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No. 11

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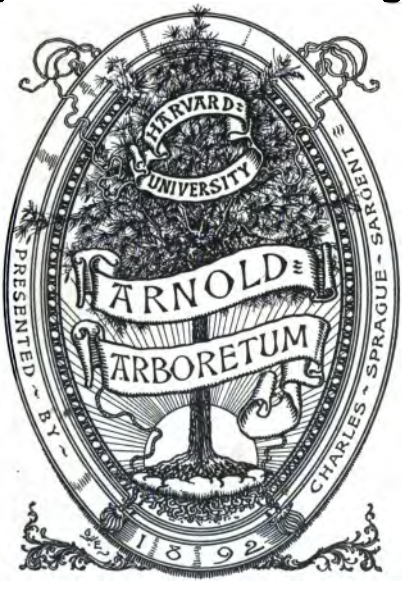

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SCIENCE AND PRACTICE
OF
GARDENING,

IN WHICH ARE EXPLAINED AND ILLUSTRATED THE PRINCIPLES
THAT REGULATE ALL THE OPERATIONS OF

HORTICULTURE;

INCLUDING DEMONSTRATIONS OF THE PHENOMENA OF
THE GERMINATION, GROWTH, DISEASES,
AND DEATH OF PLANTS.

WITH NUMEROUS WOOD ENGRAVINGS.

BY

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SOCIETIES, AND CO-EDITOR OF THE JOURNAL OF HORTICULTURE, ETC.

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PREFACE.

THE intention of the Author of this volume is to place before all who delight in Gardening not only directions how to perform its various operations, but to explain why those operations are needful. In doing this the Author has followed a cultivated plant through its whole existence, from its birth to its death; explained all the modes and phenomena of propagation, growth, disease and decay; at the same time fully illustrating, as he proceeds, all that can be done for the protection and prolongation of the life of plants.

Such knowledge is absolutely necessary for all who require to cultivate plants intelligently, whether in the open ground or in glass structures; and to place such knowledge within the power of the greatest possible number of readers this volume is published at the lowest remunerative price.

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THE

SCIENCE OF GARDENING.

CHEMISTRY teaches us of what all things in and upon the earth are composed, the changes to which they are liable, and how to promote or prevent those changes. Chemistry, therefore, is peculiarly applicable to gardening, for gardening has for its objects the production of the fruits, flowers, and culinary vegetables of any climate, in any habitable place, in perfection, and at the least possible expense.

Now, to attain that perfection, and as much as possible to avoid unnecessary expense, a gardener ought to understand the changes going on in every part of his plants during every period of their growth, and how those changes may be modified. Not any of this can he understand, unless he has a knowledge of chemistry. Chemistry, as applied to the cultivation of plants, has made large onward progress since the days when Sir Humphry Davy first lectured upon the theme; yet even then he justly pointed out, that, "If land be unproductive, and a system of ameliorating it is to be attempted, the sure method of obtaining the object is by determining the cause of its sterility, which must necessarily depend upon some defect in the constitution of the soil, which may be easily discovered by chemical analysis.

"Some lands of good apparent texture are yet sterile in a high degree; and common observation and common practice afford no means of ascertaining the cause, or of removing the effect. The application of chemical tests, in such cases, is obvious; for the soil must contain some noxious principle which may be easily discovered, and, probably, easily destroyed.

"Are any of the salts of iron present? they may be decomposed by lime. Is there an excess of siliceous sand? the system of improvement must depend on the application of clay and calcareous matter. Is there a defect of calcareous matter? the remedy is obvious. Is an excess of vegetable matter indicated? it may be removed by liming, paring, and burning. Is there a deficiency of vegetable matter? it is to be supplied by animal and vegetable manure.

"A question concerning the different kinds of limestone to be employed in cultivation often occurs. To determine this fully in the common way of experience would demand a considerable time—perhaps some years, and trials which might be injurious to crops; but by simple chemical tests the nature of a limestone is discovered in a few minutes; and the fitness of its application, whether as a manure for different soils, or as a cement, determined.

"Peat earth of a certain consistence and composition is an excellent manure; but there are some varieties of peats which contain so large a quantity of ferruginous matter as to be absolutely poisonous to plants. Nothing can be more simple than the chemical operation for determining the nature, and the probable uses, of a substance of this kind.

"The phenomena of vegetation must be considered as an important branch of the science of organised nature; but, though exalted above inorganic matter, vegetables are yet, in a great measure, dependent for their existence upon its laws. They receive their nourishment from the external elements; they assimilate it by means of peculiar organs; and it is by examining their physical and chemical constitution, and the substances and powers which act upon them, and the modifications which they undergo, that the scientific principles of cultural chemistry are obtained."—(*Davy's Lectures.*)

Science, it is true, can never supersede the necessity for a practical acquaintance with the operations of the spade, the knife, and the hoe; but it is their best guide—a pilot needed even by the most experienced.

The growth of horticultural science has been slow; for, although its dawn was in the Elizabethan age, yet it never afforded any distinct light to gardening until the beginning of the present century.

It is undoubtedly true, that in much earlier ages there were surmises born of inquiring minds, that are startlingly in accordance with the results afforded by modern vegetable chemistry and physiology; but they were no more than surmises—fortunate guesses, that, among many totally erroneous, happened to savour of truth. Thus Pythagoras forbade the use of Beans as food, because he thought that they and human flesh were created from the same substances, and modern research has rendered it certain that that pulse has among its constituents more animo-vegetable matter than most other seeds. Empedocles maintained that plants are sexual; that they possess life and sensation; and that he remembered when he was a plant himself, previously to being Empedocles.

Theophrastus and Pliny wrote more voluminously upon plants, but not with more knowledge of their physiology; and little or no improved progress is really visible until the sixteenth century was well advanced; for this branch of science was no bright exception from the darkness enveloping all human knowledge during the middle ages; and it was not until that period in which Bacon lived, that the human mind threw off the trammels of the schoolmen, and instead of arguing as to what *must be*, proceeded to examine and search out what *is*. The Reformation, the spirit of the age, was then not confined to religion. By delivering the human mind from thraldom, and teaching man to search all things, but to retain only that which is good because true, it gave an impetus to improvement which no tyrant opposition has ever since been enabled to check.

Such men as Bacon, Peiresc, Evelyn, Grew, and Malpighi arose. Bacon was the first to teach aloud, that man can discover truth in no way but by observing and imitating the operations of nature; that truth is born of fact, not of speculation; and that systems of knowledge are to be founded, not upon ancient authority, not upon metaphysical theories, but upon experiments and observations in the world around us.

Peiresc was a munificent man of letters, whose house, whose advice, and whose purse were opened to the students of every art and science. His library was stored with the literature of every age, and his garden with exotics from every clime, from whence he delighted to spread them over Europe.

Grew, in England, and Malpighi, in Italy, devoted themselves to the anatomical examination of plants, and these were followed by Linnæus, Gærtner, and others, who, trusting only to the dissecting knife and the microscope, soon precipitated into ruins all the fanciful fabrics of the Aristotelians, or guessers at truth. They were the founders of that science of vegetable physiology, which, enlarged and carried into practice by the late Mr. Knight and others, has advanced horticulture to a degree of improvement undreamed of by their immediate predecessor, Heresbach, when he informed the world, that, if the powder of rams' horns is sown, and well watered, "it will come to be good Asparagus."

The researches of Hales, upon the circulatory power of the sap-vessels; of Bonnet, upon the functions of the leaves; and of

Du Hamel, Priestley, Ingenhousz, Sennebier, Saussure, and others, upon the action of light, and the nature of the gases developed during the respiration of plants, imparted still more useful knowledge to the gardener, and rendered his art still less empirical.

The same philosophers directed their attention, also, to the food of plants imbibed by their roots, and to the examination of their various secretions; but here they were joined by another band of nature's students; and no one conversant with the philosophy of plant-culture but will remember the debt he owes to Vauquelin, Lavoisier, Johns, Davy, and Liebig.

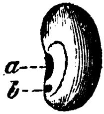
We shall endeavour to concentrate and arrange the results of the researches of the above-named disciples of nature, adding such rays, derived from lesser lights, as aid to render the whole more luminous, and such links of experiments and observations from similar sources, as make the work more connected than it would be without their aid.

