at present without any comment upon it), that I have observed a jaundiced condition produced by the operation on the sympathetic with the injection of the acid. The urine has been deeply tinged with bile, and has given the characteristic play of colours upon the addition of nitric acid. In the experiments with the injection of the acid alone, it has been a matter of constant observation that a flow of bile has been excited into the duodenum and towards the stomach, the pyloric extremity of which has been highly tinged of a yellow colour.

Although a diabetic state of the urine may be thus artificially induced, apparently by the direct chemical agency of an acid upon the liver, yet I am not prepared to say that, beyond the addition of another significant fact to our knowledge upon this matter, any at present available assistance has been gained towards unravelling the nature of the diabetic disease. Possibly in some cases an insufficiently alkaline state of the portal blood may be the cause of a temporary slightly saccharine state of the urine; but from the observations I have conducted upon diabetics, I certainly am not permitted to think that such is the cause of the well-marked diabetic disease. The immediate cause of the production of sugar in idiopathic diabetes, and in diabetes artificially produced by operations upon the nervous system (the sympathetic and cerebro-spinal), still remains an open point for discovery.

Usually in my experiments with the acid injections the liver has been found fairly charged with amyloid substance; but in a few instances an absence of this principle has been observed, although only a short time has elapsed between the injection and the period of destruction of life.

X. "On the Chemical and Physical Conditions of the Culture of Cotton." By J. W. Mallet, Ph.D., F.C.S., Professor of Chemistry in the Medical College of Alabama. Communicated by Robert Mallet, Esq., F.R.S. Received June 4, 1861.

(Abstract.)

This communication embraces the first portion of an elaborate physical and chemical investigation, in which the author has been and is still engaged, upon the scientific conditions involved in the successful agriculture of the cotton plant. To this train of research he has

brought peculiar advantages, holding his professorial chair in the great cotton-growing State of Alabama (North America), having been the editor of the Government Geological Report of that State, and having had placed at his disposal (for experiment and comparison) by the Indian Government, a magnificent collection, specially made, of the various cotton soils and plants of India, as well as the like from other Powers.

The author remarks that, although an examination of the conditions under which the cotton plant may be cultivated with success is one of much interest both in a scientific and economic point of view, yet it is strange that science, botanical, chemical, and climatological, should as yet have supplied so little information with respect to this plant, the most important source of the clothing of man. That, while other cultivated species, many of them of far less general value, have been the objects of careful experimental research—their botanical relation and improvement by hybridization settled—the character and extent of their demands for atmospheric and mineral food ascertained—the soils upon which they thrive or fail analysed—the climatal conditions which favour or impede their growth observed, the culture of cotton under favourable circumstances has, *as an art*, been advanced in one great locality almost to perfection, but without the scientific *principles* upon which the art is based, and by the application of which alone success or failure in any new attempts elsewhere and under new conditions can be predicted. He shows that the immediate cause of this neglect of the science of cotton-culture has been the facility with which the vast and growing demand of the world for cotton has been met by the vast surface of fertile and virgin soil and other favourable conditions of the southern states of North America, yielding wealth to the planter too readily to incite him to inquire much as to the conditions of his success.

Although much virgin soil remains in the southern states untouched by the cotton-planter, the author states that it needs but slight knowledge of the country to discover the vast extent of "worn-out" cotton fields already existing even in the most recently settled states, or to predict a time when the growing demands for the staple must compel, there and elsewhere, the attention of the economist to the scientific aspects of the problem of cotton-cultivation. To fix with exactness the conditions under which the cotton plant

thrives, how far it can be brought to bear unfavourable circumstances, and by what means the latter may be modified to suit its requirements,—such are the "fruit-bearing" objects of the author's researches; he remarks, however, that in the purely scientific aspect of his subject it is difficult to overrate the interest that attaches to every question touching the sure production of a material that, in its husbandry, manufacture, and consumption, closely concerns so immense a proportion of the human race. In the present paper, that branch of the subject which relates to the *soil* is taken up.

The author in commencing gives a careful summary of all such experiments on American cotton soils as have been recorded prior to his own labours. These are not numerous.

