the iodized chloride of zinc and iodized sulphuric acid, which I think may lead to some misconceptions, and therefore demand to be briefly commented upon in this place. Professor Virchow says,[1] "I perceive, with much astonishment, that in England many conceive that the amylaceous nature of the bodies is proved by this reaction,"—*i.e.* the production of a blue colour in contact with these re-agents. "This is altogether erroneous, for it is precisely this which is to be regarded as characteristic of cellulose." Now, although it is perfectly true that we are not justified in deciding bodies to be of an amylaceous nature by their becoming blue under the influence of the re-agents just mentioned, we have certainly as little right to conclude that they consist of cellulose, for both substances are similarly affected by them, as I have proved by experiment. If, indeed, in any texture we should discover bodies which will not, with a simple solution of iodine, assume a blue or purple tint until chloride of zinc or sul-

[1] *Microscopic Journal*, July 1855, p. 286.

phuric acid be added, we may then be allowed to conjecture, but not to affirm, that they consist of cellulose.

In illustration of what has just been said, and of the error of supposing that the blue reaction produced by the iodized chloride of zinc is "especially characteristic of cellulose," I will quote the words of the same author in relation to this test. "I had hoped that it would afford a new test by which to distinguish cholesterine; but it was soon apparent that it also induced a most beautiful blue colour with that substance, although very slowly."[1] As a further proof of the erroneousness of Virchow's statement, let me call attention to the following note, which will be found in my Inaugural Dissertation (p. 24), the facts contained in which I have since had opportunities of confirming.

"I may here advert to a circumstance which lately fell under my notice, when examining the urine of a patient in the Infirmary who was affected with Bright's disease, which shows how necessary it is to use additional means to those generally employed, in order to determine with certainty the presence of cellulose in any situation. The urinary secretion of this individual was highly albuminous, and contained a very abundant flocculent sediment, consisting of desquamative and fatty tube-casts, epithelia of the pavement and globular varieties, stringy mucus, nuclei, granules, and a large number of starch corpuscles. On the simple addition of iodine to the sediment, the starch grains assumed the usual purple tint, and some of the epithelial cells became of a bright yellow hue, while others were tinged of a peculiar reddish-brown colour. Thinking that these latter cells had undergone the so-called amyloid degeneration, I added a small quantity of sulphuric acid, to ascertain if they would pass from reddish-brown to blue; no difference in their tint, however, could be perceived after the expiration of twenty-four hours. While watching for the effects of the acid on the epithelium, I was surprised to observe a precipitation of an amorphous purple substance, small portions of which, when subjected to the rolling process, occasioned by the passage of the glass cover over the slide, assumed the form of globular or ovoidal bodies, in appearance exactly resembling starch corpuscles after they have been subjected to the influence of iodine. In this urine, then, there was a substance in a state of solution which was neither starch nor cellulose, but which might readily have been mistaken for the latter, had it been infiltrated into any of the solid textures."

Let it not be supposed, from anything I may have said in the previous discussion, that I ignore the presence of cellulose in the tissues of man, or of the higher animals. Although its presence has not yet been satisfactorily demonstrated, as any candid person will, I think, admit, there is every probability in favour of the supposition of its existence. "We have in the human subject, as

[1] *Microscopic Journal*, July 1855, p. 286.

normal constituents, starch, sugar, and lactic acid,—why not cellulose? Then, from actual observation, I can testify to having seen, on more than one occasion, considerable portions of tissue become blue with iodine alone (obs. 18) (which I am confident was not due to contamination with the extruded contents of a starch corpuscle); this being as strong, or stronger, evidence of the existence of cellulose in the textures, than any which has hitherto been brought forward in its support."[1]

The dry, and perhaps uninteresting details, through which the reader has been led, will, it is trusted, be pardoned, in consideration of the importance, both in a physiological and pathological point of view, of accurately distinguishing between cellulose and starch. The necessity of this may not be apparent to some, seeing that the two are identical in composition. It by no means follows, however, as the physiological chemist well knows, that identity of composition argues similarity of physical or physiological qualities; for isomeric compounds, although containing the same kind and number of elemental atoms, are often far more distinct from one another in general properties, than they are from substances to which they have no chemical relationship. The isomeric compounds of which I have been speaking, perform in the plant two separate functions,—the one a mechanical, the other a chemical: is it not probable that the same remark holds good regarding certain animals which are in a healthy condition?