A few gardeners may still exist who venture to think science useless—as there once existed a devotee of fashion who wondered why it was not always candle-light; but the greater majority of gardeners are now men of science, endeavouring thoroughly to understand the reason of every practice, and the supposed cause of each effect. To those differing from them we might name, if it would not be invidious, nearly all the most successful of our modern gardeners To a man, these are well acquainted with gardening's relative sciences. We forbear from mentioning names, but we may remind our readers, without fearing to offend, of two departed scientific cultivators, M. Lavoisier, and our fellow-countryman, Mr. Knight. Lavoisier cultivated his grounds in La Vendée on scientific principles, and in a few years the annual produce of those grounds doubled that from equal spaces of his neighbour's soil. Mr. Knight has scarcely left a department of our horticulture unimproved, by that combination of scientific with practical knowledge which he, perhaps more than any man, had united in his own mind.

It behoves every gardener to follow in their steps, for though those great men who have gone before have done much for gardening, yet still more remains to be accomplished. We yet, on most points, do, and must ever, see through a glass darkly; but that is no reason why any one should withhold from the effort to elicit some light towards diminishing the obscurity; and we may all, without fear of misspending our labour, continue to act as if chemistry and physiology had still some secret to reveal to the inquirer.

SOWING.

The seeds of plants present an endless variety of forms and colours, and sizes; but in their structure they are chiefly divided into two great divisions—seeds with one cotyledon, or seed-lobe, and seeds with two cotyledons, or seed-lobes. Plants with seeds having two lobes, come chiefly under the care of the gardener; therefore, from one of these, the Kidney Bean, we shall derive our drawings illustrative of the germination, or sprouting, of seeds.



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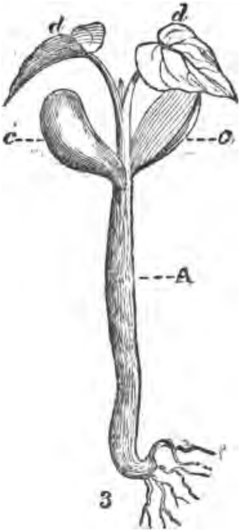

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Fig. 1. represents the seed before it is committed to the soil; *a* is the *hilum*, or point of union, by which it was united to the

seed-pod; *b* is the small opening (*micropyle*) through which the rootlet (*radicle*) is protruded. When the seed is placed in circumstances favourable to germination, it absorbs moisture, and is swollen; its radicle is elongated through the opening, Fig. 2, and penetrates into the soil; the skin is ruptured; the young stem (*caulicle*), Fig. 3, A, extends upwards, bearing the two seed-leaves (*cotyledons*), *c*, *c*, which furnish nutriment to the young plant, and which, when the young stem and first leaves, *d*, *d*, are developed, wither and fall off.

That the seed should have a perfectly developed embryo, and have arrived to nearly perfect ripeness, is essential to its being able to germinate. The reason for this is obvious: the young plant requires for its earliest nourishment a peculiar compound—usually saccharine, or sugary, matter; and this compound, in accordance with that universal fitness of things which demonstrates the wisdom of God, is always generated by the combined agency of heat, moisture, and oxygen gas,* from the substances most abundant in the fully-ripened seed. Let Barley be the example. Saccharine matter is essential for the first nourishment of the radicle, or first root, and plumule, or first stem, and leaves of the seedling; and into such saccharine matter is starch converted, by the combined agency we have named. It is starch, therefore, that is the chief constituent of the seed. But if Barley is gathered imperfect, and is dried, the chief ingredient is mucilage or gum; and this, if exposed to the essentials for germination,—heat, moisture, and oxygen gas,—instead of passing into saccharine matter, is converted into acetic acid, or vinegar, and the seed decays instead of sprouting.

As it is necessary that every seed should have nearly attained to ripeness before it acquires the power of germinating, so it is

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* Oxygen gas is a chief constituent of the air, without which gas neither a seed could sprout nor an animal breathe.

equally certain, that the length of time it retains the power to germinate differs in almost every plant. The seed of the Coffee shrub loses all power to grow, unless sown within a few weeks after it has been gathered, whilst that of the Melon improves by being stored for one or two years, and Celery remains capable of germinating for five times the last-named period.[*] These and some other instances within our knowledge demonstrate, that the more starchy and other matters, into which nitrogen does not enter as a constituent, that a seed contains, the longer, usually, will it retain its power to grow; and two instances are, common Rice and the Kidney Bean.[†] Rice contains eighty-five per cent. of starch, and will retain its vegetative powers for many years; whilst Kidney Beans, which contain one-third their weight of animo-vegetable matter and other constituents, of which nitrogen is a component, will not vegetate healthily a second season.

CAROLINA RICE.	
Water	5.00
Starch	85.07
Parenchyma	4.80
Gluten	3.60
Uncrystallisable sugar	0.29
Gummy matter, approaching starch	0.71
Oil	0.13
Phosphate of lime	0.13
	99.73

KIDNEY BEANS.	
Skins	288
Starchy fibrous matter	425
Starch	1380
Animo-vegetable matter	799
Extractive	131
Albumen and vegeto-animal matter	52
Mucilage	744
Loss	21
	3840

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[*] Melon seeds, by keeping, improve only in the sense in which gardeners consider the plant improved—viz., less of stem is produced, and the fruit is matured earlier. Whatever checks the development of the early organs, —the radicle and plumule,—produces this effect, and this is effected by age in the Melon seed; its starchy component diminishes in quantity, being gradually converted into albumen, a substance like the white of an egg. This is less easily changed to the soluble matters necessary for the nourishment of the parts of the plant first developed.

[†] Nitrogen is another gas found largely in the air we breathe; it is a chief part also of ammonia.

This speedy loss of growing power to which seeds abounding in nitrogenous matter are liable, is just what the chemist would predict, for all bodies so constituted are most prone to decomposition and decay.

The following list, furnished by the late Mr. Loudon, shows the greatest age at which some of our common garden seeds germinate freely; and this result of experience is quite concurrent with our knowledge of their chemical constitution:—

One year.—Peas, Beans, Kidney Beans, Carrot, Parsnip, Oraches, Herb-patience, Rhubarb, Elm, Poplar, and Willow.

Two years.—Radish, Salsafy, Scorzonera, Purslane, the Alliums, Cardoon, Rampion, Alisander, Love Apple, Capsicum, Egg-plant.

Three years.—Sea-kale, Artichoke, Lettuce, Marigold, Rue, Rosemary.

Four years.—Brassicas, Skirret, Spinach, Asparagus, Endive, Mustard, Tarragon, Borage.

Five and six years.—Burnet, Sorrel, Parsley, Dill, Fennel, Chervil, Hyssop.

Ten years.—Beet, Celery, Pompion, Cucumber, Melon.

Now, in this list, generally, as already observed, those with the most of nitrogenous matters among their component parts are the first to decompose, and consequently lose their vitality; and those with the greatest amount of starch and lignin, or more carbonaceous constituents, retain their germinating power the longest, and for the evident reason, that such are less prone to decay.

From other reliable sources we learn, that the seeds of the following plants have vegetated after being kept for the number of years affixed in this list:—

Tobacco	10 years.
Stramonium	25 „
Sensitive Plant	60 „
Melon	41 „
Cucumber	17 „

These periods are not conclusive that the seeds would have retained their vitality no greater length of time, but the following results are from experiments much more conclusive:—

Gladiolus psittacinus.—One year old, 42 out of 300; at three years old, 17; and at eight years old, none.

Allium fragrans (Sweet-scented Garlic).—One year, 143 of 300; at three years, 102; at eight years, 4; at fourteen years, none.

Asparagus officinalis (Common Asparagus).—One year, 250 of 450; at three years, 97; at eight years, none.

Quercus robur (Oak).—At three years, 3 of 30; at eight years, none.

Cucurbita pepo (Pumpkin).—One year, 35 of 45; at three years, 37 of 45; at eight years, 19 of 45; at thirteen years, none.

Tacsonia pinnatistipula.—Six years, none of 150.

Matthiola annua (Ten-week Stock).—One year, 203 of 600; three years, 236; eight years, none.

Erysimum Peroffskyanum.—At one year, 234 of 300; three years, 82; at eight years, none.

Lepidium sativum (Cress).—One year, 262 of 300; three years, 195; eight years, 19; thirteen years, none.

Brassica oleracea (Cabbage).—One year, 67 of 150; three years, 11; eight years, none.

Crambe maritima (Sea-kale).—One year, 105 of 300; three years, 6; eight years, none.

Tropæolum majus (Nasturtium).—One year, 64 of 75; three years, 52; eight years, none.

Anemone coronaria (Anemone).—One year, 46 of 300; three years, none.

Pelargonium sp.—Four years, 15 of 50.

Dianthus barbatus (Sweet William).—One year, 242 of 300; three years, 181; eight years, 2; 14 years, none.