The second chapter describes, by the aid of a large geological and climatological map, the precise geographical boundaries of the regions of American cotton-culture, the geological or agronomic, climatal, and meteorological and general superficial conditions of these great surfaces, and the relations of each of these to the growth and culture of the several varieties or staples, such as "Sea Island" or "long staple," and "upland" or "short staple," &c. The latter sort, constituting the vast bulk of the crop, and bearing, in 1858, the ratio of eleven hundred and six and a half millions to only about twelve million pounds of the "Sea Island," the author deems worthy of prior investigation. In the first instance, limiting himself to this, he discusses carefully in his third and fourth chapters, the choice of district from which the most typical and important soils for examination should be collected, and decides upon the selection of "fair normal specimens of prairie soil" and its underlying subsoil, and to examine them "as minutely and accurately as possible," believing that thus a clue would be more readily found to the causes of fertility as dependent on soil (for which this region is remarkable), than by a less careful examination of many specimens from this or that locality over so vast a surface. This method, without teaching *all* that we may want to know, is certain most readily to show us the right direction in which to push further inquiry. Seven specimens of soil and subsoil were finally selected for comparison and analysis, mainly from that class of "prairie land" known as "canebrake land," in Marengo, County Alabama, in lat. 32° 35′ N., long. 87° 36′ W., the points being marked upon the map accompanying the paper.

The characteristics of this very peculiar soil, its prevailing weeds, and most important Silva and Flora, its average depth, nature of surface, effects upon it of rain and of drought, the form of its water-courses, and general conditions affecting the cotton plant are carefully described, and their bearings on the subject discussed. The examination of these soils was twofold—physical or chemico-physical, and purely chemical or analytical. The methods employed in each are detailed; and in the former, those of Schübler and of Schulze, with modifications by the author, were principally employed, attention being also given to the methods and results of Liebig's recent experiments, and those of others, on the power of withdrawal by soils of saline and other substances from their solutions. The external characters of the soils examined are then described; the real or true specific gravity, and the weight of a given volume in known conditions of moisture and dryness—the contraction in volume on drying from a determinate extreme of wetness—the cohesion of the soil, or adhesion of its particles (in known conditions as to moisture) to each other, are all determined, the last by a method believed new. The adhesion of these soils to the surfaces of iron implements, as ploughshares, hoes, &c., was ascertained in the state of "maximum moisture," as proposed by Schübler, of whose method, however, the author expresses some disapproval.

The next physical condition determined is the absorption of heat from the sun's rays, with tabulated results, both for the absolute maximum temperature attained; and the rate at which the increment takes place. The results indicate the importance of noting the latter, and prove that the statements of Malaguti and Durocher, in opposition to Schübler, that mineral composition has a more important influence than colour upon the thermo-absorptive capacity, and that of sand is greater than that of clay, must be accepted with considerable limitations. Conversely, the author has determined the relative retentive powers of these soils for heat, having intimate relations with the rate at which they lose heat after the sun has become absent, and tabulated his results, which differ considerably, as he notices, from those of Schübler in analogous cases,—the discrepancies remaining after repetition, by the author, of his own experiments. He points out some of the probable causes of this.

He then proceeds to the power of absorption and retention of

water, with tabulated results. The extreme tenacity with which the best cotton soils retain a very large proportion of their water of saturation after lengthened periods of exposure to dry air is remarkable, and the importance of this in the hot climate of cotton-culture is pointed out. In immediate connexion with this point, their permeability, or the rate at which water percolates through these various soils was ascertained, the relations of which to partial rain or dews, and to the desiccation of one mass and species of land in times of drought by others adjoining are important and obvious; and again, in the same relations, the capillarity, or rate at which water is drawn through and upwards in the soils from deep moisture below, was determined. In this part of his labours the author considers with some exactness the nature and measures of the true capillary power of soils, refers to the recent interesting researches of Jamin on the capillarity of porous bodies, and describes some new and peculiar apparatus by which he has determined this for the soils in question, the results being given in several tables. These indicate strikingly one of the remarkable properties due to the extremely fine state of division of these "best cotton soils," on which, in part, their fertility depends, viz. that they draw up moisture from the subsoil with immense power, and therefore from great depths, but yet do so with great slowness; so that in a torrid climate the subsuperficial supply of water fluctuates but little, and is slowly supplied and long in being exhausted in drought; while other soils pump it up rapidly, and as rapidly waste it. This property becomes more important as the distribution of rain, both in season and in space, is more unequal naturally.