My aim in being thus minute, has been, not merely to show that certain corpuscles found in the animal textures are grains of starch and not of cellulose, but at once, and it is hoped for ever, to rescue them from the heterogeneous collection of "amyloid bodies," "substances," and "degenerations," with which, in the majority of cases, they have not the remotest connection. It would, indeed, be singular if they had, seeing that individuals of the mass do not exhibit the slightest true relationship to each other.[2] I will do no more here than enumerate the bodies termed "corpora amylacea" by various authors, in illustration of what has just been said; leaving the reader to deplore the confused condition of this subject, which has arisen from observers confining their attention either to the general appearance, physical qualities, or chemical reactions of the corpuscles, and not considering that in matters of this kind a coincidence of the whole of their properties is absolutely essential to the establishment of identity. Virchow gives the following as those

[1] I am gratified to find that this observation has recently been confirmed by Dr N. Freiedreich, of Würzburg, who, however, labours under the impression that he has been the first to notice it (*Virchow's Archives*, April 1857, p. 390). The whole of the succeeding paragraphs which are included within inverted commas, are, unless otherwise stated, verbatim extracts from my prize Inaugural Dissertation entitled, "Starch as a constituent of the animal body; together with some observations on the formation of fat in animals;" which was delivered to the Medical Faculty of the University of Edinburgh in April 1856.

[2] See *Inaugural Diss.*, p. 284; and Quain's *Anatomy*, p. 26.

which persons have busied themselves in associating with his amyloid bodies: brain sand, gelatinous granules, concentric epidermis globules met with more especially in cancroid growths, certain corpuscles termed Hassalian, a medullary matter described by the author, and granules of Leucine. I am the more anxious to draw a clear line of demarcation between the two kinds of corpuscles,—or, to speak more correctly, between the one and the many,—from having observed that an English author has, since the publication of Busk's observations and my own, either from diffidence of his observing powers, or some other reason, placed in the category of amyloid bodies, those which, from the evidence adduced, must be acknowledged to have displayed a combination of qualities which belong to no other known corpuscles than those of starch.[1]

I may now proceed to describe the method which I have always followed in the examinations of tissues for starch corpuscles, by means of an aqueous solution of iodine. The strength of the solution is a matter of no moment; that, however, which I have employed, and which, I think, will be found the most convenient, is made by dissolving just so much iodine in a watery solution of iodide of potassium as to communicate to it an intensity of colour equal to that of port wine. A spirituous solution should be avoided, as it allows of the precipitation of iodine when brought into contact with watery fluids, and is otherwise ill adapted for purposes of demonstration. The procedure I have been induced to adopt, is one, I believe, which will infallibly indicate these bodies, if they be present in any situation, provided that due attention be paid to the caveats which will presently be mentioned. It differs but little from that generally pursued by histologists in displaying tissues, etc.; but upon this slight difference, and some niceties of manipulation, depend, as I know from experience, the success or failure of a search, when but few corpuscles are dispersed throughout an organ, or mingled in small quantity with the fluids of the body.

To examine an organ, such as the spleen or kidney, for starch, we should commence by making a clean incision into it, and then, by gently scraping the freshly cut surface, procure a semi-solid pultaceous material, which should at once be transferred to a glass

[1] The following is the description given of the "corpora amyloidea" found in the human crystalline lens by Dr Kirk (*Trans. Path. Soc.*, vol. vi., p. 303):—"Immediately under the capsule, and imbedded in the superficial lens substance, was found a layer of peculiar bodies, which varied much in form and size. The predominant form was the spheroidal, more or less elongated; sometimes larger at one extremity than at the other. In a few, a series of concentric markings was evident; but in most they were absent. Under the polarizer, several of the larger bodies presented a distinct cross; in the smaller ones the cross was faintly marked, or altogether absent. Tested with tincture of iodine, they assumed a deep blue colour, gradually increasing in intensity till they became opaque." I am surprised to observe that the President of the Society, after this paper was read, expressed doubts as to the amylaceous nature of the bodies described. (*Med. Times*, Feb. 20, 1855.)

slide, and with it intimately mixed a little of the iodine solution. The cover should now be imposed, and just such an amount of pressure exercised upon it as to cause the extension of the fluid to its margin. This having been accomplished, the preparation is ready for inspection. I have insisted upon the necessity of limiting the matters to be examined to the area of the covering-glass, from the conviction that, if attention be not directed to this, errors from negative results will almost certainly occur, in consequence of the tendency of these bodies to roll beyond the margin of the disc.