Beta vulgaris (Red Beet).—One year, 146 of 215; three years, 155; eight years, 23; twelve years, none.

Pisum sativum (Pea).—One year, 92 of 150; three years, 94; eight years, 15; thirteen years, none.

Faba vulgaris (Bean).—One year, 71 of 75; three years, 71; eight years, 40; thirteen years, none.

Phaseolus multiflorus (Scarlet Runner).—One year, 67 of 75; three years, 47; eight years, 1; thirteen years, none.

Verbena Aubletia.—One year, 55 of 300; three years, none.

Cichorium endivia (Endive).—One year, 228 of 450; three years, 260; eight years, 139; thirteen years, none.

Lactuca sativa (Lettuce).—One year, 53 of 150; three years, 1; eight years, none.

Daucus carota (Carrot).—One year, 155 of 300; three years, 79; eight years, 1; ten years, none.

Of the seeds which retained their vitality longest, the following are some examples:—

A species of Hibiscus . . .	27 years.
A species of Colutea . . .	43 ,,
A species of Coronilla . .	42 ,,
A species of Dolichos . . .	27 ,,

These experiments were conducted by Mr. W. H. Baxter, Curator of the Oxford Botanic Garden, and were embodied in a report, made by Professors Daubeny, Henslow, and Lindley, to the British Association for the advancement of Science, in 1857 That our quotations form a very small portion of these very useful and carefully-conducted experiments will be appreciated, when we state, that Mr. Baxter tested the seeds of 289 different cultivated plants. One general result of the experiments is, that very few seeds retain their germinating power for eight years; and even if they do then germinate, it is not at all certain that the seedlings would advance into productive growth.

At the same time, let us not be misconceived as saying, that the changes mentioned are the only chemical causes for a seed's shortened or lengthened growing power. On the contrary, we are well aware there are other causes, and for example may be taken many seeds abounding with oil. These, exposed to the free operation of the air, gradually lose their vitality, or power to grow, as the oil they contain becomes rancid—a change produced by its partial conversion into capreoic acid. Preserved from the action of the air, no seeds are more retentive of vitality, apparently because, when so preserved, the oil they contain will remain sweet and unchanged for ages. This is the reason that in earth excavated from great depths below the surface, Charlock, Mustard, and such like plants, having oily seeds, are found to have retained their vitality.

In considering this subject, let it ever be kept in mind, that almost every species of seed has a peculiar degree of heat, and a peculiar amount of moisture, at, or approaching to which, its vitality will be excited into action. Therefore, in all observations on the life-retaining power of seeds, and in conclusions deduced from experiment, it must be carefully secured that they have not been excited to those first steps of germination, which steps, if taken and then checked, invariably cause the destruction of a seed's vegetating powers.

This brings us to the consideration of the contingencies necessary to cause a seed's germination.

HEAT.—A degree of warmth is essential, for no cultivated plant has seeds that will germinate below, or at, the freezing point of water. A temperature above 32° of Fahrenheit's thermometer, therefore, is requisite; and the plants of which the seeds will germinate nearest to that low degree of temperature, in this country, are the winter weeds. For example, we have found the seeds of the *Poa annua*, the commonest Grass of our gravel walks, germinate at 35°, and the seeds of Groundsel (*Senecio vulgaris*) would probably require no higher temperature. But, on the other hand, the temperature must not be excessively high. Even no tropical seed, probably, will germinate at a temperature much above 120° F.—(*Journal de Pharmacie*, xxii. 210.)

Other experiments, to ascertain the degree of cold which would destroy the germinating power of seeds, have given as a result, that even the extreme cold at which quicksilver freezes does not destroy the vitality of seeds. It is, indeed, probable that a continuance of such a degree of cold would kill the seeds; but it is not easy to determine this by experiment, as so low a degree of cold cannot be maintained very long. It is otherwise with the influence of heat, for seeds no longer germinate in water at the heat of 122° F. In vapour, it requires a heat of 143½° F. to destroy speedily the vitality of seeds of corn; and in dry air, 167° F. are necessary to prevent these seeds germinating. However, the influence of a high temperature is strikingly different according to its longer or shorter continuance; for a temperature of 95° F., for three days, destroys the germinating power of grain.—(See *Ann. des Sci. Nat.*, 1834, p. 257—270.)

Although seeds unsprouted will bear, uninjured, intense degrees of cold, it is far otherwise when once germination has commenced. A temperature of 32° will then usually kill them.

Every seed, differing in its degree of excitability, consequently has a temperature without which it will not vegetate, and from which cause arise the consequences that different plants require to be sown at different seasons, and that they germinate with various degrees of rapidity.

For example, two varieties of early Pea, sown on a south border on the same day, and treated strictly alike throughout their growth, were about a fortnight differing in all their stages of vegetation.

	Sown.	In bloom.	Gathered from.
Cormack's Prince Albert	Jan. 4.	April 1.	May 14.
Warwick . . .	Jan. 4.	April 13.	May 28.

Adanson found that, under the most favourable circumstances, various garden seeds might be made to germinate in the following very different spaces of time :—

Spinach, Beans, Mustard . :	3 days.
Lettuce, Aniseed	4 "
Melon, Cucumber, Cress . .	5 "
Radish, Beet	6 "
Orache	8 "
Purslane	9 "
Cabbage.	10 "
Hyssop	30 "
Parsley	40 or 50 do.
Almond, Chestnut, Peach . . .	1 year.
Rose, Hawthorn, Filbert . .	2 "

—(*Familles des Plantes*, i. 85.)

In one instance, M. Adanson certainly must have experimented with old seed, for we have found good new Parsley seed, sown on fresh fertile soil, in May, had germinated in two days, and its leaves were above the surface within a week from the day of sowing. Then, again, in the case of Rose seed,—at all events, in the case of that of the *Dog Rose*,—if the hips be allowed to endure the frosts of winter before they are gathered, the seed will germinate in much less time than is named by M. Adanson. This lesson was probably taught the gardener by nature, for the hips of Roses never shed their seed in this country until they have been frosted.

The gardener should always bear in mind, that it would be a very erroneous conclusion, because a seed does not germinate at the accustomed time, that, therefore, its vegetating powers are departed. No two seeds taken from the same seed-vessel germinate precisely at the same time; but, on the contrary, one will often do so promptly, while its companion seed will remain dormant until another year. M. De Candolle relates an instance where fresh Tobacco seedlings continued to appear annually for ten years on the same plot, though no seed was sown after the first sowing; and the same phenomenon usually occurs for two or three years, when the seeds of either the Pæony or Hawthorn are sown. Why one seed is more easily excited than another is as yet unexplained, but the wisdom of this one of many provisions for avoiding the accidental extinction of a species in any given locality is readily discerned. An ungenial spring may destroy the plants arising from those seeds which first germinated, but this could scarcely occur also to those of the second and third year, or even to those which vegetated only a few weeks later.

It is not possible to declare a general rule, relative to germinating temperatures, requiring no exceptions, but, in general, for the seeds of plants, natives of temperate latitudes, the best germinating temperature is about 60° F.; for those of half-hardy plants, 70° F.; and for those of tropical plants, about 80° F.; and the necessity for such temperatures depends upon the same causes that prevent the hatching of eggs, unless they be kept for a certain period at a temperature of about 100°. The requisite changes are not produced either in the seed or in the egg, unless it be submitted to the propitious temperature; but why this is requisite to develop the forms, and effect the changes, without which there is no vitality, is a secret at present withheld from man's understanding by their Creator, and we must rest satisfied with the approximate knowledge that caloric is the vast and all-pervading agent he employs to call life into existence.

Although temperatures ranging between 60° and 80° are those most usually propitious to germination, yet, as already noticed, a much higher temperature can be endured by seeds without their vitality being destroyed, and, indeed, in some instances, may be employed with great advantage, when the seed, from age or other cause, germinates with difficulty. The heighth of the temperature required for destroying their vitality varies with the species of seed. In water at 122° F., we have seen that the germinating power of corn was destroyed; but Dr. Lindley found the seeds of a Raspberry germinate, though they must have endured a temperature of 230° in the boiling syrup of the jam, whence they were taken; and other instances are known where Peas submitted to a temperature of 200°, and, left in the water for twenty-four hours until cool, germinated more readily than other Peas not so treated. The seeds of *Acacia lophantha* also produced seedlings after being boiled in water for five minutes. The effects produced by this high temperature, are to permanently soften the cuticle of the seed, and render it more readily permeable by the air; also aiding the conversion of the starchy components of the seed into saccharine matter; but if the boiling be continued until the composition of the germen is altered, the germinating power of the seed, in every instance, is destroyed.

