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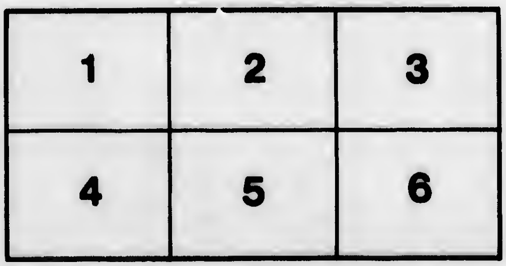
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CATECHISM

OF

AGRICULTURAL CHEMISTRY

AND

GEOLOGY.

BY

JAMES F. W. JOHNSTON, M.A., F.R.SS.L. & E.

HONORARY MEMBER OF THE ROYAL ENGLISH AGRICULTURAL
SOCIETY, AND AUTHOR OF "LECTURES ON
AGRICULTURAL CHEMISTRY AND GEOLOGY."

WILLIAM BLACKWOOD AND SONS,
EDINBURGH AND LONDON.
M.DCCC.XLIV.

PRINTED BY STARK AND COMPANY, EDINBURGH.

TO

THE SCHOOLMASTERS AND TEACHERS OF GREAT BRITAIN AND IRELAND.

GENTLEMEN,

HAVING written the present little work with a view to the more speedy improvement of the agriculture of our common country, I take the liberty of dedicating it to you. No class of men possesses in so high a degree the power of promoting an object so important to all. I am anxious, therefore, to secure, not only your willing support, but your cordial co-operation also.

The land from which our crops are raised must be rendered more productive, if food is to be grown *at home* for our increasing population. But the produce can be largely increased only by the application of increased knowledge to the culture of the soil; —and it is the rising generation now under your care which must possess and apply this knowledge. You can scarcely render a higher service to your country, therefore, than by imparting, along with your other instructions, the rudiments of that kind of knowledge on which its prosperity must so greatly depend. Few of your pupils will then escape from your hands so early as not to have already learned what may enable them on some spot or other in after life, "*to make two blades of grass grow where only one grew before.*"

I have the honour to be,

GENTLEMEN,

Your obedient Servant,

JAMES F. W. JOHNSTON.

EDINBURGH,
1st *February* 1844.

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ADVERTISEMENT.

The Author believes that the country teacher who may introduce this little Catechism into his school will find no difficulty in making his elder classes understand the different subjects which are successively adverted to. It will not be necessary to make them commit the very words of each answer to memory, but rather so to make themselves masters of the matter of each, as to be able to express the sense of the answers in words of their own.

On first going over the questions, the pupils' attention may be confined to such only as the teacher may consider most important, or most applicable to local practice. The other questions will be taken up on a second perusal, and an occasional general catechising upon the whole book will fix the matters treated of more firmly in the minds of his scholars.

The teacher himself will find further information in the Author's *Elements* and published *Lectures on Agricultural Chemistry and Geology;* and any little apparatus he may require will be readily obtained, at the cost of a few shillings, from Richard Griffin and Co. of Glasgow.

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CATECHISM

OF

AGRICULTURAL CHEMISTRY AND GEOLOGY.

Q. What is agriculture?

A. Agriculture is the art of cultivating the soil.

Q. What is the object of the farmer in cultivating the soil?

A. The object of the farmer in cultivating the soil is, to raise the largest crops, at the smallest cost, and with the least injury to the land.

Q. What ought the farmer especially to know, in order that he may attain this object?

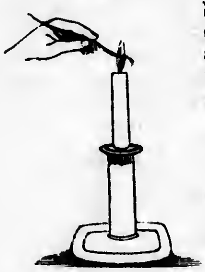
A. The farmer ought especially to know the nature of the crops he raises, of the land on which they grow, and of the manures which he applies to the land.

I.—OF THE NATURE OF THE CROPS HE RAISES.

Q. Of what parts do all vegetable substances consist?

A. All vegetable substances consist of two parts, one which burns away in the fire, called the organic part, and one which does not burn away, called the inorganic part.

Fig. 1.



Here the teacher will burn a bit of straw or wood in the candle, and show that one part burns away and that another *very small* part—the ash—does not burn away.

Q. Which of these two parts is the greater in quantity?

A. In all vegetable substances, the organic part is very much the greater. It forms from 90 to 99 out of every 100 lbs. of their weight.

Q. Of what elements does the organic part of plants consist?

A. The organic part of plants consists of four elements, known by the names of carbon, hydrogen, oxygen, and nitrogen.

Q. What is carbon?

A. Carbon is a solid substance, usually of a black colour, which has no taste or smell, and burns more or less readily in the fire. Wood-charcoal, lamp-black, coke, and black-lead, are varieties of carbon.

The teacher will here exhibit a piece of charcoal and show how it burns in the fire, or in the flame of a candle.

Q. What is hydrogen?

A. Hydrogen is a kind of air or gas which burns in the air as coal gas does, but in which a candle will not burn, nor an animal live, and which, after being mixed with common air, explodes when it is brought near the flame of a candle. It is also the lightest of all known substances.

Here the teacher will take a beer or champaign glass (fig. 2), will put into it some pieces of zinc or iron filings, and pour over them a small quantity of oil of vitriol (sulphuric acid) diluted with twice its bulk of water, and cover the glass for a few minutes. On putting in a lighted taper, an explosion will take place. He will then repeat the same

Fig. 2.

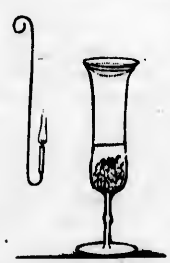


Fig. 3.

experiment in a phial, into the cork of which he has introduced a common gas jet (fig. 3). After a short time, when the hydrogen gas produced has driven out all the common air from the bottle, a light may be applied to the jet, when the gas will take fire and burn. The cork and jet may now be taken out of the bottle, and a lighted taper introduced into it, when the taper will be extinguished, while the gas itself will take fire and burn at the mouth of the bottle. Lastly, if the teacher possesses a small balloon, he may fill it with the gas by attaching it to the mouth of the

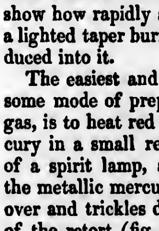
Fig. 4.

bottle, and may thus show that the gas is so light that it will carry heavy bodies up with it through the air.

Q. What is oxygen?

A. Oxygen is also a kind of air, in which a candle burns with great brilliancy, in which animals also can live, and which is heavier than hydrogen or common air. It forms one-fifth of the bulk of the air we breathe.

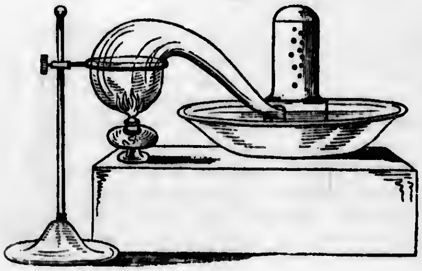
Fig. 5.



The teacher will here exhibit a bottle of oxygen gas, and show how rapidly and brilliantly a lighted taper burns when introduced into it.

The easiest and least troublesome mode of preparing oxygen gas, is to heat red oxide of mercury in a small retort by means of a spirit lamp, and to collect the metallic mercury as it distils over and trickles down the beak of the retort (fig. 6). This is not so very costly a process as it

(Fig. 6.)



appears to be, since there is no loss of any thing. A pound of the red oxide costs 6s. 8d., and gives 14 oz. of metallic mercury, worth 4s. 8d.

Q. What is nitrogen?

A. Nitrogen is also a kind of air differing from both of the other two. Like hydrogen, a taper will not burn nor will an animal live in it, but unlike hydrogen, it will not burn, and it does not take fire when brought near the flame of a candle. It is a little lighter than atmospheric air, of which it forms four-fifths of the bulk.

The teacher will here exhibit a bottle of this gas, and show that a lighted taper is extinguished when introduced into it.

The easiest mode of preparing nitrogen is by mixing together a quantity of sal ammoniac with half its weight of salt-petre, both in fine powder, and heating them in a retort over a lamp. The gas which comes off is collected over water, as shown above (fig. 5).

Q. Do all vegetable substances contain these four elements?

A. No, the greater number contain only three, viz. carbon, hydrogen, and oxygen.

Q. Name some of the more common substances which contain only these three.

A. Starch, gum, sugar, the fibre of wood, oils, and fats, contain only these three elements.

Q. Of what substances does the inorganic part of the plant consist?

A. The inorganic part of plants contains from eight to ten different substances, namely, potash, soda, lime, magnesia, oxide of iron, silica, chlorine, sulphuric acid, or oil of vitriol, and phosphoric acid.