My reasons for recommending this process in preference to those ordinarily employed, are, that by traversing a comparatively large surface of an organ, from which the corpuscles are easily detached, we generally succeed in surmounting the difficulties arising from their occasional paucity, as well as from their frequent irregularity of distribution; they are, moreover, on account of their isolated condition, better adapted for the action of tests, and a satisfactory exhibition of their effects, than when obscured by structurally complex masses of tissue.

In the instance of highly congested organs, it will be found advisable, after incision, to squeeze them, and before scraping to remove lightly the exuded blood with the back of a scalpel or other instrument.

The fibrous and nerve tissues are examined in the usual manner, with the exception of the iodine solution replacing the distilled water or other fluid.

It may here be stated that especial caution is demanded in conducting examinations of the pulmonary substance, lest deeply seated air-bubbles, or masses of pigment, be mistaken for the dark purple coloration induced in starch grains by the operation of iodine.

In consequence of the corpuscles being of a higher specific gravity than most, if not all of the fluids of the body, they are easily collected from them by means of precipitation. Greater precaution to avoid an excessive amount of materials is here, if possible, required, than in the instance of solids, for the reasons which have already been given.

It is important that we should commence our investigations as soon after the death of the individual as circumstances will permit, because the corpuscles are prone to undergo change and solution, by the catalysis induced by contact with decomposing albuminous substances. They are not, it is true, metamorphosed so quickly as the soluble sugar, but still with sufficient rapidity to render an examination fruitless, which might have been otherwise had it been conducted at an earlier period. I may also mention that the soluble gaseous products of the putrefactive process, by entering into combination with the iodine, will, if present in sufficient quantity, entirely frustrate the object for which the re-agent is applied.

Errors arising from alkalinity, or from the sources just adverted to, admit of an easy remedy, if remediable, which consists in con-

tinuing the addition of the iodine solution until an unmistakeable and persistent yellow tinge is communicated to the preparation. If, however, the materials be extremely alkaline, as is sometimes the case with the urine, it is advisable to saturate them with acetic acid before applying the iodine test, because so much of the latter, of the strength indicated, would be required to produce the desired effect.

The following examples of the wide distribution of starch corpuscles throughout the tissues of the human body, have been numbered as continuations of those given in a former number of this *Journal*, in order to avoid confusion and repetition when making reference:—

Obs. 14. A child who died 27 hours after birth; cause of death unascertained.

The kidneys, pancreas, and liver, contained the usual amount.[1] In the latter organ, however, a mass of fifty, or more, were discovered, individual grains of which did not exceed in diameter the one-half of a blood corpuscle. In a demonstration from the pancreas, membrane-like masses were observed to become blue on the application of iodine; these, I am disposed to believe, were the extruded contents of starch corpuscles, extended by pressure. Starch was found in the lungs and areolar tissue of this subject.

Obs. 15. A male, æt. 15 years; died from the effects of diarrhœa.

The liver, which was enlarged and "waxy," exhibited the usual amount, as did the lungs, which were the seats of tubercular deposit. The enlarged and waxy spleen, and the waxy and tuberculous kidneys, yielded bodies of a larger size, and in greater numbers, than the preceding viscera.

Obs. 16. A man, A. W., æt. 48, who died comatose. Inflammatory condensation of the lung and softening of the pons Varolii were found after death.

Starch was discovered in the lung, liver (indurated), grey and white matter of the brain and spinal cord, and also in the retina. The corpuscles were more numerous in the spinal cord than elsewhere.

Obs. 17. A male; death occasioned by the growth of a tumour in the brain.

The kidney, spleen and pancreas, mucous membrane of the urinary bladder, and areolar tissue of the mesentery, contained starch, but in small quantity. The mucus of the bladder yielded more than any other part. All the organs and tissues were apparently healthy.