These facts lead to the very important inquiry, whether the soil has any influence over the temperature occurring to the seed, and to the roots of plants placed beneath its surface? The researches of M. Schubler were the first to answer this query in the affirmative. This distinguished German chemist found, that when the temperature of the upper surface of the earth was 77° in the shade, various soils, exposed to the sun from eleven to three, in vessels four inches square and half an inch deep, attained the temperatures shown in this table.

	Wet.	Dry.
Siliceous sand, bright yellowish grey	99.1	121.6
Calcareous sand, whitish grey	99.3	112.1
Gypsum, bright white grey	97.3	110.5
Sandy clay, yellowish	98.2	111.4
Loamy clay, yellowish	99.1	112.1
Stiff clay, or brick earth, yellowish grey	99.3	112.3
Fine blueish grey clay	99.5	113.0
Lime, white	96.1	109.4

	Wet.	Dry.
Magnesia, pure white	95.2	108.6
Garden mould, blackish grey	99.5	113.5
Arable soil, grey	97.7	111.7
Slaty marl, brownish red	101.8	115.3

The results of M. Schubler's experiments demonstrate that which our knowledge of the laws of caloric would have induced us to pre-suppose—namely, that light-coloured earths, by reason of their reflecting most rays of heat, are warmed much more tardily than dark coloured earths. It was this conclusion which induced us, many years since, to try the effect of sprinkling coal ashes over rows of autumn-sown Peas. The Peas invariably appeared above the soil some days before those in rows not similarly treated. This acceleration of vegetation continued equally marked throughout their growth, and is further explained by other experiments of M. Schubler, which testify that those soils in the above table which absorbed the heat most readily retained it most tenaciously, and, consequently, were longest cooling. Magnesia cooled in one hour and twenty minutes as much as the garden mould did in two hours and sixteen minutes, and the slaty marl in three hours and twenty-six minutes.

From more recent experiments, made in the Horticultural Society's Garden at Chiswick, and in other parts of England, we have the following results, confirming M. Schubler's experiments.

In the Chiswick garden,—

1844.	Minimum Temp. of air.	Earth 1 foot deep.	Earth 2 feet deep.
Dec. 4	22	40	43
5	14	38	43
6	14	37	42
7	20	37	41
8	26	36	41
9	28	36	40
10	28	36	40
11	22	36	39

In a stiffish loam on a gravelly subsoil near Sheffield after a fortnight's exposure to a minimum temperature, varying between

21° and 31°, the soil had frozen to a depth of four inches and a half. But at lower depths the temperatures were as follows:—

At 6 inches . . . . . 34°
„ 12 „ . . . . . 36½°
„ 24 „ . . . . . 39°

In every instance the lighter soils were frozen to a less depth than the more tenacious, the former in no case having the frost penetrate lower than six inches, but in heavy soils two inches deeper.—(*Gardeners' Chronicle.*)

The following table, kept by Mr. Sharp, the scientific manager of the Winchester gas-works, shows the lowest temperature of the air at night, and its highest temperature by day, during the January of 1845, as well as the temperature of the soil at six inches, and at twelve inches below its surface. The soil is black, rich, and siliceous, resting on a chalky subsoil:—

January.	Night.	Day.	Ground.		January.
			6 in.	12 in.	
1	35	44	39	39	1
2	34	38	37½	39	2
3	25	40	34	37	3
4	32	47	35	36	4
5	38	51	38	38½	5
6	42	52	41	40	6
7	45	50	42½	41½	7
8	35	42	40	41	8
9	32	39	27½	40	9
10	35	39	37½	39½	10
11	43	50	42	41½	11
12	39	45	42	42	12
13	38	45	41	41½	13
14	36½	49	40	41½	14
15	38	46	40	41	15
16	38	46	40	41	16
17	39	45	40	41	17
18	38	48	40	41	18
19	32	46	38	40½	19
20	34	45	38	40	20
21	30	42	36	39	21
22	25	47	35	39	22
23	35	49	40	39½	23
24	36	49	40	40½	24
25	29	51	37	39	25
26	42	47	41	41	26
27	34	46	38	39	27
28	28½	40	35	37½	28
29	27	39	34	37	29
30	31	39	38	37	30
31	25	35	33	36	31

Professor Dove, of Berlin, published, in 1855, the following table, giving the mean results of his observations made at that city during the five previous years :—

	4 feet above the ground.	On the surface of the ground.	At a depth below the surface of						
			1 foot.	1½ ft.	2 feet.	2½ ft.	3 feet.	4 feet.	5 feet.
January......	32.67	33.35	36.72	37.80	38.18	39.02	40.07	42.44	44.44
February ...	32.74	32.60	36.18	37.19	37.67	38.23	39.31	41.47	43.13
March	35.53	36.05	37.33	38.00	38.14	38.54	39.17	40.91	42.28
April	45.68	44.80	43.72	43.83	43.52	43.63	43.43	43.88	44.01
May	58.59	57.24	52.13	51.48	50.76	50.72	49.57	48.96	48.15
June	63.61	60.48	57.80	58.15	56.68	56.66	55.26	54.41	52.99
July	68.47	65.43	62.46	61.04	60.55	60.48	59.00	57.78	56.21
August	64.91	61.97	60.57	60.53	60.50	60.66	59.72	59.00	57.85
September	58.16	56.72	57.35	57.78	58.10	58.41	58.01	58.01	57.49
October	49.43	48.31	51.12	51.80	52.25	52.52	52.97	54.18	54.88
November	38.63	38.79	43.94	45.07	45.68	46.44	47.43	49.55	51.26
December ...	34.43	34.97	39.20	40.19	40.68	41.69	42.59	45.00	47.09

The temperature of the soil, especially near the surface, varies considerably, according to the mildness or coldness of the season. Dr. Lindley very erroneously concluded from this fact, that flower-seeds should not be committed to the ground until it attained a temperature of 46°. So far from this precaution being needful, it is a well-known fact, as already stated, that seeds—are uninjured by the severest frosts, unless these occur after the seeds have germinated. In confirmation of this, one of our best gardeners, Mr. R. Fish, writes as follows :—

" Natural-sown seeds come up earlier, and, what is strange, will often, at first, look more healthy than plants from seed sown carefully by the hand. This is owing to the fact, that the seeds scattered from the plant—at least, those of them that grow, are almost certain to be little covered. When we sow seeds early, and cover them as carefully as we can, yet this covering, if the ground is at all loamy, is apt to enclose the seeds in an air-tight covering after heavy rains, and thus germination is impossible. Hence the importance of sowing all seeds in the open air when the ground is dry. The seeds, from the moisture even then in the earth, and the free admission of air, begin to swell at once. If coated with loamy, moist soil, air is excluded, and the seeds either rot, or refuse to vegetate. Seeds thrown from the seed-vessel on the surface of the ground, may, in many cases, be scorched up by the sun; but, in many cases, also, they may just be sufficiently sheltered by the crumblings and the interstices of small lumps of soil, as to be in the best position for germinating, whenever the heat is sufficient for that purpose. Few things feel the first effects of frost more than the tender Purslanes, such as *Portulaca splendens*, *Thellusonii*, *grandiflora*, and their varieties; and yet the self-sown seeds pass the winter apparently uninjured." —(*Cottage Gardener.*)

The self-sown seeds of Mesembryanthemums and Balsams also endure the frosty temperatures of winter unharmed, although the parent plants are proverbially tender.

These facts, and the frequent failure of our Potato crops, led to the very judicious suggestion of planting these crops in autumn, which must be the best time, if practicable, for it is pursuing the dictate of nature. That it is practicable, we have long since proved. Frost in this country, where the soil is a light loam, and its surface level, never freezes, in the severest of our winters, to a greater depth than six or seven inches; and where any cause for fear exists, no frost would injure the sets if a little coal ashes were put over them; for coal ashes are an excellent non-conductor of heat, and, consequently, opposed to the admission of cold, and are, at the same time, a good preservative from excessive moisture.

The fact that the earth, in regions not eternally ice-bound, never is reduced in temperature, at a few inches from the surface, so low as the exterior air in winter, nor is elevated at a similar depth to an equal degree of warmth in summer, suggests the necessity for more attention to the temperature of the soil in our horticultural houses than it has hitherto obtained.

Attention is more awakened to it now than formerly, and by *bottom heat* our gardeners now intend something more than a mass of fermenting matter for forcing Cucumbers and Pine Apples.