The hygroscopic power, or power of absorbing aqueous vapour from the atmosphere, is next experimented upon, and the results are tabulated, and also represented graphically by curves, as are several of the other numerical results.

The author then proceeds to the highly important subject of the absorptive power of the soils for gases directly or indirectly affecting the growth of plants.

Tabulating the results for oxygen, carbonic acid, and ammonia, the most striking result here exhibited is the prodigious power of absorbing ammonia possessed by the dry canebrake soils. This soil condenses 52 volumes (equal to its own) of ammonia, and its

subsoil 64 volumes. It will be remembered that De Saussure found that the most impalpable powder of boxwood charcoal only absorbed 90 volumes equal to itself. Another cause of the extreme fertility of these soils is thus brought into evidence.

From this the experimenter proceeds to the determination of absorption or withdrawal by the soils of inorganic substances in contact with them, and in solution; experimenting on ammonia, chloride of ammonium, sulphate of ammonia, nitrate of potass, phosphate of soda and silicate of potass, and determining the proportions both of acid and of base withdrawn. The methods by which he proceeded are described with reference to each of the above salts. In several cases the acids and bases are not absorbed in the proportions in which they constitute the salts. These very curious and suggestive results are graphically given as well as tabulated. The labours of various other chemists in this direction are referred to and discussed in reference to those of the author.

Professor Mallet then refers to what he denominates the mechanical analysis of the soil, pointing out the necessity, in all agronomic determinations, of finding, by methods admitting of comparison with distant soils, the texture, coarseness, or fineness, &c. of the constituent particles. These results are given in eight consecutive comparable tables. Each soil was separated into six solid portions and the remaining water making up its total weight—viz. into the material passing through sieves respectively offering 36, 100, 400, and 1600 meshes to the square inch, and into suspended matter of two decantations.

The proportion of impalpable material is very remarkable, amounting in the best soils to more than 70 per cent. of the whole. Not a pebble or particle almost, exceeding $\frac{1}{40}$th of an inch in diameter, is to be found in those best cotton soils whose comminuted state permits the free pushing out of root-fibres in all directions.

The purely chemical part of the investigation is then proceeded with. The methods employed for the chemical analysis of the soils are given under the heads of water, organic matter, inorganic matter soluble in water, inorganic matter soluble in hydrochloric acid, inorganic matter decomposable by strong sulphuric acid, and that not acted on by this acid. And the results follow in eight tabular statements, but are of too detailed a character to be brought into

an abstract, and without such the discussion that succeeds would not be sufficiently intelligible to be useful. It may be interesting to state that measurements have shown that the average mass of soil interpenetrated by the roots of each cotton plant in Alabama is about 5 cubic feet; within this bulk of soil a sufficient amount of inorganic constituents for the plant must be found naturally, or be artificially transferred to it.

Professor Mallet compares his results with the analyses of Indian soils made by Dr. Forbes Watson, pointing out both similarities and differences.

In concluding his analyses of the soils and subsoils, the author gives also one of the so-called "Rotten Limestone," and of the "Bored Rock," both calcareous rocks of a very friable character that underlie the Cane Brake soils. He concludes his elaborate research with some general deductions from his examination of Alabama cotton soils, and with an appendix, in which he describes the mechanical or agricultural methods employed in that State in the treatment of the same. These are given as follows in the words of the paper.

General Deductions from the examination of Alabama Cotton-soil.

In order to draw any useful conclusions from experiments such as the above, upon a soil, the plant to be cultivated must be noticed, as well as some of the modes in which it is affected by climate.

A few remarks upon the cotton plant and its climatal peculiarities must therefore be made here in anticipation of a future part of the paper.

Annual cotton, as cultivated in America, is a plant which attains its principal growth in about four months, although it continues to develope seed and fibre for a much longer period.