Obs. 18. A female, M. R., æt. 27 years; died of phthisis pulmonalis.

The liver, spleen, pancreas, kidneys, and areolar tissue, exhibited a rather smaller amount than usual. All the organs men-

[1] For the quantitative value of "usual amount," "small quantity," etc., see note in former paper, *Edinburgh Medical Journal*, August 1855, p. 131.

tioned were healthy, with the exception of the hepatic, which was pale and somewhat fatty. In one demonstration of the spleen, a blue coloration was observed in a mass of homogeneous tissue, on the simple addition of the iodine solution.

Obs. 19. A man, J. M., æt. 45 years; died from cerebral apoplexy.

The liver of this subject yielded a more than usual amount; the spleen, kidneys, pancreas, supra-renal capsules, cerebrum, and cerebellum, less than usual. All the organs were healthy, with the exception of certain parts of the brain.

Obs. 20. A female, M. F., æt. 27 years; died of Bright's disease with lung complication.

The liver, lungs, spleen, pancreas, and areolar tissue from under the skin, contained the ordinary number of corpuscles. The liver was in a slightly indurated condition, the spleen of its ordinary dimensions, but exceedingly "waxy." Some of the malpighian tufts of the kidney were covered with fatty granules, and struck with a weak solution of iodine a yellowish-pink colour, or, with a stronger solution, a tint which I conceive to be that described as iodine red. The addition of sulphuric acid produced no change in the colour of these vessels, after a lapse of twenty-four hours. Both kidneys had undergone the stearotic degeneration, and the pancreas was "waxy." Large portions of the lungs were completely hepatized; the parts, however, selected for examination, were free from disease.

Obs. 21. A female child, which died shortly after birth. No food had been administered.

The liver, spleen, and kidneys, contained the usual amount of starch; the areolar tissue of the mesentery more than is ordinarily met with in this situation.

To prevent misunderstanding with regard to the "Observations" in this, as well as in my former communication, it is necessary to remark that I have not, as might perhaps be supposed, suppressed those instances in which particular subjects or organs did not afford evidence of the existence of the corpuscles. I have made a number of isolated observations on the different textures, the results of which, from corresponding with those already given, I have not thought worth while committing to print. Upon looking over my notes, however, I find that starch corpuscles are to be detected in some parts to which allusion has not yet been made, viz., in the stroma of the ovaries, and among the fibres of voluntary muscles; rarely, if ever, among the closely set fibres of the healthy heart. They are also to be found in some of the normal and abnormal secretions and excretions of the body, as in the mucus of the bronchial passages and of the bladder, and in the urine; in certain growths and exudations, as in cancer; and in the tubercular and ordinary inflammatory deposits. Textures from the following animals have been submitted to examination, and were found to furnish results precisely similar to those

which have been related in connection with man: the dog, cat, pig, ox, sheep, hare, rabbit, mouse, domestic fowl, swallow, frog, toad, perch, roach, dace, herring, haddock, crab, garden snail, oyster, star-fish, and actinia.

With the mass of facts now before us, we are in a position to draw a few inferences as to the source from whence animal starch corpuscles are derived, the physiological purposes which they subserve in the economy, and the pathological conditions which, under certain circumstances, they may indicate.

But before proceeding thus far, I may offer some brief remarks on the anatomical position which the corpuscles occupy in relation to the textures in which they occur, commencing with the ordinary white fibrous tissue. When well displayed, this tissue exhibits them, for the most part, in an isolated condition, though occasionally aggregated into groups; in either case they lie among, or are enveloped in, the bundles of fibrils of which the texture is composed. I saw on one occasion, in the areolar tissue of the mesentery, a mass of these bodies (probably contained in a cell) arranged with such regularity, and so compressed, as to simulate very closely the appearance of a fir-cone, or perhaps more nearly the fruit of the raspberry.

I am led to conclude, that organic connection sometimes exists between the corpuscles and the tissues in which they are imbedded, from having observed on the margins of some, ragged portions of homogeneous membrane-like substance, which remained unaffected or only slightly tinged yellow by the iodine solution. The tenacity, too, with which some adhere to portions of tissue, more especially when they occur in masses, lends support to this opinion.