It is quite certain, that every plant, when growing in a favourite soil in its native climate, has its roots growing in the temperature which is best accordant with that in which its branches are delighting. Under no circumstances, if the plant is flourishing, will the temperature in summer, at twelve inches from the surface, be found to be less than 2°, nor more than 5° *lower* than the average temperature of the atmosphere; and in winter, that temperature, at the same depth, will be found to range similarly *above* the atmospheric temperature. It is quite true, that at the Chiswick Garden of the London Horticultural Society, and elsewhere, there is a difference of 10°, or more, between the temperature of the soil at that depth, and the temperature of the air; but this only is evidence that the drainage, or composition of the soil, are defective. If the difference of temperature was less, the plants grown on such soils would be more early, and more healthy in their vegetation.

There is no doubt, that in tropical climates, the bare, exposed soil becomes heated, for a few inches in depth, to a degree higher than that of the air incumbent upon it. But this is not the case about the roots of plants; for their foliage, and the herbage naturally clothing the soil, preserve this from such a pernicious elevation of temperature. Besides, we have seen that a foot below the surface the temperature is but slightly elevated, or depressed. That an excessive elevation is injurious, is known to every observer of plants, whether the plants are growing in the tropics or in a stove. The roots are stimulated to imbibe moisture faster than the foliage can sufficiently digest the sap thus forced to them, and that foliage is expanded wider and more weakly, in the vain effort to keep pace with the supply. This is only one among many instances of that property, so wisely given to organised beings by their Creator, of adapting themselves to circumstances; and it is only when the vicissitudes of those circumstances are too violent, or too long continued, that they fail in their effort at conformity.

If the temperature of the soil be unnaturally below that in which the branches are vegetating, the effects are equally, though differently, disastrous. The supply of sap is too much diminished in quantity, and the edges of the leaves consequently die, or the blossoms fall, or disease attacks some part of the fruit, according to the nature of the plant, or the stage of growth in which it occurs. The shanking in Grapes appears traceable to this cause.

A soil abounding in superfluous water is always colder than a soil of similar constitution that has been well drained. The reason for this is obviously, that the same quantity of caloric which will heat the earth 4° will only heat water 1°; or, to use the language of the chemist, the capacity for heat of water is four times greater than that of the earth's. In everyday experience, we see the low lying, and, consequently, the wettest portions of a field, are always those on which the evening mist, or fog, first appears; for at one season of the year it becomes colder than the air, and the atmospheric moisture always precipitates first on the coldest surface. At other seasons of the year, evaporation from the wettest portion of a field is the most abundant; and, at those seasons, mists are formed by the temperature of the air being much below that of the earth, and, consequently, condensing its watery exhalations. The greater the difference of temperature, the denser is the mist, the condensation being more complete.

When the season for sowing arrives, we may fearlessly commit our seed to the ground whenever it is in good working condition; although, by observing the coincidences of Nature, we may prejudge when late sowing will be as efficient as early sowing, in producing forward crops.

The attempt to attain knowledge on this subject is not new; for, nearly a century since, Harald Barck and Alexander Berger, in Sweden, made many observations directed to this object; and in later years, Stillingfleet and Martyn have done the same, in England.

The first-named of these botanists thus expresses himself upon the subject:—"If botanists noted the time of the foliation and blossoming of trees and herbs, and the days on which the seed is sown, flowers, and ripens; and if they continued these observations for many years, there can be no doubt but that we might find some rule from which we might conclude at what time grains and culinary plants, according to the nature of each soil, ought to be sown; nor should we be at a loss to guess at the approach of winter; nor ignorant whether we ought to make our autumn sowing later or earlier."

M. Barck would derive his intimations from the vegetable tribes alone; but we think the other kingdoms of organic nature might be included—as the appearances of certain migratory birds, and the birth of certain insects. For example, in the East of England, it is a common saying among gardeners,—confirmed by practice,—"When you have seen two swallows together, sow Kidney Beans."

This synchronical mode of regulating the operations of the cultivator of the soil is no modern suggestion; but the efforts of Barck, and his successors, have only been to find such indications in our northern clime that would be of the same utility, and similarly admonitory as others adopted by the ancients in more sunny latitudes. Thus, Hesiod says, "If it rain three days together when the *Cuckoo* sings, then late sowing will be as good as early sowing; and in another place, when *snails* begin to move and climb up plants, cease from digging about Vines, and take to pruning."

That our operations may be made justly synchronical with certain appearances in nature, is supported even by our present limited knowledge. "It is wonderful," says Mr. Stillingfleet, "to observe the conformity between vegetation and the arrival of certain birds of passage. I will give one instance, as marked down in a diary kept by me in Norfolk, in the year 1755. 'April 16th. *Young Figs* appear; the 17th of the same month the *Cuckoo* sings.' Now the word *κοκκυξ* signifies a *Cuckoo* and the *Young Fig*, and the reason given for it is, that in Greece they appeared together. I will just add, that the same year I first found the *Cuckoo flower* in blossom, the 19th of April."

"Linnæus says, that the *Wood Anemone* blows when the *Swallow* arrives. In my diary for the year, 1755, I find the swallow appeared April 6th, and the *Wood Anemone* was in blow on the 10th of the same month. He says that the *Marsh Marygold* blows when the *Cuckoo* sings. Accordingly, in my diary, that flower was in blow April 7th, and the same day the *Cuckoo* sang."

Then, again, whatever may be the character of the season, whether it be unusually cold, or preternaturally mild, the same order prevails in the leafing of plants:—

1. Honeysuckle
2. Gooseberry
3. Currant
4. Elder
5. Birch
6. Weeping Willow
7. Raspberry
8. Bramble
9. Briar
10. Plum
11. Apricot
12. Peach
13. Filbert
14. Sallow
15. Alder
16. Sycamore
17. Elm
18. Quince

19. Marsh Elder
20. Wych Elm
21. Quicken Tree
22. Hornbean
23. Apple
24. Abele
25. Chestnut
26. Willow
27. Oak
28. Lime
29. Maple
30. Walnut
31. Plane
32. Black Poplar
33. Beech
34. Locust Tree
35. Ash
36. Carolina Poplar

This invariable simultaneous change, this consistent adherence to the same order of time, seems to demonstrate that the same circumstances, the same variations of cold and moisture endured, produce this general similar effect: they make all plants delay or accelerate their leafing to the most favourable time for vegetating. It seems to follow, therefore, that if it be found one year that the best Potato crop was obtained by planting on the 15th of March, being the first day the Gooseberry-leaves opened, and that the following year the leaves of the same tree did not open until the 7th of April, that in such case the Potato planting might be delayed until then; for, as M. Barck observes, "No one can deny but the same influences which bring forth the leaves of trees will also make grain vegetate, and no one can justly assert that a premature sowing will always and everywhere accelerate a ripe harvest."

We beg to explain, that our illustration by Potato planting is a mere assumption, and that we do not intend to advance that the leafing of the Gooseberry and Potato planting ought to be simultaneous. We only throw out the suggestion for others to confirm, or to refute by observation and experiment, adding only thus much, that Mr. Stillingfleet, one of the most careful of Nature's observers, says, that in his time "the prudent gardener never ventured to put his house-plants out until the Mulberry leaf was of a certain growth."

As no seed will germinate unless a certain degree of heat is present, so also does it require that a certain quantity of water be in contact with its outer skin or integument; and this is required, not only to soften this covering, and thus permit the enlargement of the cotyledons (seed lobes) always preceding germination, but also to afford that water to the internal components of the seed, without which the chemical changes necessary for the nutriment of the embryo plant will not take place.

Pure water, or some other liquid of which it is a large constituent, is absolutely necessary: no other fluid will advance germination a single stage. The quantity of water, necessary to be present before germination will proceed, varies much. The seeds of aquatic plants require to be completely and constantly submerged in water; others, natives of dry soils and warm climates, will germinate if merely exposed to a damp atmosphere, of which the Spanish and Horse Chestnut afford ready examples; but the far larger majority of seeds require and germinate most healthily in contact with that degree of moisture which a fertile soil retains only by its chemical and capillary attraction. If the soil be inefficiently drained, and there is, consequently, a superfluity of stagnant water, the seeds either decay without germinating, or germinate unhealthily. This arises neither merely from its keeping them in an ungenial temperature, nor only from the usual tendency of excessive moisture to promote putrefaction; but also because the vegetable decomposing matters, in a soil where water is superabundant, give out carburetted-hydrogen, with acetic and gallic acids—compounds unfavourable to the vegetation of most cultivated plants, whilst the evolution of carbonic acid and ammonia is prevented, which two bodies are beneficial to the embryo plant.