The extent to which its roots penetrate the soil has been noticed above, and from this some imperfect idea may be formed of the power which it possesses of drawing upon the earth for nourishment, although no measure is thereby obtained, I think, of the capacity of the earth to *yield* nourishment*, as is shown by the experiments upon capillarity and saline absorption. Nor, indeed, do we even obtain any cer-

* On the assumption of Liebig—that mineral food is taken up only by direct contact with the roots—the surface exposed by the latter does become a measure of the capacity of any particular soil to yield such nourishment.

tain knowledge of the power with which the plant takes up its food from the soil, unless, by microscopic examination, and by experiments such as those of Hales, some estimate be formed of the combined effects of capillary and osmotic action in drawing up liquids of various composition.

The special mineral food required by the cotton plant, and the amount of this food, remain to be examined by analyses of the ash, which will form another part of the investigation. Some statements with regard to the *nature* of the mineral constituents have been made, drawn from the results of Dr. Jackson's analyses, and all these substances needed by the plant have been seen to exist in the soil. As to the *extent* to which they are withdrawn from the soil by cultivation, it may be remarked generally that cotton is by no means an exhausting crop under proper management.

The great mass of the plant—root, stem, branches, leaves, and emptied boles—remains upon the field, and is ploughed into the soil, which is enriched by the rapid decay of the organic matter. Nothing is removed except the fibre and seed, and a large proportion, if not the whole of the latter, is by judicious planters* returned to the land; cotton seed is in fact almost the only material used as *manure* in the cotton region of America; a large amount is added to the soil by the ordinary mode of planting, the seed being thickly strewn by handfulls in a continuous row, upon which, after thinning, but a few plants are allowed to remain. The cotton fibre, which constitutes the saleable product, and is absolutely carried off from the land, must be looked upon as a very light crop; a bale of 400 or 500 lbs. to the acre is sometimes obtained under favourable circumstances, but this is much above the average for upland cotton. The fibre yields 1 or 1½ per cent. of ash, so that at the most 7½ lbs. of mineral matter per acre will be removed from the soil annually.

According to Johnston (Lectures on Agricultural Chemistry, p. 216), a crop of wheat of 25 bushels to the acre removes from the soil, *in the grain alone*, about 17·65 lbs. of mineral matter; a crop of barley of 38 bushels carries off, *in the grain*, 46·98 lbs.; a crop of oats of 50 bushels, *in the grain*, 58·05 lbs. According to Liebig

* The practice of selling cotton-seed from the plantation is one to be strongly deprecated; it is beginning to be common in some districts, owing to the increasing manufacture of cotton-seed oil and exportation of the cotton seed-cake to Europe.

(Letters on Modern Agriculture, p. 41), an average crop of potatoes removes from each acre about 163 lbs. of mineral matter; and one of beet about 458 lbs. (leaves included).

With respect to climate, cotton needs a high summer temperature; although not properly a tropical plant, it produces fibre in diminished quantity, though of improved quality, when removed from a southern locality to one further north; it never seems to be directly injured by the most intense midday heat; when other crops, including even Indian corn, are drooping under a blazing sun, the large succulent-looking leaves of a cotton-field will but seem to enjoy the congenial temperature. As is said by the writer of a pamphlet published by the Cotton Supply Association—"*cotton is decidedly a sun-plant.*"

The proper supply of moisture is a point of at least equal importance with temperature, and here appears undoubtedly to lie the main difficulty hitherto experienced in attempts to extend the culture of cotton into new regions. Published statements differ greatly as to the effect of moisture or dryness upon the plant, some writers saying that a wet season is ruinous to cotton and that drainage is of the first importance; while others, especially many of those treating of cultivation in India, insist that irrigation is more necessary than anything else. Dr. Royle* well says, "such terms as moisture and dryness are so entirely comparative, that in one country we hear the cotton plant described as one requiring moisture, and in another we find it stated that no plant requires so little; the fact being, that the plant can bear both great heat and considerable want of water, provided it is growing in a not over-dry atmosphere."

The last sentence states an important part of the truth, but, I think, not the whole; it draws a distinction between *two* forms in which moisture may be supplied to the growing plant, whereas it would seem that *four* should be separately noticed.