Not wishing to be prolix, nor to weary the reader by the narration of the details of the anatomical relations of the corpuscles in each organ, I shall simply state the general conclusions at which I have arrived on this point, descending afterwards to a few particulars where these appear to be demanded. It may be said, then,

1*st*. That whenever areolar tissue, or tissue homologous with it, is found, we may expect to meet with starch corpuscles: for example, they are present in the stroma of the ovary, in the intertubular substance of the kidney, in the interlobular substance of the pancreas, etc.

2*d*. They frequently occur among the cell-elements of which organs are chiefly constructed; as observed in the liver and brain, and among the epithelial cells of mucous membrane.

3*d*. Although they are now and then found enclosed within a cell, and occurring among the cell structures of organs, they never, so far as I am aware, take the place of the nucleus, or are co-existent with it. The foregoing assertion is based upon the fact, that the cells which contain starch grains do not resemble in the smallest degree those which are peculiar to the organs in which they are imbedded. Mr Busk was, I believe, the first to notice in the

substance of the brain amylaceous particles contained in cells;[1] but he does not inform us whether these cells were the nerve corpuscles or not. For my own part, I incline to the belief that these envelopes are entirely new formations, produced probably in the same manner as those which surround blood corpuscles, when extravasated into the brain and other textures, or enclose foreign bodies, when these do not excite so much inflammation as to lead to their extrusion by suppuration.

When blood is procured from the finger by means of acupuncture or incision, and examined with the microscope, there will sometimes be seen a certain number of starch corpuscles, some attaining to a size considerably above the 1-1000th of an inch in diameter. It would of course be absurd to suppose that such bodies exist in the blood, and traverse the capillary system of vessels. The explanation of the circumstance would seem to be, that they are derived either from the fibrous tissue situated immediately beneath the basement membrane of the skin, from which they are displaced by the current of blood, or from the epidermis as a natural secretion, or as accidental occupants of that part.

In some cases of icthyosis it is certain that the skin does secrete starch corpuscles, for I have discovered them in considerable numbers in dermal plates taken from the lowest stratum that it was possible to detach, and which would not therefore have been at any time in contact with amylaceous substances; but whether the skin, in its natural condition, secretes these bodies, I am unable at present to say. I am still disposed to believe that starch corpuscles of minute size do circulate with the blood, because in clots taken from the heart there are to be seen bodies, scarcely exceeding a blood-disc in dimensions, which appear to assume a deep blue tint on the addition of iodine; it is possible, however, that some of these may be blood corpuscles in a particular stage of degeneration.

I have mentioned that the kidneys are frequently the seats of notable quantities of starch corpuscles; and from this it might be imagined that the urinary secretion owes to these organs that which it so generally contains; but the following considerations seem to show that this supposition is untenable. The starch grains observed in these viscera always, so far as I have ascertained, occupy an intertubular, and never an intratubular position, except from accident, and therefore their egress, in healthy states of the organ, without damage to texture, is a physical impossibility. It must, of course, be allowed that, in organic lesions accompanied by disintegration of texture, some of the corpuscles found in the urine may emanate from this locality. After the examination of several specimens of urine, I came to the conclusion that their numbers bore, in general, a direct relation to the amount of epithelium or epithelial

[1] *Microscopic Journal*, Jan. 1854, p. 108.

debris which was present, and from this was induced to believe that their source is to be traced to the mucous lining of the bladder and urinary passages.

The discovery of starch in the urine would appear to clear up an obscure, but interesting point in animal chemistry, connected with the generation of lactic acid in this fluid, after its exposure for a certain length of time to atmospheric influences; for acid urine, from containing an animal ferment, is capable, as Majendie[1] has shown, of converting the insoluble starch into certain soluble substances, the last of which series, at ordinary temperatures, is the lactic acid, and occasionally the butyric.

Lehmann speaks thus when treating of the analysis of the urine —"In determining the presence of lactic acid, we must always employ fresh urine, if we wish to draw any conclusion regarding the composition of the renal secretion. The admirable investigations of Scherer regarding urinous fermentation were the first to direct attention to the circumstance, that there is a gradual augmentation of the free acid when the urine is exposed to the atmosphere. *The lactic acid must be formed from some unknown matter*,—probably from what we term the extractive matter."[2]

From a consideration of the facts which I had at my command when writing my previous communication, I considered myself justified in drawing the inferences, "that starch corpuscles, when met with in the animal body, must generally be esteemed as physiological products;" and "that man, in common with some of the lower animals, must be regarded as a starch-secreting organism." The results of the investigations which I have conducted in reference to this subject since that time, will, for the most part, be found incorporated in the present paper, and tend, as it appears to me, still further to verify the correctness of the opinions which were then expressed.