As water is essential to germination, and only a certain quantity is requred for its healthy progress, so is it by no means a matter of indifference what matters it holds in solution. Until germination has commenced, no liquid but water, at common temperatures, will pass through the integuments of a seed. So soon as germination has commenced, this power to exclude foreign fluids ceases; but the organs starting into activity, the radicle and the plumulé, or young root and stem, are so delicate, that the weakest saline solutions are too acrid and offensive for them. So utterly incapable are the infant roots of imbibing such solutions, that at first they are absolutely dependent, themselves, for their very existence, upon the seed-leaves; and if these be removed, the plant either makes no further advance, or altogether perishes. Many years since, we tried various menstrua, to facilitate the germination of seeds; but, with the exception of those which promoted the decomposition of water, and the consequent more abundant evolution of oxygen, we found none of any efficiency. As to keeping the seeds in saline solutions until they germinated, we never, certainly, carried our experiments so far as that; and shall be most astonished, if any other effect than injury or death to the plant is the consequence. Such has been the result in the Horticultural Society's gardens, where the seeds of *Lupinus Hartwegii* were made to germinate in a weak solution of phosphate of ammonia.

No liquid in which water does not preponderate, will enable a seed moistened with it to germinate; for we have treated Broad Beans, Kidney Beans, and Peas, with pure alcohol (spirit of wine), olive oil, alcohol and water, in equal proportions by measure, and with a solution of carbonate of ammonia, but in no instance did they germinate.

It may be noted as a warning to those who employ steeps for seed, with the hope of promoting the vigour of the future plant, that they must keep the seed in those steeps a very few hours. In forty-eight hours, if the temperature be 60° or more, putrefaction commences, and germination is weakened, or entirely destroyed.

M. Vogel, of Munich, has published an extended course of experiments upon this subject; and they fully confirm our opinion, that salts, harmless when the plant is of robust and advanced growth, are fatal to it at the time of germination; for he found that seeds germinate, without injury, in carbonate of lime (chalk), carbonate of strontian, litharge, red oxide of lead, phosphate of lead, black oxide of manganese, calomel, and cinnabar. That they germinate feebly in carbonate of magnesia, copper filings, sulphuret of antimony, red oxide of mercury, and aqueous solution of iodine. Lastly, that they refused to germinate at all in carbonate of barytes, hydrate of barytes, iodine pulverised and moistened, kermes mineral, golden sulphur of antimony, oxide of bismuth, arseniate of lead, and green oxide of chromium. These are facts which explain the result of practice, that saline manures are generally injurious if applied with the seed, though they may be beneficial if applied long before the seed time, or subsequently, when the plants are of advanced growth.

Nothing is so injurious to a germinating seed as great vicissitudes of temperature and moisture, or a lengthened exposure, to excess, of the latter; in either case, the awakening life of the seed is frequently entirely extinguished. Nothing is more dreaded by the maltster than a sudden check to his germinating Barley; and, as a chill to the incubating egg effectually prevents the formation of a chick, so does a sudden degree of cold often destroy the sprouting seed. To preserve the seeds of our winter crops from such vicissitudes, they may, in clayey soils, be sown beneficially upon, and covered with a thin stratum of, coal ashes: these are an excellent drainage, as well as a good non-conductor of heat.

It affords a warning, too, to those who have to pack seeds for lengthened transport in tropical regions. They cannot be kept too dry, for heat alone will have no influence over their germination; and they should, therefore, be put into small, open, canvass bags, and suspended from the beams of the upper cabins, where a current of air will keep the seeds as free as possible from damp. Close packing, in paper, in boxes, and in tin cases, stowed away in the hot hold of a ship, causes such a heating of the seeds, such an extrication of moisture from them, as is just enough to commence germination; and which, only carried through its first stage, ceases, and then decomposition ensues, which effectually destroys the arousing vitality.

Water being such an essential application to the seed, as well as to the growing plant, it may be observed, further, that the source from whence it comes is by no means immaterial. The best for the gardener's purpose is rain water, preserved in tanks sunk in the earth, and rendered tight by puddling, or bricks, and Parker's cement. To keep these replenished, gutters should run round the eaves of every structure in the garden, and communicate with these tanks. Every 100 cubic inches of rain water contain more than four cubic inches of air, of which more than half are carbonic acid gas, and the remainder nitrogen and oxygen, in the proportion of sixty-two of the former to thirty-eight of the last named.

That a particular proportion of gases is most beneficial when presented to the seeds and roots of plants, in rain water, is shown by the fact, that it contains in solution the gases of the atmosphere from which it is deposited, but in a very different proportion. Thus, the atmosphere contains 21 per cent. of oxygen, and .04 of carbonic acid; but the air extracted from rain water contains from 30 to 32 per cent. of oxygen, and from 11 to 60 per cent. of carbonic acid.

Liebig, from actual experiment on a large scale, states that both rain and snow contain ammonia; and if there be only one-fourth of a grain in each pint of water, the annual deposition from the atmosphere would be more than sufficient, on half an acre of ground, to give all the nitrogen contained in the vegetable albumen of 150 cwt. of Beet Root. Rain water also contains a peculiar organic substance, analogous to the extractive matter and gluten of plants, though differing from them chemically. To this substance Dr. Daubeney has given the name of *Pyrrhine.* Traces of salts and oxides have also been found in rain water; but, compared with all other naturally produced, it is so pure, and so abounds with the gases beneficial to plants, that none other can equal it for their service. That obtained from ponds or springs often contains matters offensive or deleterious to plants. Those known as hard water, containing in excess salts of lime or magnesia, are invariably prejudicial, and pond water is scarcely less so. If it be stagnant and loaded with vegetable extract, it is even worse than hard spring water. These last named, if obliged to be employed for tender plants, should have a pint of the ammoniacal water of the gas works mixed thoroughly with every sixty gallons, an hour or two before they are used.

If pond-water be clear, and not only not loaded with putrid or mineral matters, but containing *Confervæ,* or other growing aquatic plants, it may then be used very beneficially for the watering of plants. This is ascertained from long experience, and it is explained by the fact, that such water contains an excessive amount of oxygen gas. This excess is greater in proportion to the brightness of the sunshine, and the length of time to which the water has been exposed to it. During such bright weather, the aquatic plants give out oxygen most abundantly. M. Morren found, that in the afternoon of a sunshiny day, the oxygen in such water amounted to sixty per cent. of the bulk of the air which it contained.

The presence of one of the constituent gases of the atmosphere, as oxygen, is also essential to germination. Ray proved that Lettuce seeds will not germinate in the exhausted receiver of an air pump, though they did so when the air was re-admitted; and, though the experiments of Homberg threw some doubt upon this conclusion, yet it was fully confirmed by the researches of Boyle, Muschenbrock, Boerhaave, and Saussure; for they showed that Homberg must have employed an imperfect apparatus, and their experiments embraced many other seeds than those of the Lettuce. So soon as pneumatic chemistry demonstrated that the atmospheric air is composed of several gases—viz.:—

Oxygen	21
Nitrogen	79
	100

With about one per cent. of aqueous vapour in the driest weather, and about one part in every thousand of carbonic acid gas, the question then arose—Which of these gases is necessary for germination? and Scheele was the first to demonstrate that it is the *oxygen*. Achard afterwards proved that seeds will not germinate in nitrogen, carbonic acid, or hydrogen gases, unless mixed with oxygen; and though Carradori doubted the correctness of his experiments, his doubt was shown to be groundless, by the more accurate researches of Gough, Cruickshank, Saussure, and others.* Senebier carried his experiments still further; and has determined, that although seeds will germinate in an atmosphere containing one-eighth of its bulk of oxygen, yet that the proportion most

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* Although seeds will not germinate in an atmosphere of nitrogen, yet they all absorb a small quantity of this gas when germinating. It is a constituent of most young roots, especially of their spongioles, or extreme points. There is reason to believe that ammonia is formed during germination, and that it acts as a stimulant and food to the young plant. Seeds containing nitrogen, germinate more rapidly than seeds of the same genus which do not contain this gas.

favourable to the process, is one-fourth. Germination will proceed in an atmosphere of pure oxygen, but not so readily as when it is mixed with other gases. The same phenomena attend the incubation of eggs—they will not hatch in the vacuum of an air pump, nor will the process proceed so satisfactorily in any other mixture of gases than atmospheric air.

Radish seed refuses to grow when the oxygen in the air about it amounts to no more than one-fortieth part; and Lettuce seeds require in it, at the least, one-sixth: when it amounts to only one-eighth, they refuse to germinate. This is a reason why of all kitchen-garden seeds, the Lettuce is one of those which require the most shallow sowing.