Here the teacher may exhibit to his pupils, potash in the form of the common *pearl ash* of the shops; soda, in that of the *common soda* of the shops; lime and magnesia, in the forms of *quicklime* and *calcined magnesia;* oxide of iron, in the form of *rust* of iron; silica, in the form of a piece of *flint*, *rock crystal* or *quartz*, (*chucky-stone*); a bottle of *chlorine gas*, one of sulphuric acid, (*oil of vitriol*), and one containing a little phosphoric acid, or burnt bones in which phosphoric acid is present. By placing these substances, or the bottles containing them, before the eyes of the pupils occasionally, they will soon become familiar with their names and with their several qualities.

Q. What is potash?

A. The common potash of the shops is a white powder, which has a peculiar taste called an *alkaline* taste, and which becomes moist, and at last runs to a liquid when exposed for a length of time to the air. It is obtained by washing wood ashes (the ashes left by wood when it is burned) with water, and afterwards boiling the liquid to dryness.

The teacher will here allow his pupils to taste the potash, that they may become familiar with the meaning of the word alkaline as applied to taste.

Q. What is soda?

A. The common soda of the shops is a glassy or *crystallized* substance, which has also an alkaline taste, but which, unlike potash, becomes dry and powdery by being exposed to the air. It is manufactured from sea salt.

The teacher will show a crystal of the common soda of the shops, and explain the meaning of the word *crystallized.*

Q. What is lime?

A. Lime or *quick*-lime is a white earthy substance, which is obtained by burning common limestone in the lime-kiln. It has a slightly burning taste, and becomes hot and *slakes* when water is poured upon it.

The teacher will exhibit a piece of quicklime, will allow his pupils to taste it, and will pour water upon it, that it may fall to powder. They will thus become familiar with the word *slake*.

Q. What is magnesia?

A. Magnesia is the white powder sold in the shops under the name of *calcined* magnesia. It has scarcely any taste, and is extracted from sea water and from some kinds of limestone rock.

Q. What is iron?

A. Iron is a hard bluish-gray *metal*, which is manufactured in large quantities in our iron-works, and is used for a great variety of useful purposes.

The teacher will here explain the word *metal*, by showing that such common metals as iron, copper, lead, silver, and gold have a lustre, weight, and malleability not possessed by wood, stones, and other substances to which the name of metals is not applied.

Q. What is *oxide* of iron?

A. When polished iron is exposed to the air it gradually becomes covered with rust. This rust consists of the metal iron, and of the gas oxygen which the iron has attracted from the air, and hence it is called an *oxide* of iron.

The teacher will explain more fully, that, when metals combine with oxygen, they form *new* substances, to which the name of *oxides* is given, and illustrate this by a reference to the *red oxide* of mercury, which, by the heat of the lamp, he had resolved or *decomposed* into oxygen gas and metallic mercury (see fig. 5).

Q. What is silica?

A. Silica is the name given by chemists to the substance of flint, of rock-crystal, and of sandstones.

Q. What is chlorine?

A. Chlorine is a kind of air which has a greenish-yellow colour, and a strong suffocating smell. A taper burns in it with a dull smoky flame. It exists in common salt in large quantity.

The teacher will exhibit a bottle of this gas, and may advert to the remarkable fact that this very noxious gas should form more than half the weight of the very wholesome substance common salt. It is readily made by pouring muriatic acid on black oxide of manganese in a retort, and applying a gentle heat. It should be collected over hot water.

Q. What is sulphuric acid or oil of vitriol?

A. Sulphuric acid or oil of vitriol is a very sour burning oily liquid, which is manufactured from burning sulphur (brimstone). It exists in common gypsum, in alum, and in Glauber and Epsom salts.

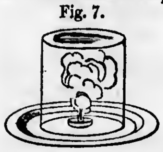
The teacher will here exhibit oil of vitriol, and show that when a piece of straw is put into it, it is charred or burned black. He will also exhibit gypsum, alum, Glauber and Epsom salts, and show, that, though the sulphuric acid exists in them, they have none of its burning properties.

Q. What is phosphoric acid?

A. Phosphoric acid is also a very sour substance, which is made by burning phosphorus in the air. It exists in large quantity in the bones of animals.

If the teacher possess any phosphorus, he may here show how it burns with *white fumes* in the air, and may collect these white fumes—which are phosphoric acid—by holding over them a cold glass or metal plate, or he may simply burn the phosphorus in a little cup under a tumbler (fig. 7).

Fig. 7.



Q. Are all these substances to be found in the inorganic part of plants?

A. Yes, they are to be found in the ash of all our usually cultivated plants.

Q. Do all plants leave the same quantity of ash when burned?

A. No. Some leave much more ash than others. Thus 100 lbs. of hay leave 9 or 10 lbs. of ash, while 100 lbs. of wheat leave less than 2 lbs. of ash.

Q. Does the ash of different plants contain all these substances in the same proportion?

A. No. They exist in different proportions in the ash of different plants—the ash of wheat, for example, contains more phosphoric acid than that of hay, while that of hay contains more lime than the ash of wheat.

II.—OF THE ORGANIC FOOD OF PLANTS.

Q. Do plants require food as animals do?

A. Yes, all plants require constant supplies of food in order that they may live and grow.

Q. Where do plants obtain their food?

A. They obtain it partly from the air and partly from the soil.

Q. How do they take in their food?

A. They take it in by their leaves from the air, and by their roots from the soil.

Q. Do plants require two distinct kinds of food?

A. Yes, they require organic food to support their organic part, and inorganic food to support their inorganic part.

Q. Whence do they obtain their organic food?

A. They obtain their organic food partly from the air and partly from the soil.

Q. Whence do they obtain their inorganic food?

A. They obtain their inorganic food wholly from the soil in which they grow.

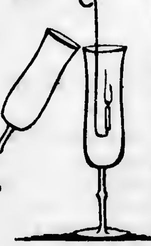
Q. In what form do plants take in organic food from the air?

A. In the form chiefly of carbonic acid gas.

Q. What is carbonic acid gas?

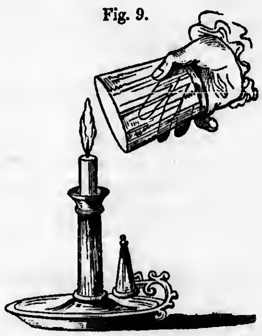
A. It is a kind of air, which has no colour, but has a peculiar smell. Burning bodies are extinguished in it, and animals die, and it is heavier than common air. It causes the boiling up of soda water, and the frothing of beer, and forms nearly half the weight of nearly all limestone rocks.

Fig. 8.



Here the teacher will prepare carbonic acid gas, by pouring dilute muriatic acid (spirit of salt) upon bits of limestone in a tall covered beer glass (as in fig. 2)—show that a burning taper is extinguished by it; but that it does not, like hydrogen, take fire itself;—that it is so heavy, that it may be poured from one glass to another (fig. 8); and that, when poured from a large tumbler, a common candle may be put out by it (fig. 9).

Fig. 9.



Q. Does carbonic acid gas form a large part of the atmospheric air?

A. No, the atmospheric air consists almost entirely of a mixture of oxygen and nitrogen gases. Five gallons of air contain about four of nitrogen and one of oxygen, but in 5000 gallons of air there is only 1 gallon of carbonic acid gas.

Q. Do plants drink in much carbonic acid from the air?

A. Yes, they drink it in in very large quantity.

Q. How can plants drink in so large a quantity of this gas from the air, which contains so little?

A. They spread out their broad thin leaves in great numbers through the air, and thus are able to suck in the carbonic acid from a large quantity of air at the same time.

Q. How do they suck it in?

A. By means of a great number of small openings or small mouths which are spread every where, especially over the upper surface of the leaf.

Q. Do the leaves suck in this carbonic acid at all times?

A. No, only during the daytime. During the night they give off a quantity of carbonic acid.

Q. What does carbonic acid consist of?

A. Carbonic acid consists of carbon, or charcoal, and oxygen.

Q. How do you prove this?

A. By burning charcoal in oxygen gas, when carbonic acid gas will be found.

The teacher will show this experiment, by introducing a piece of red-hot charcoal into a bottle of oxygen gas until the charcoal is extinguished, when, upon putting a lighted taper into the bottle, he will find carbonic acid has been formed, for the taper will be extinguished.