A revolution has lately taken place in the opinions of M. Bernard touching the functions of the liver, in consequence of his having by a simple chemical process, which it is unnecessary here to describe, been able to extract from the hepatic organ of dogs, fed entirely on flesh, a substance possessing all the known properties of starch in its hydrated condition. He now therefore believes, what appears to be exceedingly probable, that the sugar found in the hepatic vein is not generated directly by the liver from substances contained in the blood, but indirectly by the catalytic action of this fluid upon the starch previously contained in the organ, and which he considers to be one of its true secretions.

This distinguished physiologist has, as it would seem unwittingly, given his assent to the truth of those generalizations which I first announced two years ago, which, supported by additional observations, were repeated in my thesis of last year, and which, it is anticipated, will soon take their places as established doctrines in physiological

[1] *Compt. Rend.*, xxiii. 189. [2] Lehmann's *Chem.*, vol. i., p. 100.

science. Without, however, appealing to the facts recently brought to light by M. Bernard, those which I had previously elicited were, I think, amply sufficient to establish the truth of those propositions; for who could resist evidence so conclusive as that furnished by the constant appearance of the corpuscles among the morbid and healthy textures of individuals, dead of various disorders, as well as among the tissues of the lower animals, which, when killed, were known to be healthy, and which, there were no grounds for supposing, had ever been the subjects of disease?

"The principal conclusions pertaining to the physiological relations of animal starch, deducible from the previously recorded data, will now be given in the form of propositions, followed by the facts upon which they are based, so as to curtail as much as possible what has to be said on this division of the subject. They are:—

"1*st*. That the presence of starch in the animal body is necessary for the well-being, if not for the preservation of the lives, of individuals belonging to the principal groups of animals;—as shown by its constant occurrence in well-marked members of those groups.

"2*d*. That the corpuscles undergo processes of development, growth, and decay; as proved by their variable dimensions, the diverse conditions of their outer wall, and the different appearances of their contents.

"3*d*. That its function is not local but general; as indicated by its tolerably equal dissemination throughout nearly the whole of the textures of the body.

"4*th*. That some of the starch found within the organism in its healthy state is apparently functionless and excrementitious; as shown by its presence in the urinary excretion, and in the mucus of the bronchial tubes, etc.

"In describing the different varieties of starch corpuscles met with in animals, it may be remembered, that some were mentioned as presenting a rugose or undulated surface, and others whose contents were of a decidedly granular aspect.

"Thinking that these appearances denoted alteration in composition of a retrograde character, I investigated the morphological changes which occur during the germination of certain seeds, with a view of ascertaining whether my surmises were correct or not. For this purpose, I procured some barley that had been subjected to the process of malting, which, as is well known, when carried to its fullest extent, issues in the conversion into grape-sugar of nearly the whole of the starch contained in the grain. If, however, as generally happens, it is not permitted to proceed thus far, a certain proportion of it remains intact after the completion of the operation. This substance, then, we may presume, presents every condition necessary for the complete study of the morphological changes induced by the catalytic action set up by a nitrogenous substance undergoing decay by oxidation.

"The chemical changes observed during the germination of seeds

is now universally admitted to be strictly similar to those which occur during life in the textures of animals, inasmuch as the primary phenomena are, oxidation, the generation of heat, and the liberation of carbonic acid. We may, therefore, cull all the information we are able from this source, without doing the slightest violence to analogy. A microscopic examination of the corpuscles contained in malt, revealed these bodies in all phases of destruction: some exhibited a merely undulated surface, others were flaccid and half empty; while others, again, whose external characters coincided with those just described, contained a granular material which communicated to them a nebulous or mottled appearance."