It is necessary that the oxygen should penetrate to the cotyledonous or inner parts of the seed, as is evident by the changes which take place during germination: and it is further proved by experiment. When healthy seed is moistened and exposed in a suitable temperature to atmospheric air, it absorbs the oxygen only. This power of separating one gas from the others, appears to reside in the skin of the seed, for old seeds lose the power of absorbing the oxygen, and, consequently, of germinating; yet they will frequently germinate if soaked in a solution of chlorine in water—a gas which has the power of attracting hydrogen from its compounds, and releasing the oxygen, doing so in the case of seeds within their skin, as well as without. Humboldt and Saussure have also shown, that the application of chlorine to seed accelerates its germination; and Cress seed, which, under ordinary circumstances, requires some days to complete the process, they found effected it in no more than three hours.

The late Mr. George Sinclair, author of the excellent "Hortus Gramineus Woburnensis," informed us that he employed chlorine with singular success. He obtained it by mixing a tablespoonful of muriatic acid (spirit of salt), with a similar quantity of black oxide of manganese, and half a pint of water. After allowing the mixture to remain two or three hours, the seed is to be immersed in the liquid for a similar period, and then sown. Another, and, we consider, the most eligible mode of applying the chlorine; was also suggested to us by the same distinguished horticulturist. In this way, he said, he made tropical seeds vegetate, which refused to germinate by other modes of treatment. He placed the mixed ingredients, mentioned above, in a glass retort, inserting its bulb in the hotbed, and bringing its beak under the pot in which the seeds were sown, connecting it with the draining aperture of the pot. The chlorine gas is gradually evolved, passing through the earth of the pot to the seeds, accordingly as the heat required for the different species induces.

We are indebted to M. de Humboldt for a number of very curious observations on the property which chlorine possesses of stimulating, or favouring, germination. The experiments of M. de Humboldt were made in the first instance, on the common Cress (*Lepidium sativum*). The seeds were placed in two test-tubes of glass, one of which contained a weak solution of chlorine, the other common water. The tubes were placed in the dark, the temperature being maintained at about 59°. In the chlorine solution, germination took place in six or seven hours; from thirty-six to thirty-eight were required before it was manifest in the seeds in the water. In the chlorine, the radicles had attained the length of 0.0585 Eng. inch, after the lapse of fifteen hours, whilst they were scarcely visible at the end of twenty hours in the seeds submerged in water.—(*Flora Fribergensis subterranea*, p. 156.)

In the botanical gardens of Berlin, Potsdam, and Vienna, this property of chlorine has been made available to excellent ends; by its means many old seeds, upon which a great variety of trials had already been made in vain to make them sprout, were brought to germinate. At Schœnbrunn, for instance, they had never succeeded in raising the *Clusia rosea* from its seed; but M. de Humboldt succeeded at once, by forming a paste of peroxide of manganese, with water and hydrochloric acid, in which he set the seeds of the *Clusia*, and then placed them in a temperature of from 143° to 167°.

This absolute necessity for the presence of oxygen, is a reason why seeds will not germinate if buried beyond a certain distance from the earth's surface; and why clayey soils often fail of having a good plant—an impervious coat of the clay enveloping the seed, and preventing the air's access.

M. Burger found that seeds of Rye, buried one inch below the surface, had their leaves above it in eight days and a half; whereas those at a depth of six inches, had only just sprouted at the end of twenty-two days.

But too-deep sowing inflicts another injury; though it be not at such a depth as to entirely prevent germination, it so consumes the matter of the seed in forming the useless elongation of stalk necessary to bring the leaves above the surface, that all further progress in vegetation has been prevented. M. Burger found that Rye seeds sown five inches and a half deep, forced their blades to the surface in seventeen days and a half, but these remained green only for six days and then withered; and that in every instance, the most shallow-sown seeds produced the most stalks. We have observed the same in the case of Kidney Beans, Windsor Beans, and Peas of various varieties; those seeds buried one inch and a half below the surface, invariably grew higher and were more prolific than those buried at double or even greater depths.

From Saussure's experiments we learn that, weight for weight, Wheat and Barley, during germination, absorb less oxygen than Peas; whilst these consume less than Beans and Kidney Beans.

This explains why, in proportion to their size, the two first may be sown at a greater depth below the soil's surface than the three last named, without vegetation being prevented.

It is chiefly the want of a due supply of oxygen that forbids seeds germinating, which are buried at great depths; seeds thus deposited, or similarly excluded from the air in the Egyptian mummy cerements, will often retain their vegetative power for an apparently unlimited time. Hence, earth taken from far below the surface will often become covered with Charlock. This is an oleaginous-seeded plant; and such, when thus excluded from the air, retain their vitality most pertinaciously for reasons already assigned.

There are some seeds, Peas for instance, and the seeds of aquatic plants, which have the property of germinating under water. Some observers have, from this fact, come to the erroneous conclusion that atmospheric air, and consequently oxygen, were by no means necessary to germination. Saussure has explained this anomaly by referring to the constant presence of air in a state of solution in water. In fact, having placed some seeds of the *Polygonum amphibium* under water, deprived of its air by long-boiling, Saussure proved that germination could not take place.—(*Recherches chimiques, &c.*, p. 3.)

Under like circumstances, the quantity of carbonic acid generated in a given time, is by so much greater, the larger the quantity of oxygen in the atmosphere which immediately surrounds the germinating seed. Carbonic acid gas is of all the gases which have been tried, that which is most unfavourable to germination; and one way of hastening the process, is to place, under the receivers which cover the seed, some substance capable of absorbing that gas as fast as it is formed—quicklime, for example. By this arrangement, the growth of the rootlet is sensibly accelerated.—(*Idem*, p. 26.)

Inasmuch as seeds during germination yield carbonic acid to the atmosphere, it is quite obvious that they must lose some part of their original weight. And this they do, in fact; but the loss experienced by seeds which have germinated, is always greater than that which would have resulted from the removal of carbon which takes place. Saussure attributed this excess of loss to the volatilisation of a portion of the water which entered into the composition of the seed.—(*Idem*, p. 20.) According to Saussure, therefore, the phenomena of germination resolve themselves into the diminution of carbon, and of the elements of water. It is nevertheless, doubtful whether the chemical actions are so simple as this: we know, for example, that M. Becquerel considered the acid which appears during germination, as acetic acid. There is certainty of the formation of an acid during germination; to prove its development, it is sufficient to make a few moist seeds sprout on blue litmus paper, which speedily acquires the permanent red indicating the presence of an acid; and if seeds whilst sprouting are surrounded by lime, in powder, it is converted into acetate of lime.

So far are plants at their first germination from being benefited by the application of stimulants, as is supposed by the advocates of those menstrua, that if the air supplied to them during that process, is contaminated by stimulating vapours, such as that of sulphuric æther, camphor, spirits of turpentine, or ammonia, germination is always in some degree retarded and injured.

How oxygen operates in aiding the seed to develope the parts of the embryo plant we cannot even guess—we only know that most seeds have more carbon (pure charcoal), in their composition than other parts of their parent plant; that the oxygen absorbed by the seeds, combines with a portion of that extra carbon, and is emitted in the form of carbonic acid. These are the attendant phenomena, but we can penetrate the mystery no farther.

We have never been able to discover that light has any injurious influence over germination; and in those experiments apparently proving the contrary, due care was not taken to prevent the seed being exposed to a greater degree of dryness as well as to light. If seed be placed on the surface of a soil, and other seed just below that surface, and care be taken to keep the former constantly moist, it will germinate just as speedily as the buried seed; and if exposed to the blue rays only of the spectrum, by being kept under a glass of that colour, even more rapidly.

M. Saussure found that when the direct rays of the sun were intercepted, though light was admitted, seeds germinated as fast as when kept in the dark.—(*Recherches sur la Vegetation*, 23).

This was confirmed by Messrs. Lawson, at the Meeting of the Association of Science in 1853. Therefore, the object of sowing the seed below the surface, seems to be for the purposes of keeping it in a state of equable and salutary moisture, as well as to place the radicle in the medium necessary for its growth into a root, immediately it emerges from the integument of the seed.

We are aware that Mr. Hunt arrived at a different conclusion from his experiments; but it is very evident, from his own statement of his experiments, that he did not secure an equal supply of moisture, nor an equal amount of temperature to each sowing. Therefore, it was not the light only which influenced the results.