Q. Does the plant retain both the carbon and the oxygen contained in the carbonic acid that is absorbed by its leaves?

A. No, it retains only the carbon, giving off the oxygen again into the air.

Q. How do you show that the leaves give off this oxygen gas?

A. By putting a few green leaves under a tumbler or gas-receiver full of water, and setting them out in the sunshine, when small bubbles of oxygen gas will be seen to rise from the leaves, and to collect in the upper part of the tumbler (fig. 10).

Fig. 10.

Q. Do the leaves of plants drink in anything else from the atmosphere?

A. Yes, they drink in watery vapour.

Q. What purpose does this vapour serve?

A. It serves in part to moisten the leaves and stems, and partly to form the substance of the plant itself.

III.—OF THE SUBSTANCE OF PLANTS.

Q. What does the substance of plants chiefly consist of?

A. The substance of plants chiefly consists of woody-fibre, starch, and gluten.

Q. What is woody fibre?

A. Woody fibre is the substance which forms the greater part of all kinds of wood, straw, hay, and chaff, of the shells of nuts, and of cotton, flax, hemp, &c.

Q. What is starch?

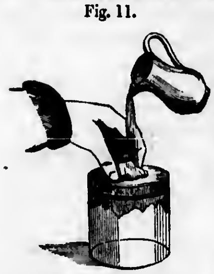
A. Starch is a white powder, which forms nearly the whole substance of the potatoe, and exists in large proportion in oat-meal, in wheaten flour, and in the flour of other kinds of grain cultivated for food.

Q. What is gluten?

A. Gluten is a substance like bird-lime, which exists, along with starch, in almost all plants. It may be obtained from wheaten flour, by making it into a dough, and washing it with water.

The teacher will here mix flour with water into a dough, and wash it with water upon a piece of thin muslin tied over the mouth of a tumbler or large glass, and will show how the milky water carries the starch through the muslin, and leaves the gluten behind, and how, after a time, the starch settles at the bottom of the water, in the form of a white powder.

Fig. 11.



Q. Which of these three substances is usually most abundant in plants?

A. The woody fibre is the most abundant in nearly all plants.

Q. In what part of the plant is the starch found most plentifully?

A. The starch is found most abundantly in the seeds of plants, and in the roots of such as resemble the potatoe.

Q. What do woody fibre and starch, and also gum and sugar consist of?

A. They all consist of carbon and water only.

Q. May they then be formed from the substances which the leaves drink in from the air?

A. Yes, because the leaves drink in carbonic acid and water.

Q. Can you tell then, why the leaves give off the oxygen of the carbonic acid into the air?

A. Yes, they require only carbon and water to form the woody fibre and starch, of which they consist, and therefore they give off the oxygen of the carbonic acid because they cannot make use of it.

Q. If plants suck in so much carbonic acid from the air, may they not at length rob the air of the whole of the small proportion of carbonic acid it contains?

A. No, because new supplies of this gas are continually returning into the air.

Q. Whence do those supplies come?

A. They come from three sources; *first*, from the breathing of animals, since all animals continually throw off carbonic acid from their lungs every breath they exhale.

Second, from the burning of wood, coal, candles, &c. since the carbon which wood contains, when it burns in the air, forms carbonic acid gas just as carbon when burnt in oxygen does.

Third, from the decay of vegetables and roots in the soil, since this decay is only a slow kind of burning, by which the carbon of plants becomes converted into carbonic acid.

Q. Do animals and plants thus appear to live for each other's support?

A. Yes, the animal produces carbonic acid, upon which plants live, and from this carbonic acid and water together, plants produce starch, &c. upon which animals live.

Q. Woody fibre, starch, gum, and sugar consist of carbon and water only, of what does water itself consist?

A. Water consists of oxygen and hydrogen.

Q. How much of each of these elements is contained in water?

A. Every 9 lbs. of water contain about 8 lbs. of oxygen, and 1 lb. of hydrogen.

Q. Is it not a very extraordinary thing that *liquid* water, which puts out all fire, should consist of two *gases*, one of which (hydrogen) burns readily, while in the other (oxygen) bodies burn with great brilliancy?

A. Yes, it is very wonderful, but there are many other substances the composition of which is almost equally extraordinary.

Q. Can you name any such substances?

A. Yes, it is almost equally extraordinary that *white* starch should consist of *black* charcoal and water only,—and that sugar and gum should consist of the same elements as starch and woody fibre.

Q. Of what *elements*, then, do all these substances consist?

A. They consist of carbon, hydrogen, and oxygen.

The teacher may take this opportunity of explaining more particularly the word elements, contrasting the nature of the *elementary* bodies, hydrogen, oxygen, carbon, and nitrogen, *which cannot be separated or split up into more than one kind of matter*, with such *compound* bodies as carbonic acid, water, starch, and oxide of mercury, which *can be separated* into more than one.

Q. Of what does gluten consist?

A. Gluten consists of all the four elements—carbon, hydrogen, oxygen, and nitrogen—united together.

Q. Can the plant derive from the air all the elements of which gluten consists?

A. No, it can obtain carbon, hydrogen, and oxygen, as we have seen, from the air, but the nitrogen it obtains only from the soil.

IV.—OF THE SOIL ON WHICH PLANTS GROW.

Q. What does the soil consist of?

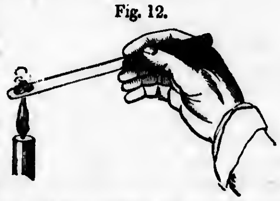
A. The soil consists of an organic or combustible, and of an inorganic or incombustible part.

Q. How do you show this?

A. By heating a portion of soil to redness on a bit of sheet iron, or on the end of a knife, either in the fire or over a lamp. The soil will first turn black, showing the presence of *carbonaceous* matter, and will then be changed to a brown or reddish colour as this black organic matter burns away.

The teacher will show this experiment, and will explain the meaning of the new word *carbonuceous.*

Fig. 12.



Q. Whence is the organic part of the soil derived?

A. It is derived from the roots and stems of decayed plants, and from the dung and remains of animals and insects of various kinds.

Q. Does this organic part form a large proportion of the soil?

A. Of peaty soils it forms sometimes three-fourths of the whole weight, but of rich and fertile soils it does not form more than from a twentieth to a tenth of the whole weight.

Q. Can a soil bear good crops which does not contain a considerable proportion of organic matter?

A. Not in our climate. A rich soil generally contains at least one-twentieth of its weight (5 per cent.) of organic matter.

Q. Does the organic matter increase or diminish in the soil, according to the way in which it is cultivated?

A. Yes, it diminishes when the land is frequently ploughed and cropped, or badly manured; and it increases when the land is laid down to permanent pasture, or when large doses of farm-yard manure or of peat compost are given to it.

Q. What purpose does this organic matter serve in the soil?

A. It supplies the organic food which plants draw from the soil through their roots.

Q. Do plants draw much of their organic food from the soil?

A. The quantity they draw from the soil varies with the kind of plant, with the kind of soil, and with the season; but it is always considerable, and is necessary to the healthy growth of the plant.

Q. If plants always draw this organic matter from the soil, will the soil not become gradually poorer and less productive?

A. It will, if badly managed and constantly cropped.

Q. Then how can you keep up the supply?

A. By ploughing in green crops,—by growing clovers, and other plants which leave long roots in the soil,—by restoring all the hay and straw to the land in the form of manure,—or by laying down to pasture.

The teacher may illustrate this answer beneficially, by referring to the practice in his own or the neighbouring parishes, and pointing out its advantages or defects.

Q. Whence is the inorganic part of the soil derived?

A. The inorganic part of the soil is derived from the crumbling down of the solid rocks.

The teacher will satisfy his pupils—by drawing their attention to the decaying walls of buildings, to the heaps of what is called *rotten rock* (decomposed trap or whinstone)—of limestone gravel, &c., which are found at the foot of the hills—that rocks really do crumble down in the air.

Q. Of what do these rocks principally consist?

A. They consist of more or less hardened sandstones, limestones, and clays.

The teacher may exhibit as specimens of

Sandstone—red and white, or other freestones;

Limestone—chalk and blue or other limestones;

Clays—roofing slate, and the shale and shiver of the coal beds.