It may be objected to my second proposition, that the nebulous and other appearances occasionally presented by animal starch corpuscles are due to *post-mortem* influences, and are not attributable to any physico-chemical agency during life; and so, in some instances, they undoubtedly are, for precisely similar phenomena occur in corpuscles placed in contact with putrefying animal matters; but such as I have described, are also to be found in animals immediately after being killed, and probably before the tissues in which they are imbedded have entirely lost their vitality.

"It is not difficult, even at this early step of the inquiry, to assign to these bodies a general function in the economy; but it appears impossible at present to say whether, besides a general function, they fulfil any special physiological purpose. Judging from their composition, the circumstances in which they are placed, and the appearances presented by certain corpuscles, there can be but little doubt that they are ultimately converted into sugar and lactic acid, whose combustion, as shown by experiment, must serve to keep up the temperature of the body.

"After due reflection, it has appeared to me that two special functions may be subserved by starch; the one, depending on its ready convertibility into soluble, easily oxidizable, compounds, that it may furnish the thermogenic material when a sudden demand for caloric is made upon the system; the other, that by its metamorphosis it may supply some of the lactic acid of the gastric juice. A degree of plausibility is conferred on the latter idea, from the fact that this fluid is poured out at irregular intervals, its secretion depending upon the introduction of food into the stomach; so that we might naturally be led to suspect that a store, adapted for its almost instantaneous production, lay hid in some part of the organism. It must, however, remain an undetermined question, whether these bodies perform all the offices I have here allotted to them, until a larger mass of facts have been accumulated, and the number of observations greatly multiplied.

"It has already been, I think, satisfactorily shown that starch grains, when situated in the generality of tissues and organs, are strictly physiological; but it yet remains to be ascertained whether, in certain localities, and in certain quantities, they must not be

esteemed as indicative of a pathological condition of the part or of the general system. I cannot say that any of the observations which I have had opportunities of making, tend to throw much light upon this part of the subject. It is true that the corpuscles were extremely abundant in one patient, who died of phthisis pulmonalis (Obs. 3); but the pancreatic organ, although somewhat harder than natural, was apparently structurally healthy, and the mesenteric glands were but slightly enlarged. The increase in their numbers cannot be fairly attributed to the effects of the pulmonary lesion, because many other cases have fallen under my notice in which no abnormal increase was capable of being detected, although the disease was in a much further advance than in this woman."

Mr R. Taylor has placed on record[1] a curious case, in which a diseased human crystalline lens was the seat of a large number of starch corpuscles (corpora amyloidea); but it appears impossible to say what relation subsisted between the presence of these bodies, and the disease which affected this part of the visual apparatus. It is clear that their formation might have preceded, and thus have occasioned the other changes observed in the lens, or their development might have succeeded, and resulted from, the degeneration of its tissue,—their subsequent growth proceeding from the powers of vital attraction and assimilation with which they are endowed. That starch corpuscles may arise amidst disintegrating animal matters within the organism, is evident, from the fact of their having been found in pericardial and other exudations (Obs. 6), which had undergone the fatty degeneration;—there being, of course, no corpuscles in the liquor sanguinis immediately after its passage through the walls of the blood-vessels, nor under ordinary conditions in the sac of the pericardium. At present, it is impossible to decide in any given instance of a misplacement, or of an excess of starch corpuscles in a part affected by disease, as in the lens before mentioned, whether such a deposition is but the local manifestation of a generally diseased state of the system, combined perhaps with a deficiency in the vitality of the part affected; or whether it is the result of a pre-existing local affection which allowed of the formation, or tended to the production, of these bodies.

It is quite conceivable that we may yet discover an abnormal state of the economy such as that to which allusion has been made, indicated by a superabundance of starch granules among the various textures of the body, and by their occupying positions which, under ordinary circumstances, they are not found to hold, resulting from an inherent cacoethes of the tissues themselves. I mean, that the tissues, by a tendency either original or acquired, may, during their histolysis, be resolved into a more than normal amount of the amyliferous principles, with, as a necessary consequence, a diminution

[1] *Path. Soc. Trans*, vol. vi.

in the quantity of some of the other retrograding organic compounds. There may also be a pathological condition of the system totally opposed in its nature to that just described, and indicated by a deficiency or entire absence of the corpuscles. Speculations of this kind may perchance be thought premature and uncalled for; but they are not, if based upon strict analogical data, and tend to any useful result. Analogy would inevitably lead to the inferences which I have advanced—would compel us to believe that lesions such as I have mentioned will at some time be discovered, whatever be the explanation of their origin, because every known organic or organized constituent of the healthy body is capable of undergoing an increase or diminution in amount, which, extending beyond certain ill-defined limits, constitutes in itself, or is characteristic of, disease: and I think it is obvious that, sooner or later, advantages to science must accrue from such surmises, if they serve to awaken the vigilance of those who, from their position, are capable of obtaining information on this subject.