1°. The atmosphere may contain a greater or less amount of water in the state of vapour, up to the point of so-called saturation.

2°. The atmosphere may be supersaturated, or in other words, precipitation of liquid water, as rain, &c., may take place from it.

3°. The *soil* may contain a greater or less amount of water intimately united with it, whether by adhesion or chemical combination

* Dr. J. Forbes Royle 'On the Culture and Commerce of Cotton in India and elsewhere,' p. 223.

—such water as is rapidly absorbed from the air by artificially dried soil, and can afterwards be expelled only by the application of a high temperature. This water does not render the soil moist to the touch. It can accumulate in a particular soil to a certain extent only, and this limit may be called the point of saturation of the soil.

4°. The soil may be supersaturated, that is to say, liquid water, evident to the senses as such, may mix with the earth and render it, in the common sense of the term, moist or wet.

Now it would seem that the larger the relative amount of water in the 1st and 3rd of these forms taken up by the cotton plant, and the smaller the quantity received in the 2nd and 4th forms (at least during the greater part of its period of growth), the more favourable will be the result.

In water-soaked soil, *i. e.* holding water in the 4th condition mentioned, cotton will not thrive. The following statements* are borne out by the general experience of planters. "The tap-root of the cotton plant will not strike down into wet soil. . . . . . On wet land the cotton plant grows small, looks sickly, or *scalds* in the hot sun, and bears but little raw cotton, and it takes twice the labour to cultivate it, as the grass usually grows the faster, and is much more difficult to kill out." Such soil will obviously be benefited by draining. On the other hand, the state of things demanding artificial irrigation —very necessary probably in some parts of India—would seem to be simply the absence of water in any one of the three other conditions noticed.

In the early stages of growth the plant receives a moderate supply of rain, *i. e.* water in the 2nd condition named, with advantage; but even then heavy rains are very injurious, and later in the season they are absolutely destructive; the bolls do not open, but fall off, or rot upon the branches—a surface growth of grass and weeds accumulates so rapidly as to choke the crop—the boll worm and other destructive insects make their appearance—and the cotton from bolls already open hangs out in trailing locks, draggled, dirty, and matted together. Dry years are emphatically those of the largest and best crops.

Yet, like all other plants, cotton must be supplied with moisture;

* From the pamphlet 'On the Cultivation of Orleans Staple Cotton,' published by the Manchester Cotton Supply Association, p. 14.

this even seems to be needed in considerable quantity, judging from the extensive leaf-surface from which evaporation is carried on. Aqueous vapour in the air, as suggested by Dr. Royle, and abundant hygroscopic moisture in the soil itself, as I would add, seem to be decidedly the sources from which this requirement is to be met.

The great advantage derivable from a soil of high capacity for absorbing and retaining moisture will be, that it will enable the plant to withstand vicissitudes of weather and season; in damp weather hygroscopic water will be condensed, to be stored up in the retentive soil until required in the midst of drought; in August or September, when seed and fibre are to be formed, and when therefore diminished leaf-activity is desirable, the roots will gradually draw up a supply of this water, limited*, but sufficient to maintain healthy life.

These remarks no doubt apply also to the absorption of gases, and of mineral matter withdrawn from solution, as has been noticed in a previous part of the paper. The power of steadily accumulating and gradually dispersing seems to be one of the well-marked and beautiful provisions of the "*economy of nature*."

The soil of the prairie region of central Alabama fulfils the above conditions admirably, and to this fact should, I believe, be in large measure attributed the success with which cotton is cultivated upon it.

To sum up the results of the examination of this fertile cotton soil, it is shown to be a stiff aluminous clay, containing moderate amounts of organic matter and of the mineral substances needed by the plant as food—of great uniformity, and in an exceedingly fine state of division—above all, possessing a very high capacity for absorbing and retaining heat, moisture, gases, and soluble mineral matter.

APPENDIX.

Mechanical Treatment of Cotton-soil, as practised in Alabama.