Q. Do soils consist principally of the same substances?

A. Yes, soils consist principally of sand, clay, and lime.

Q. How would you name a soil which contained one or other of these in large quantity?

A. If it contained very much sand, I would call it a sandy soil; if much clay, a more or less stiff clay soil; if much lime, a *calcareous* soil.

The teacher will explain the new word *calcareous*.

Q. But if they were mixed together in large proportions how would you name them?

A. A mixture of sand and clay with a little lime I would call a loam; if much lime was present, I would call it a calcareous loam; and if it were a clay with much lime, I would call it a calcareous clay.

Q. What do you understand by *light* and *heavy* lands?

A. *Light* lands are such as contain a large proportion of sand or gravel; *heavy* lands, such as contain much clay.

The teacher may illustrate this, by referring to the different kinds of land which occur in the neighbourhood.

Q. Which of these two kinds of land is most easily and cheaply cultivated?

A. The light lands, called often also barley or turnip soils.

Q. Why are these lands called barley or turnip soils?

A. Because they have been found to be peculiarly fitted for the growth of barley and of turnip and other green crops.

Q. Do heavy or light lands usually stand most in need of draining?

A. The heavy clay lands retain water most, and should therefore be generally drained first.

Q. Do light lands not require draining?

A. Yes, though dry at the surface, such soils are often wet beneath, and would pay well for draining.

The teacher may illustrate this, by referring his pupils to what they may see on the sea beach, or on the banks of a river, where the surface of the sand may be dry and drifted by the wind, while it is quite wet a few inches below.

Q. To what depth would you drain your lands?

A. If I could get a fall I would never have my drains shallower than 30 inches.

Q. Why would you put them so deep?

A. Because the deeper the soil is made, the deeper the roots can go in search of food.

Q. Can you give me any other reason?

A. Yes, when my drains are so deep I can go down 20 or 22 inches with my subsoil-plough without any risk of injuring them.

Q. Does draining serve any other purpose besides that of carrying off the water from the land?

A. Yes, it lets in the air to the subsoil, and allows the rain-water to sink down and wash out of it any thing which may be hurtful to the roots of plants.

Q. Do such hurtful substances often collect in the subsoil?

A. Yes, very often, and crops which look well at first, often droop or fail altogether when their roots get down to the hurtful matter.

The teacher may illustrate this answer by referring to the layers of iron-ochre, or *pan*, which in many districts, are met with,—and to such curious facts as that observed in the East of Fife, where the beans and oats, which look well up to April or May, often blacken and fail in June or July, when the roots get down to the ochrey subsoil. It is the local saying when this happens—that *the beans or oats have gone to Auchtermuchty*—a fair being held there about the time when the beans usually fail.

Q. Why are many of the heaviest clays in the country laid down to permanent pasture?

A. Because the expense of ploughing and working these soils is so great, that the value of the corn reaped from them is not sufficient to pay the farmer for his trouble.

Q. How could these heavy clay lands be rendered lighter and more cheap to work?

A. By draining, subsoil ploughing, and by the addition of lime or marl when it is required.

The teacher will here explain to his pupils the difference between *common ploughing*, which merely turns over the surface soil,—*subsoil ploughing*, which only stirs and loosens the subsoil,—and *trench ploughing* or trenching, which brings the subsoil to the surface.

Q. Would the land after this treatment also give greater crops of corn?

A. Yes, not only would it be more cheaply worked, but it would yield a greater number of bushels of wheat an acre than before.

Q. Would this increase be sufficient to pay the cost of draining?

A. Yes, the cost of draining clay lands is generally paid back in three, or, at the utmost, in five, years, and the crops still continue greater than before.

V.—OF THE INORGANIC FOOD OF PLANTS.

Q. What are the purposes served by the inorganic part of the soil?

A. The inorganic or earthy part of the soil serves two purposes; *first*, it serves as a medium, in which the roots can fix themselves, so as to keep the plant in an upright position; and, *second*, it supplies the plant with inorganic food.

Q. The inorganic part of the soil consists *chiefly* of sand, clay, and lime; does it contain no other substances?

A. Yes, it contains small quantities of eight or nine other substances.

Q. Name these substances?

A. Potash, soda, magnesia, oxide of iron, oxide of manganese, sulphuric acid, phosphoric acid, chlorine.

Q. Are not these the same substances which exist in the ash or inorganic part of plants?

A. Yes, the same substances exactly—only they form a much larger proportion of the soil than they generally do of plants.

Q. Do you understand, then, where plants obtain all the inorganic matters they contain?

A. Yes, they obtain them from the soil only.

Q. Why can they not obtain them from the air?

A. Because potash, soda, magnesia, &c. do not exist in the air.

Q. How does this earthy matter enter into the plant?

A. It enters by the roots.

Q. In what state?

A. In a state of *solution.* The rain and spring waters *dissolve* them and carry them into the roots.

Here the teacher will explain the meaning of the new words *dissolve* and *solution*—showing how salt and sugar melt away or *dissolve* in water, forming clear *solutions* of salt or sugar in which these substances can be recognized only by the sense of taste—but from which they may again be obtained *unchanged* by boiling off the water.

Q. Do all soils contain every one of the inorganic substances, potash, soda, lime, &c. which you have mentioned?

A. All fertile or productive soils do.

Q. Why *must* a fertile soil contain them all?

A. Because plants require them all for their healthy growth.

Q. Do plants require them all in equal proportion?

A. No. Plants must have a certain small quantity of each of them, but they require more of some substances than of others.

The teacher may illustrate this question by directing the attention of his pupils to the following table, which he should cause to be copied upon a large piece of calico, and hung upon the wall of his school-room. He can thus readily point out, that, while 1000 lbs. of red clover hay leave 75 lbs. of ash, there are present in this ash 28 lbs. of lime, but only 20 lbs of potash, and less than 4 lbs. of magnesia,—and so on with the ash of the other kinds of hay mentioned in the table.

Quantity of ash left by 1000 lbs. of hay from

	Ryegrass.	Clover. Red.	Clover. White.	Lucerne.
Potash, - -	9	20	31	13½
Soda, - - -	4	5¼	6	6
Lime, - -	7	28	23½	48
Magnesia, -	1	3	3	3½
Alumina, - -	⅓	trace	2	—⅓
Oxide of iron,	—	—	½	—⅓
Silica, - -	28	4	15	3⅓
Sulphuric acid,	3⅔	4½	3½	4
Phosphoric acid,	¼	—6½	5	13
Chlorine, -	trace	3½	2	3
	53¼	74¾	91½	95

This table will suggest to the teacher many instructive questions—which his pupils will readily understand and answer, when they have the table hanging before them.

Q. Are those substances which are present in the plant in such minute quantities really necessary to its growth?

A. They appear to be all equally necessary—just as the few ounces of nails or glue are as necessary to the joiner in making a box, as the many pounds of wood which the box contains.

Q. Suppose a soil to be entirely destitute of some one of these substances, what would happen?

A. Good crops would not grow upon it.

Q. Suppose it to contain a large supply of all the others, but only a small supply of some one or two of these substances, what would happen?

A. Those plants would grow *well* upon it which require only a small quantity of these two substances,—but those which require a large quantity of them would be stunted and unhealthy.

Q. Give me an example.

A. If the land contained little lime, it might grow a good crop of rye-grass, and yet not be able to grow a good crop of lucerne.

By referring to the above table the teacher may exercise the understanding of his pupils by asking for other examples of a similar kind, which the intelligent boy will readily give by considering the numbers on the table. Thus he may say lucerne requires more phosphoric acid than rye-grass does; therefore if there be little phosphoric acid in the soil lucerne will not grow so well upon it as rye-grass would do. Other tables of a similar kind also the teacher may make use of, which he will find in the author's "*Elements*," and especially in his "*Lectures on Agricultural Chemistry and Geology*."

Q. Suppose a soil to be destitute of a considerable number of these different inorganic substances,—what would happen?

A. It would refuse to grow good crops of any kind whatever. It would be *naturally* barren.

Q. Are any soils known to exist which are naturally barren or naturally fertile?

A. Yes; some large tracts of country which have never been cultivated by man are known to be naturally fertile, and others naturally barren.

Q. How is the natural difference between such soils explained?

A. In the fertile soils all those inorganic substances exist, which our cultivated crops require; in the barren soils some of these substances are wholly wanting.