It was originally my intention to have offered some remarks as to the source, or sources, from whence is derived a blastema adapted for the formation and nutrition of the starch corpuscles, found so universally distributed among the different textures; but I find that to do this in a satisfactory manner would incur the necessity of more space than can at present be conveniently devoted to this branch of the subject. I may, however, place before the reader the views I entertain, without entering into an elaborate explanation of them. There are, of course, two great sources to which we must look for an explanation of the occurrence of starch in the body,—to the ingesta, and to the products resulting from the histolysis of the tissues. Chemico-physiological considerations, taken in connection with the experiments of Majendie, Bernard, and others, would lead me to exclude the whole of the nutritive principles of the food, with the exception of gelatine, as going to form the blastema to which I have before alluded; and the tissues which, during their histolysis, yield such a blastema, are, I believe, the albuminous and the gelatinous. Indeed, I regard the starch of animals in the light of a step in a descending series of organic compounds, as in the vegetable I regard it as a step in the ascending series. The corpuscles themselves I look upon as examples of nature's conservative powers, and as tangible illustrations of a physiological dogma in which few would probably hesitate to concur, namely, that in all the processes of oxidation and degradation of chemically complex substances—which processes appear to be inseparably connected with the manifestations of animal existence,—nature invariably so contrives to resolve such complex matters into those more simple, which are still eminently qualified for the fulfilment of some ulterior useful office in the economy.

For the present, it is difficult, if not impossible to say whether any particular organ is set apart for the generation of starch. M.

Bernard[1] has lately stated it as his opinion, that he shall be able to limit its formation to the liver; but he does not appear to be aware that this substance, in a corpuscular form, has been found in other parts of the body as well as in this organ. If the liver be the sole originator of starch, it is evident that this substance must, in a state of fluidity, or in a finely divided molecular condition, pass into the blood, and with this through the lungs, before it can reach the tissues in which the corpuscles are seen. But it is open to grave doubts whether fluid starch is capable of resisting, for a sufficient length of time, the powerful catalytic influence of the blood, to allow of its being carried to, and deposited in, the localities where it is observed; for M. Majendie has demonstrated that the hydrate of starch, when injected into the blood-vessels of a living animal, is rapidly converted into grape-sugar. It is nevertheless conceivable that, under certain physiological states of the system, it may, like sugar, preserve its integrity during the whole circulatory cycle. For example, if the blood be at its maximum of normal saccharine saturation, it is possible that the sugar may play the part of a protective material, the catalytic force being entirely expended on its conversion into lactic acid, thus preventing the changes which would otherwise inevitably occur in the starch.

If this hypothesis were correct, it would be easy to understand how the starch found in the liver might be conveyed by the blood, and deposited, after permeating the walls of the intermediary vessels, in the various textures, there to be detained until required to meet the future demands of the economy. The converse of this supposition would also account for the subsequent solution and re-entrance of the starch into the circulatory channels of the body, in the form of either dextrine sugar or lactic acid.

Until M. Bernard adduces, as he undoubtedly will, further evidence in support of his opinion, it will perhaps be more prudent, instead of framing an hypothesis to defend a supposition, in the face of a few apparently well-authenticated facts, to say that the starch found elsewhere than in the liver, results from the decay of the gelatinous and albuminous tissues, as the former of these is well known to result from the latter.

ARTICLE IV.—*Case of Imperforate Anus. Proposed Modification in Operative Interference.* By REDFERN DAVIES, M.R.C.S., Birmingham.

THE surgical epoch in which congenital imperforate anus will cease to be regarded as an anatomical *lusus naturæ*, or as an opprobrium to the art and science of our profession, will arive only when success

[1] *Compt. Rend.*, t. 44, p. 578.