In order to complete the subject of Alabama cotton-soil, it seems desirable that to the preceding results should be added a brief state-

* The porous chalky substance referred to as "rotten limestone," which underlies the soil of the cane-brake, has itself very similar capillary and absorptive power; it is penetrated by sandy strata, through which water can readily flow, and hence it is not at all inconceivable that supplies of moisture may even through this be drawn up from the depth of 20 or 30 feet, at which the first sandy bed is often met.

ment of the way in which this soil is usually cultivated, which may easily be done in a few paragraphs.

As early in the winter as the weather is favourable and the condition of the ground suitable, *i. e.* when not too wet*, the preparation for the crop commences by "bedding" the land. This is done by running a narrow plough called a "bull-tongue" at regular intervals across the field, the common distance being four feet between the rows. In very rich alluvial land the distance is sometimes five or even six feet, and in thin poor land not more than three feet. Upon the furrow thus produced the ridge or "bed" is made by ploughing to it on either side with a turning plough, called a "Carey" plough, drawn by two mules or horses, until the space between the rows has been ploughed out. The whole field is in this way thrown into ridges, which should run horizontally round any elevated portions of the plantation, so that heavy rains may not wash away the soil.

When the time for planting arrives—about the beginning of April—a furrow is run along the top of each ridge by a narrow plough, and in this furrow the cotton seed is pretty thickly strewn by handfulls as the labourer goes along the row. It is then covered with earth by a heavy wooden block, which a mule or horse draws along, so as not only to cover up the seed, but to press the earth firmly upon it.

If the weather be favourable for the germination of the seed, it comes up in ten days or a fortnight, and soon afterwards the cultivation commences by thinning out the cotton with hoes, so as to leave but a few stalks together at intervals of eight or ten inches, removing also any grass or weeds which may have grown with the cotton. The space between the rows is at the same time ploughed to make the earth light and mellow, and to destroy grass and weeds. Great skill is shown by trained negroes in the use of the plough and hoe,—the former is often run within two inches of the cotton, and the latter used to cut out a weed within an inch or even half an inch, without in either case injuring the cotton itself. The process of working the crop with plough and hoe is continued at intervals of three weeks, and at each time of thus going over the field the cotton is thinned out, until it is brought to a "stand," that is, reduced to single

* The peculiar condition of the "cane-brake" soil (to which the above remarks apply) intermediate between a dry and a thoroughly wet state, in which alone ploughing can well be carried on, has been noticed in an earlier part of the paper.

stalks 12 or 18 inches apart upon the rows. Early in July the plant has usually acquired sufficient size to shade the ground and prevent the further growth of grass, and the crop is then "laid by." It is of the first importance that the land should have been kept perfectly clear of weeds up to this time, and in a hot climate the task is often a difficult one.

Simultaneously with the cultivation of cotton, the cultivation of Indian corn, sweet potatoes, &c., proceeds, in order to furnish food for the negroes of the plantation, for the mules or other draught animals, and for a sufficient number of hogs to yield meat for the labourers.

In middle Alabama the cotton plant usually commences flowering early in June, and continues to bloom until frost kills it, bolls continuing therefore to form during several months. The earliest bolls open, in ordinary years, from the 10th to the 15th of August, when the "picking" season commences. This lasts until the cotton is all gathered—until January or even February, if a full crop be made. The bolls continue gradually to open long after frost has prevented the formation of any more. In picking the cotton from the boll, surprising manual dexterity is shown by negroes accustomed to the task from early youth.

The seed cotton, as it is collected into large baskets by the pickers, is carried to the "gin-house" of the plantation, and "ginned;" and when enough of the clean fibre has accumulated, a day or two is devoted by a part of the hands to pressing it with the large wooden "screw" into bales ready for shipment by river to the sea-port.

XI. "Account of Experiments made at Holyhead (North Wales) upon the Transit-Velocity of Waves through the Local Rock Formations." By Robert Mallet, Esq., C.E., F.R.S. Received June 18, 1861.

(Abstract.)

These experiments were made by the author at the joint request of the Royal Society and of the British Association for the Advancement of Science, aided by grants from each of those bodies.

Their object was to ascertain the transit rate or velocity of propagation of waves of elastic compression, analogous to those of na-