This answer the teacher will illustrate by a reference to the following table, which he will also hang up on the wall of his school-room. It can only do good, indeed, to have this and the preceding table suspended as *permanent fixtures* in the room. The youngest child will thus soon become familiar with all the names,—so difficult for grown-up farmers to recollect.

	Fertile, without Manure.	Fertile, with Manure.	Barren.
Organic Matter, - - - - -	97	50	40
Silica (in the sand and clay),	648	833	778
Alumina (in the clay), - -	57	51	91
Lime, - - - - - - - -	59	18	4
Magnesia, - - - - - - -	8½	8	1
Oxide of iron, - - - - -	61	30	81
Oxide of manganese, - - -	1	3	½
Potash, - - - - - - - -	2	trace	trace
Soda, } chiefly as common salt,	4	—	—
Chlorine, } chiefly as common salt,	2		
Sulphuric acid, - - - - -	2	¾	—
Phosphoric acid, - - - - -	4½	1¾	—
Carbonic acid (combined with the lime and magnesia), -	40	4½	—
Loss, - - - - - - - -	14	—	4½
	1000	1000	1000

The soil, of which the composition is given in the first column, had produced crops for 100 years without manure,—*and still contained a sensible quantity of all the substances required by plants.* That in the second column produced good crops when regularly manured,—*it was in want of three or four substances only which were given to it by the manure.* The third was hopelessly barren,—*it was in want of many substances which ordinary manuring could not supply.*

Q. May a soil be barren though it contains all the substances which plants require?

A. Yes, if it contain a very large proportion of some one, such as oxide of iron, which in great quantity is injurious to the soil.

Q. How would you improve a soil of this kind?

A. I would thorough-drain and subsoil it, that the rains might sink through it and wash out the injurious matter, and I would lime it if it required lime.

Q. May a soil which is naturally fertile, be rendered barren by continued cropping?

A. Yes, if the *same kind* of cropping be carried on for a long time, the land will gradually become less and less productive.

Q. How is this explained?

A. Every crop takes away from the soil a certain quantity of those substances which all plants require. If you are always taking out of a purse it will at last become empty.

Q. Then you liken exhausted land to an empty purse?

A. Yes, the farmer takes his money out of the land, and if he is always taking out and putting nothing in, it must at last become empty or exhausted.

Q. But if he puts something into the soil now and then, he may continue to crop without exhausting it?

A. Yes, if he put in *the proper substances, in the proper quantities, and at the proper time,* he may keep up the fertility of his land—perhaps for ever.

Q. How much of every thing must the farmer put into his land to keep it in its present condition?

A. He must put in at least as much as he takes out.

Q. To make his land better, how much must he put in?

A. He must put in more than he takes out.

Q. But if he is to put into the land as much or more than he takes out, where is his profit to come from?

A. His profit consists in this, that he takes off the land what he can sell for much money, and he puts in what he can buy for comparatively little money.

Q. How do you mean?

A. I mean that if I sell my oats and hay, I get a much higher price for them than I give when I buy them back again in the form of horse dung.

Q. Then the farmer can really afford to put as much upon his land as he takes off, and yet have a profit?

A. He can. He puts in what is cheap, and takes off what is dear.

The teacher may avail himself of this occasion to point out how beautifully and bountifully the earth and the plant are made to work into the hands of the practical farmer, by converting into valuable produce what he lays on in the form of a worthless refuse—and how they always do most for the skilful, the prudent, and the industrious.

Q. What do you call the substances which the skilful farmer thus puts into his land?

A. They are called *manures*,—and when putting them in, the farmer is said to manure his soil.

VI.—OF THE MANURING OF THE SOIL.

Q. What is a manure?

A. Any thing that furnishes food to plants may be called a manure.

Q. How many principal kinds of manure are there?

A. There are three principal kinds,—vegetable manures, animal manures, and mineral manures.

Q. What do you mean by vegetable manures?

A. By vegetable manures, I mean those parts of plants which are usually buried in the soil for the purpose of making it more productive.

Q. Name the most important of the vegetable manures.

A. Grass, clover, straw, hay, potatoe-tops, rape-dust, &c.

Q. Is green grass ever used for manuring the soil?

A. Yes, the soil is manured with green grass when grass land is ploughed up.

Q. Would you bury the sods deep if you were ploughing up grass land?

A. No, I would keep the sods so near the surface that the roots of the young corn could feed upon the decaying grass.

Q. Are any other plants ploughed in green for the purpose of manuring the soil?

A. Yes, clover, buck-wheat, rape, and in some places even young turnips are ploughed in green to enrich the soil.

Q. Into what kind of soils would you plough in a green crop?

A. Into light and sandy soils, and into such as contain very little vegetable matter.

Q. Is not sea-weed or sea-ware a very valuable manure?

A. Yes, wherever sea-weed can be obtained in large quantity, it is found to enrich the soil very much.

Q. How is it employed?

A. It is either spread over the land and allowed to rot and sink in, or it is made into a compost, or it is put into the potatoe drills in the fresh state.

Q. When used in this last way does it give large crops of potatoes?

A. Yes, on the west coast of Scotland it is said to give large crops of potatoes, but of inferior quality.

Q. How would you prefer to make a compost of sea-weed?

A. I would mix the sea-weed with earth and with shell sand or marl if they were to be had, and turn it over once or twice before using it.

Q. Are there any common green vegetables that are ploughed in with advantage?

A. Yes, potatoe-tops dug in, or turnip-tops, when the roots are lifted, make the next year's corn better.

Potatoe or turnip tops ploughed in make the succeeding barley or wheat crop so much better, that, about Edinburgh, the turnip tops are reckoned equal to 8 tons of farm-yard manure, or L.2 an acre. It is said, how-ever, that the clover which succeeds the corn is worse when the tops have been ploughed in,—that it is sickly, and sometimes fails altogether.

Q. How can you get the largest quantity of green manure in the form of potatoe-tops?

A. By pulling off the blossoms, the tops are kept in a green state till the potatoes are dug up, and thus give much green manure.

Q. In what form is hay usually employed as a manure?

A. Hay is usually given to the horses, and afterwards put upon the land in the shape of their dung.

Q. In what form is straw used as a manure?

A. Straw in some places is given to the cattle—in other places it is partly given to the cattle and partly trodden among the litter—while in places again, where few cattle are kept, it is sometimes rotted with water and a little cow dung, and put on the land in a half fermented state.

Q. In what state of fermentation would you prefer putting your straw into the land?

A. That would depend upon the kind of land.

Q. Suppose you had to manure light land for a green crop?

A. Then I would like to have my straw pretty well fermented and mixed with the droppings of a good many cattle.

Q. But suppose you were manuring heavy clay land during the naked fallow before a crop of wheat?

A. I would then rather have my straw more loose and unfermented. It would help to keep my land open.

Q. What are rape-cake and rape-dust?

A. Rape-cake is the refuse that remains when rape seed is crushed in the mill to squeeze out the oil. When the cake is crushed it is called rape dust.

Q. How is rape-dust applied as a manure?

A. It is applied to turnips or potatoes either in place of the whole or of a part only of the common farm-yard dung—and it is in many parts of the country applied with great profit as a top-dressing to the young wheat in spring.

Q. What are the most important animal manures?

A. The blood, flesh, bones, hair, wool, and the dung and urine of animals, and the refuse of fish.

Q. In what form is blood usually employed as a manure?

A. In this country it is usually mixed up with other refuse in the dunghills of the butchers. In other countries it is dried and applied as a top-dressing, or drilled in with the seed. It is one of the most powerful manures.

Q. How is flesh employed as a manure?

A. The flesh of dead horses, cows, and dogs buried in soil with a little marl, makes a most enriching compost.

Q. In what form are bones employed as a manure?

A. Bones are crushed in mills, and then sifted into the various sizes of inch bones, half-inch bones, and dust.

Q. In which of these forms do they act most quickly?

A. They act most quickly in the form of dust, but they do not act for so long a time.

Q. To what crops are they most usually applied?

A. Bones are most profitably employed on light or on well-drained lands, instead of the whole or of a part of the farm-yard manure. When employed without farm-yard manure, they are often mixed with wood ashes, and drilled in with the turnip seed.

Q. Would you raise all your turnip crops with bones alone?

A. No, if I raised one crop of turnips from bones alone, I would raise the next crop on the same field with farm-yard manure alone—if I could get it.

Q. Are bones ever applied to grass lands?

A. Yes, to grass lands that have long been pastured for dairy purposes, as in Cheshire, they have been applied with great profit. Even when the grass lands are wet, the bones have produced remarkable benefits.

Q. What do bones consist of?

A. Bones consist of glue or *gelatine*, which may be partly extracted by boiling them in water, and partly of bone-earth, which remains behind when bones are burned.

Here the teacher may burn a small splinter of bone in the flame of a lamp or candle, and show that though the organic part (the gelatine) burns away, the inorganic part or bone-earth (*phosphate of lime*) remains behind.

Q. Is the glue or gelatine of bones a good manure?

A. Yes, it is a very powerful manure. It is the principal means of pushing forward the young turnip plant, when this crop is raised by the aid of bones.

Q. What does bone-earth or phosphate of lime consist of?

A. It consists of phosphoric acid and lime.

Q. Does this earth of bones act as a manure?

A. Yes, because all plants contain, and therefore require for their healthy growth a certain quantity of lime and phosphoric acid (see above, Table I.)

Q. Why do old dairy pastures especially require bones?

A. Because, among other reasons, milk and cheese contain much bone-earth, and if these be carried away and sold off the farm, the land is robbed by degrees of this bone-earth, more than of any other substance. Only those grasses can then grow which require little bone-earth.

Q. And what effect follows from adding the bones?

A. The bones supply the bone-earth of which the land had been robbed. New grasses then spring up which contain much bone-earth, and which, when eaten by the cow, can produce a more abundant supply of milk, and richer in cheese.

Q. Is hair much used as a manure?

A. No, hair is generally too expensive to be used as a manure. But in China, where the people's heads are all shaved, the shavings are collected for manure, and the sweepings of our hair-cutters' rooms might be collected with profit.

Q. In what form is wool used as a manure?

A. In the form of woollen rags. Mixed with earth woollen rags make an excellent compost. They are much used for manuring the hop grounds.

The teacher may here describe the hop plant, and explain the purpose for which it is grown and employed by the brewers.

Q. What kinds of animal dung are most commonly employed as manure?

A. Night-soil, horse-dung, cow-dung, sheep's dung, pigs' dung, and birds' dung.

Q. Which of these is the most valuable?

A. In general, night-soil and birds' dung are the most valuable, next, horse-dung, after that, pigs' dung, and, lastly, cow-dung.

Q. Why is night-soil so valuable?

A. Because men generally live upon a mixture of animal and vegetable food, which renders the dung richer.

Q. Why is the solid part of horse-dung richer or hotter than cow-dung?

A. Because the horse voids little urine compared with the cow.

Q. What is the principal objection to using pigs' dung?

A. The disagreeable smell and taste it is said to give to the crops raised from it.

Q. What is the best way of using pigs' dung?

A. The best way is to make it into a compost, or to mix it with the dung of other animals.

Q. Why is cow-dung colder and less liable to ferment than most other kinds of dung?

A. Because the large quantity of urine voided by the cow carries off a great proportion of that which would otherwise cause it to ferment.

Q. In what respect does the mixed dung of animals differ from the food on which they live?

A. It differs principally in containing a less proportion of carbon, and a greater proportion of nitrogen than the food they have eaten.

Q. How comes it to contain less carbon?

A. Because animals throw off a large quantity of the carbon by their breathing.

Q. In what form does the carbon of the food come off from the lungs during breathing?

A. In the form of carbonic acid gas (see figs. 7 and 8).

Q. How much carbon does a man give off in this form from his lungs in a day?

A. A full grown man gives off about half a pound in a day, and a cow or a horse five or six times as much.

Q. Does all the nitrogen of the food remain in the mixed dung and urine of animals?

A. Yes, nearly all the nitrogen remains—mixed with a smaller quantity of carbon than was in the food.

Q. Is this larger proportion of nitrogen the cause of the greater activity of the dung of animals?

A. Yes, it is the principal cause.

Q. What form does this nitrogen assume during the fermentation of animal manures?

A. It assumes, for the most part, the form of *ammonia*.

Q. What is ammonia?

A. Ammonia is a kind of air which has an exceedingly strong smell,—that of the hartshorn of the shops,—and which is absorbed by water in large quantities.

Here the teacher may exhibit a bottle of hartshorn or of smelling salts (*carbonate of ammonia*), and make his pupils acquainted with the smell of ammonia.

Q. Under what circumstances is ammonia produced naturally?

A. It is produced in fermenting compost or manure heaps, and in fermenting urine, and it is the cause of the smell perceived in hot stables.

Q. How can you detect the presence of this ammonia?

A. By dipping a rod in vinegar, and holding it over the heap or in the stable, when, if ammonia is present in the air, white fumes will become visible.

Here the teacher will show this experiment, by dipping a glass rod in vinegar, or in muriatic acid, and holding it over the mouth of his hartshorn bottle, when white fumes will become visible, showing that ammonia is escaping in the form of gas.

Q. What does ammonia consist of?

A. Ammonia consists of the two gases, nitrogen and hydrogen.

Q. How does this ammonia enter into the roots of plants, when it is formed in the manure?

A. It is dissolved in the soil by water, and is then sucked in by the roots.

Q. What substances are formed in the plants by the aid of this ammonia.

A. The gluten and other substances containing nitrogen are formed by the aid of this ammonia.

Q. Is this ammonia, then, a very important ingredient in the manures?

A. Yes, because nitrogen, in some shape or other, is absolutely necessary to the growth of plants.

Q. In which part of the manure,—the solid or the liquid part,—is this ammonia produced in greatest abundance?

A. It is produced in the greatest abundance in the liquid part, especially of cow-dung.

Q. Is it not of great importance, therefore, to preserve this liquid part?

A. Yes, it is of the greatest possible importance, though it is too often allowed to run to waste.

Q. How would you collect the liquid manure of your farm-yard?

A. I would make a large tank or cistern in or close by my farm-yard, in which I would collect it.

Q. How would you use this liquid manure?

A. I would pump it back occasionally upon my dung heaps, so as to promote their fermentation; or I would pour it upon my compost heaps.

Q. Would you not employ it alone as a manure?

A. Yes, during the spring and summer I would dilute it with three times its bulk of water, and after it had fermented for some time, I would put it on my grass land, on my young clover, or on any other young crops, with a water-cart.

Q. Is there any other liquid containing ammonia which might be employed in a similar way?

A. Yes, the ammoniacal liquor of the gas-works, diluted with four or five times its bulk of water, should be collected and employed in the same way as the liquid manure of the farm-yard.

Q. Does birds' dung form a very valuable manure?

A. Yes, pigeons' dung, especially, is a very rich manure; and the dung of sea-fowl has lately been introduced into this country, with great advantage, under the name of Guano.

Q. To what crops can guano be profitably applied?

A. It may be profitably employed as a top-dressing to the young corn crops, or it may be used, instead of the whole or of a part of the farm-yard dung, for the turnip and potatoe crops.

Q. In using it for the turnip or potatoe crop, ought it to be allowed to come in contact with the seed?

A. No, it is better either to cover it, or to mix it with a quantity of earth, so as to prevent the seed from touching it.

Q. Is it proper to mix guano with quicklime?

A. No, because the quicklime sets free the ammonia contained in the guano, and causes it to escape into the air.

Here the teacher may mix a little slaked lime with a spoonful of guano in a wine-glass, and let his pupils smell the ammonia which will come off. Or he may hold over it a rod or feather dipped in vinegar, and show the white fumes. If he have no guano, he may use a little *sal-ammoniac* instead; and may explain that quicklime will, in the same way, drive off ammonia contained in liquid manure and in horse or farm-yard dung, if mixed with any of these.

Q. Is it better to use guano alone, or in place of one-half only of the usual farm-yard manure?

A. It is better husbandry to use it in raising turnips and potatoes, mixed with one-half manure.

Q. Why is it better husbandry?

A. Because the guano, used alone, does not supply to the land a sufficient quantity of organic matter to maintain it in the most productive state.

Q. How much guano would you apply per acre?

A. About two cwts. per acre as a top-dressing for the corn crops, and three or four cwts., when used instead of half dung, for potatoes and turnips.

Q. What kind of fish refuse is usually employed as a manure?

A. In the curing stations the guttings and cleanings of the herring and pilchard and the heads of the cod are extensively employed as a manure.

Q. How is this refuse best used?

A. The best way is to make it into a compost with earth and a quantity of marl, if any of the latter is at hand, and to turn it over once or twice before using.

Q. Name the most important mineral manures.

A. The most important mineral manures are, nitrate of soda, sulphate of soda, common salt, gypsum, kelp, wood-ashes, and lime.

Q. What is nitrate of soda?

A. Nitrate of soda is a white salt-like (saline) substance, which is found in the earth in some parts of Peru, and is often applied with great advantage as a top-dressing to grass lands and to young corn.

Q. What quantity would you lay upon an imperial acre?

A. From 1 cwt. to 1½ cwt. to an imperial acre.

Q. What is sulphate of soda?

A. Sulphate of soda is the substance commonly called Glauber salts: it sometimes produces good effects upon grass land, and when applied as a top-dressing to turnips and to young potatoe plants.

Q. How is common salt applied?

A. Common salt may either be applied as a top-dressing, or it may be mixed with the farm-yard or other manure, or with the water used in slaking quicklime.

Q. In what places is salt most likely to be beneficial?

A. In places that are remote from the sea, or are sheltered by high hills from the winds that pass over the sea.

Q. How do you account for this?

A. Because the winds bring with them a portion of the sea spray, and sprinkle it over the soil to a distance of many miles from the sea shore.

Q. What is gypsum?

A. Gypsum is a white substance, composed of sulphuric acid or oil of vitriol and lime; it forms an excellent top-dressing for red clover, and also for the pea and bean crop.

Q. Under what circumstances ought these salt-like or saline substances to be applied?

A. They ought to be applied in calm weather, in order that they may be equally spread,—and soon after or before rain, that they may be dissolved.

Q. Are mixtures of these substances sometimes more beneficial than any of them applied singly?

A. Yes, a mixture of nitrate and sulphate of soda usually produces a much more beneficial effect upon potatoes than either of them alone, and the same is often the case with a mixture of common salt and gypsum when applied to the bean crop.

The teacher will find some useful particulars upon this point in the author's *Elements of Agricultural Chemistry and Geology*, page 150, which he may consult with advantage, with a view of explaining the subject more fully to his pupils, when he shall think it proper to do so.

Q. What is kelp?

A. Kelp is the ash that is left when sea-weed is burned in large quantities.

Q. Can it be employed usefully as a manure?

A. Yes, as a top-dressing to grass lands and to young corn—or even mixed with the manure for the turnip and potatoe crop it may be employed with much advantage.

Q. Has it been generally employed as a manure in Scotland?

A. Not hitherto, but there is reason to believe that, if fairly tried, it might be profitably employed to a large extent.

Q. Are wood ashes (or the ashes of burned wood) a valuable manure?

A. Yes, applied to grass lands wood-ash destroys moss, and increases their luxuriance; upon young corn and potatoes it produces a similar effect, and is profitably mixed with bones, rape-dust, and other manures which are employed for the turnip crop.

Q. What does limestone consist of?

A. Limestone consists of lime (quicklime) in combination with carbonic acid.

The teacher may here revert to the properties of carbonic acid, and examine his pupils upon what they had previously learned upon this subject.

Q. What name is given to limestone by chemists?

A. It is called by chemists *carbonate of lime.*

The teacher may take this opportunity of verbally explaining the kind of terms by which chemists denote combinations of the sulphuric, phosphoric, and carbonic acids with potash, soda, lime, and magnesia,—that when carbonic acid combines with either of these substances it forms a carbon*ate*, phosphoric acid a phosph*ate*, sulphuric acid a sulph*ate*. Hence, that phosphate of lime denotes a combination of phosphoric acid with lime, sulphate of soda a combination of sulphuric acid with soda, and so on.

Q. Are there not many varieties of limestone?

A. Yes,—some soft, such as chalk,—some hard, such as most of our common limestones,—some of a yellow colour, like the magnesian limestones, which contain magnesia,—some pure white, like the statuary marble,—some black, like the Derbyshire black marble, and so on.

Here it would be advantageous if the teacher could exhibit these and other varieties of limestone.

Q. What is marl?

A. Marl is the same thing as limestone, namely, carbonate of lime, only it is often in the state of a fine powder, and often also mixed with earthy matter.

Q. What is shell sand?

A. Shell sand or broken sea-shells is also the same thing almost exactly as common limestone.

Q. Can these marls and shell sands be applied with advantage to the land?

A. Yes, either as a top-dressing to grass lands, and especially to sour, coarse, and mossy grass,—or they may be ploughed or harrowed in upon arable fields,—and especially they may be applied with advantage and in large quantity to peaty soils.

Q. Can they not be used also in making composts?

A. Yes, mixed with earth and vegetable matter, or with animal matter, such as fish refuse, whale blubber, &c. and even with farm-yard dung they will often produce very good effects.

Q. How would you ascertain the presence of lime in a soil or in a substance supposed to be a marl?

A. By putting a little of it into a glass and pouring upon it either vinegar or weak spirit of salt (muriatic acid.) If any bubbling up (effervescence) appeared, I should say that lime was present.

Q. To what would this bubbling up be owing?

A. It would be owing to the escape of carbonic acid which the soil or marl contained.

Here the teacher may perform this experiment by pouring weak acid upon marl or powdered chalk, and show the bubbling up. He may further convince his pupils that the gas given off is really carbonic acid, by introducing a lighted taper into the glass, when it will be extinguished. (See fig. 2).

Q. What takes place when limestone (carbonate of lime) is burned in the kiln?

A. The carbonic acid is driven off from the limestone by the heat, and the lime alone remains.

Q. What is the lime called in this state?

A. It is called burned lime, quicklime, caustic lime, hot lime, lime-shells, &c.

Q. What weight of quicklime or lime-shells is obtained from a ton of limestone?

A. A ton of limestone yields about 11¼ cwts. of quicklime.

Q. What takes place when water is poured upon quicklime?

A. The quicklime drinks in the water, becomes very hot, swells up, and gradually falls to powder.

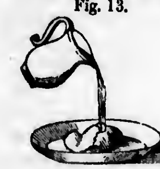


Fig. 13.

The teacher may exhibit this effect of water upon lime, and may satisfy his pupils that the heat produced is great, by showing that it will sometimes set fire to gunpowder placed upon a dry portion of the lime, or will heat a cold baked pie when put in the middle of it.

Q. What is this pouring of water upon lime, so as to make it fall, usually called?

A. It is usually called slaking the lime, and the lime is called slaked or slacked lime.

Q. Does the quicklime increase in weight when slaked?

A. Yes: one ton of pure quicklime becomes 25 cwts. of slaked lime.

Q. Does quicklime fall to powder of itself when left exposed to the air?

A. Yes, it absorbs water from the air, and gradually falls to powder.

Q. Does quicklime drink in (absorb) anything else from the air?

A. Yes, it gradually drinks in carbonic acid from the air, and returns at length to the state of carbonate.

The teacher may here satisfy his pupils that lime does thus absorb carbonic acid from the air, by pouring a little lime-water into a tumbler, and showing them that an insoluble film of white *carbonate of lime* forms on the surface. This experiment may be exhibited for the purpose of showing two things; *first*, that carbonic acid exists in the air; and, *second*, that quicklime absorbs it. Lime-water is made by pouring water upon quicklime in a bottle, shaking well up, corking, and allowing the lime to settle to the bottom.

Q. When it has thus returned to the state of carbonate, is it better for the land than before it was burned?

A. Yes; it is in the state of a far finer powder than could be got by any other means, and can thus be more thoroughly mixed with the soil.

Q. What is it usually called when it has thus returned to the state of a carbonate?

A. It is usually called mild lime, to distinguish it from the quick or caustic lime.

Q. Does quicklime act in a different way upon the land from mild lime?

A. It acts very much in the same way, but more quickly.

Q. How do they both act?

A. They act by supplying the lime which all plants require as part of their food,—by combining with acids in the soil, so as to remove the sourness of the land,—and by converting the vegetable matter into the food of plants.

Q. Would you bury lime deep, or would you keep it near the surface?

A. I would always keep it near the surface, as it has a natural tendency to sink.

Q. To what land would you apply quicklime rather than mild lime?

A. I would apply quicklime to peaty soils, to heavy clay soils, to arable lands which are very sour, and to such as contain a great deal of vegetable matter.

Q. Will the same quantity of lime produce the same or a greater effect upon drained than upon wet land?

A. The same quantity will produce a greater effect upon drained or naturally dry land, than upon wet land.

Q. Would you apply lime in large doses at long intervals, or in small doses at shorter intervals?

A. If I applied a large dose of lime at the beginning of my lease, I would apply smaller doses at the end of each *rotation*, or at the end of every second rotation, to keep up the quantity of lime in the land.

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The teacher may here explain the meaning of the new word *rotation*, and may illustrate it by reference to the course of cropping in his own or neighbouring districts; and if he make himself master of the theory of rotations (see the Author's *Lectures on Agricultural Chemistry and Geology*, page 717), he may give his pupils correct notions upon this subject, which they will seldom forget in after life.

Q. Why does lime require to be repeated?

A. Chiefly for three reasons; *first*, because the crops eat up and carry off a portion of the lime; *second*, because a portion of it sinks into the subsoil; and, *thirdly*, because the rains are always washing a portion of it out of the land.

VII.—OF THE COMPOSITION OF THE CROPS WHICH THE FARMER RAISES.

Q. Of what substances do the different kinds of grain usually consist?

A. They consist chiefly of three substances, starch, gluten, and oil or fat.

Q. What proportion of each of these usually exists in wheat?

A. 100 lbs. of wheat flour contain about 50 lbs. of starch, 10 lbs. of gluten, and 2 or 3 lbs. of oil.

Q. In what proportion do they exist in oats?

A. 100 lbs. of oats contain nearly the same quantities of starch and gluten as are in the same weight of wheat, and about 6 lbs. of oil.

Q. What do potatoes and turnips principally consist of?

A. Their principal constituent is water.

Q. How much water is contained in 100 lbs. of potatoes?

A. 100 lbs. of potatoes contain about 75 lbs. of water.

Q. How much water is contained in 100 lbs. of turnips?

A. 100 lbs. of turnips contain about 88 lbs. of water.

Q. What quantity of starch do potatoes contain?

A. 100 lbs. of potatoes contain from 15 to 20 lbs. of starch.

Q. Are these proportions of starch, gluten, &c. always the same in the same grain or root?

A. No. Some varieties of wheat contain more gluten than others, some varieties of oats more oil than others, and some varieties of potatoes more starch than others.

Q. Have the soil and climate any influence upon the proportions of these ingredients?

A. Yes, the wheat of warm climates is said to contain more gluten, and the potatoes and barley grown upon light or well-drained land more starch.

Q. When corn or potatoes are burned do they leave any inorganic matter or ash?

A. Yes, they all leave a small quantity of ash when burned.

Q. Of what does this ash consist?

A. It consists of phosphate of lime (bone-earth), phosphate of magnesia, common salt, and other saline substances.

The teacher may here explain more fully the composition of this ash, by referring to his table of the composition of the ash of different kinds of hay, and explaining that the ash of corn and of the ordinary root-crops contains a certain quantity of all the substances there mentioned, only that phosphate of lime, phosphate of magnesia, and common salt, are some of the most important compounds it contains.

VIII.—USES OF THE CROPS IN FEEDING.

Q. What natural purposes are vegetables intended to serve?

A. They are chiefly intended for the food of animals.

Q. What substances must an animal derive from its food, that it may be maintained in a healthy state?

A. It must obtain starch, gluten, oil or fat, and saline or inorganic matter.

Q. Do you recollect what starch consists of?

A. Starch consists of carbon and water.

Q. For what purpose does an animal require starch in its food?

A. It requires starch to supply the carbon which it throws off from its lungs during respiration.

Q. Do you recollect how much carbon a man throws off from his lungs in a day?

A. Yes, he throws off from six to eight ounces in a day.

Q. What quantity of starch must he eat, in order to supply the quantity of carbon given off from his lungs in a day?

A. He will require to eat about a pound of starch in a day.

Q. In what form is the carbon given off from the lungs of animals?

A. It is given off in the form of carbonic acid gas.

Q. What becomes of the carbonic acid gas thus given off?

A. It is diffused through the air, and afterwards absorbed again by plants, in order that new quantities of starch may be produced from it.

Q. For what purpose does an animal require gluten in its food?

A. An animal requires gluten for the purpose of repairing the daily waste of the muscles or lean part of its body.

Q. Are the muscles of an animal really subject to waste?

A. Yes, nearly all the parts of the body suffer a certain waste every day.

Q. What becomes of the part that thus wastes away?

A. It is carried through the body, and forms part of the dung and urine of the animal.

Q. How can the gluten repair the waste of the muscles or lean part of the animal?

A. Because the gluten of plants is exactly the same thing as the muscles of animals.

Q. Why does the animal require oil or fat in its food?

A. To supply the natural waste of fatty matter which takes place.

Q. Does it serve any other purpose?

A. Yes, when more is given than is necessary to supply the waste it may make the animal fat.

Q. Is food that contains much oil, then, the best for fattening?

A. Yes, of two samples of food that which contains the most oil will fatten most quickly.

Q. Is this one reason why oil-cake is so good for fattening stock?

A. Yes, it is one reason.

Q. Why must the food of animals contain phosphate of lime and other inorganic matter?

A. To supply the daily waste of the bones, the salt in the blood, &c.

Q. Do not the gluten and the saline matters serve a further purpose when the animal is growing?

A. Yes, when the animal is growing they not only supply the daily waste, but are daily adding to the substance of the animal's body.

Q. Will a growing animal require more of these kinds of food, then?

A. Yes, a growing animal of the same size will require more food than a full-grown animal.

Q. Suppose an equal quantity of food given to a growing and to a full-grown animal, which of them will give the richer dung?

A. The full-grown animal will give the richer dung.

Q. Why so?

A. Because the growing animal extracts and retains more of the substance of the food.

Q. Why does it do this?

A. Because it has both to supply the natural waste of its own body, and to add to its size, while the full-grown animal has only to supply the waste.

Q. Why is the dung of fattening stock richer than that of growing stock?

A. Because fattening stock extract and retain only the oil and starch or sugar of their food, and reject the remainder.

Q. Tell me now how you would convert a ton of oats or turnips into the largest quantity of beef or mutton.

A. I would keep my cattle or sheep in a warm or sheltered place,—where they might have wholesome air, but little light.

Q. If you wanted merely to fatten a full-grown beast, what would you do?

A. I would keep it warm, disturb it little, and give it oil-cake or oats, with a good supply of turnips.

Q. If you wished only to convert a large quantity of hay, straw, or turnips into manure, what would you do?

A. I would put my stock into a cool and less sheltered place, and I would make them take a good deal of exercise.

Q. If you wished to make a cow give you the largest possible quantity of milk, how would you feed her?

A. I would give her rich juicy grass, turnips, brewers' grains, mashes, or other food containing much water,—and I would supply her with drink when she would take it.

Q. But to obtain milk of the best quality, would you do so?

A. No. I would then give her as much dry food —oats, beans, or hay,—as she would eat.

Q. If you wanted milk particularly rich in butter, what would you give?

A. I would give her the same kind of food as I would to a fattening animal,—oil-cake, oats, barley, Indian corn meal, and some turnips.

Q. But if you were going to make cheese of your milk, would you give the same kind of food?

A. I would then prefer beans, peas, vetches, and clover, or clover-hay, all of which make the milk richer in curd.

Q. As a general rule in fattening off milk cows or pigs, would you give the food sweet or sour?

A. As a general rule, I would give it sour.

Q. Why so?

A. Because it has been found that much more—of pork, for example—is obtained, from green vegetables or from bean-meal when mixed with water and left to sour, than when given fresh and sweet.

Q. Is there any thing else you would do to make your stock-feeding more profitable?

A. Yes, I would keep my cow-houses well ventilated but warm, and my sheep and pigs clean.

While on this part of the subject, the teacher may draw the attention of his pupils to the beautiful connection which exists between the vegetable and animal kingdoms, and especially the marked adaptation of the living vegetable to the wants of the living animal, which is exhibited in the fact, that the animal finds ready formed in the ripened plant, all the most important substances of which its own body is composed. The gluten is identical with the fibre of its muscles, the oil similar in character with the fat of its body, while the bone-earth of the plant supplies materials for its bones, and the starch and sugar afford the carbon which is necessary for the purposes of respiration. Finally, he may also point out, that, when the vegetable food has discharged its office in the animal body, it returns to the earth in the form of dung—only to enter into the roots of new plants, and thus to produce new supplies of sustenance for other races of animals. The entire economy of vegetable and animal life, and all the changes experienced by dead matter are parts of one system—express, as it were, but one idea, the offspring of ONE MIND.

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