The seeds were sown in boxes of earth, and all similarly exposed to the sun. Those covered with ruby-coloured glass had an average temperature of 87°; those with red glass, of 83°; those with orange, 104°; those with yellow, 88°; those with blue, 94°; and those with green, 74°.

Mr. Hunt thus narrates the results of his experiments:—

"Numerous experiments have been tried with the seeds of Mignonette, many varieties of the flowering Pea, the common

Parsley, and Cresses. The seeds germinated, in general, the most rapidly under the red glass, in the spring of the year; but when the heat of summer has advanced, the temperature of the red light has been too great, and germination has been prevented. Except under the blue glass, these plants have all been marked by the extraordinary length to which the stems of the cotyledons have grown, and by the *entire absence of the plumula.* No true leaves forming, the cotyledons soon perish, and the plant dies. Under the green glass the process of germination has been exceedingly slow, and the plants, particularly the Cresses and Mignonette, have speedily died.

"Under the blue glass alone has the process gone on healthfully to the end; and, although there were a few instances of a perfect plant under the yellow glass, it on no occasion endured to the formation of a flower; excepting the plants under the yellow and blue glasses, all have been more or less blanched.

"These experiments sufficiently prove, that the process of germination is obstructed by the influence of *light* on the surface of the soil, although the seeds have been buried some depth beneath it. The effects of *heat*, as exhibited by the red rays, are not to be regarded as destructive in themselves, as plants have been found to grow under the influence of these rays when they have been supplied with an extraordinary quantity of water, to supply that drawn off by continued evaporation; whereas, although the evaporation, which has been equally rapid under the yellow media, has been met in the same manner as under the red, it has produced no beneficial results."

We draw very different conclusions from these researches. In the first place, these experiments can prove no more than that only one ray of this spectrum is, by itself, injurious to germination; but we know, from actual experiment, that when seeds are buried at the usual depth proper for their cultivation, duly supplied with moisture, and kept at similar temperatures, *germination* took place nearly equally under every coloured glass employed. So soon as germination was completed, then the coloured glasses varied extremely in their effects upon the seedlings; but were most injurious, as stated by Mr. Hunt. The influence possessed by the interposition of coloured glasses, so far as mere germination is concerned, arises, we think, chiefly from their modifying the temperature and the moisture; but the interception of the chemical, or actinic rays, may have considerable influence. M. Nicéphore Niepce, as long since as 1820, announced as a law of Nature, that "Light acts chemically upon bodies; is absorbed by them, combines with them, and imparts to them new properties." In the year just passed, his nephew, M. Niepce de Saint Victor, has shown that this law is applicable to our cultivated soils. Earth taken from a considerable depth being spread in darkness, produced no change upon paper washed over with chloride of silver placed above it. The same soil was then exposed to sunshine, one half of its surface being covered by an opaque body. Being taken into a dark room, and a similar piece of paper held over it, all that part of the paper over the half of the soil which had been quite exposed to the sunshine became darkened; but that half of the soil which had been shaded, produced no such effect.—(*Annal. Acadamie des Sciences*).

This demonstration of the absorption and retention of the sun's chemical rays, suggests an explanation of the advantages derived by the exposure of all parts of a soil to atmospheric influences, by trenching and ridging. The actinized surface-soil turned down by the spade, may have an influence upon vegetation more than we appreciate.

A seed placed in a situation where it is supplied with the desirable degrees of heat, moisture, and air, begins immediately to enlarge in size. This is occasioned by its absorbing moisture, which, passing into the cotyledons, causes their immediate increase in size. The rapidity of this process is remarkable, and warns the gardener from disturbing the seed after it is once committed to the ground. A few choice Peas, from which to raise stock, being sown, accidentally, in ground devoted to another crop, were removed after twenty-four hours, and were not again committed to the ground for some days. Not one of them produced a fruitful plant, and only two or three vegetated.

This is in no degree surprising, because in the majority of healthy seeds cultivated in our open ground departments, the embryo will be found swollen within three hours; within six hours the radicle will be perceptible; in from one to six days the radicle will have burst the integuments of the seed; within from two to seven days the plantlet will have similarly escaped; and in from four to twenty-four days perfect roots will have been developed, and the leaves appear above the surface.

Moisture, as already stated, is absorbed, and causes the immediate enlargement of the parts of the seed; and this moisture, though it will and does penetrate through the surface of the integuments, yet is chiefly imbibed through the hilum or scar. It passes to the cotyledons, causing their enlargement, and setting in motion their elaborating powers for the nutriment of the radicle and plantlet; for, if they are removed, or if they have been injured by insects, the seed does not germinate; and if they are removed even after the radicle is developed into a root, the plant's vegetation ceases.

No sooner has the radicle escaped from the seed's integument, than it immediately proceeds to elongate in the direction of the matters most promotive of the future plant's growth. If the seeds of Carrots, Parsnips, Beets, and other fusiform-rooted plants are sown in a soil with its surface richly manured, and its subsoil deficient in decomposing organic matters, the plants will have forked and abundant lateral roots, keeping within the fertile surface soil. On the other hand, if the surface-stratum is only moderately rich, but some manure is trenched in with the bottom spit so as to be about sixteen inches below the seed, the roots will strike down straight to this superior source of nutriment.

From the same cause the roots of orchidaceous plants, grown upon wood only partially charred, will be found to have their roots clamber up, and around, and along the wood, but always directing their course most numerously towards the charred portion. Again, the seeds of the Misletoe placed upon the under surface of a bough, always have their radicles grow upwards to penetrate the bark, and thus secure to themselves the moisture without which they could not exist. Lastly, if seeds of plants loving a fertile soil be sown along the partition, dividing a vessel into two portions, of which one portion is filled with rich earth, and the other with sand, though both portions are equally moist, equally loose, and equally warm, all the radicles will direct their course into the fertile soil.

These facts, with many others, all demonstrating that roots travel in the direction where the most acceptable food is presented, overturn, beyond all controversy, Mr. Knight's hypothesis, that the descent of the root is a consequence of the laws of gravitation; for these laws will not explain why roots will grow sidewise, and even upwards, if their best source of nourishment is so placed as to require it—gravitation could only influence them to a downward direction, and in a fluid medium. To maintain that the laws of gravitation will make the tender radicle of a seed pierce the hardest soil, appears to be a self-evident absurdity.

That the atmospheric air is that mixture of oxygen and nitrogen gases which is most favourable to the due progress of germination, is proved by the experiments of M. Saussure; for he found that seeds, germinating in it, always absorbed a portion of the nitrogen, but which they did not do, if the proportion of oxygen was increased.

These facts hold out some beacons worthy of being attended to, as guides for the operation of sowing. They point out that every kind of seed has a particular depth below the surface, at which it germinates most vigorously, as securing to it the most appropriate degree of moisture, of oxygen gas, and of warmth. From a quarter of an inch to two inches beneath the surface, appear to be the limits for the seeds of plants usually the objects of cultivation; these, however, must vary, for the same seeds in different grounds and countries. It must be the least, in aluminous soils and dry climates. In general, sowing should be performed in dry weather, especially on heavy soils, not only because of the greater saving of labour, but because it prevents the seed being enveloped with a coat of earth, impermeable by the air, "which," says Sir H. Davy, "is one cause of the unproductiveness of cold, clayey soils." Perhaps the time at which any ground may be raked with the greatest facility, is as good a practical criterion as any, to judge when it is most fit for sowing. In general, if clay does not predominate in its constitution, a soil rakes best just after it has been turned up with the spade. If clay does predominate, it usually rakes with most facility after it has been dug two or three days, and then immediately after a gentle rain. But it is certain, that the sooner seed is sown after the soil is dug for its reception, the earlier it germinates. In the droughts of summer, water is often required to newly-sown beds. Such application must not be very limited or transitory; for, if the soil is only moistened at the immediate time of sowing, it induces the projection of the rootlet, which, in very parching weather, and in clayey caking soil, we have known wither away, and the crop consequently lost from the want of a continued supply of moisture.

THE ROOT.

THE root is present in all cultivated plants. The truffle, which, however, can scarcely be considered as belonging to cultivated vegetables, having hitherto defied all attempts to subjugate it, may be considered as consisting of nothing but root.*

A root is annual, biennial, or perennial. In the two former instances, if the individuals to which they belong, be allowed to perfect their seed, no care can protract their existence beyond the ensuing winter, however genial the temperature, and other circumstances, in which they are made to vegetate; but, if the ripening of seed be prevented, it is undetermined how long, in most instances, they may be sustained in life. We have known Mignonette continued in healthy vegetation for four years by this precaution.

In all roots, and under any mode of management, the fibrous parts (radiculæ) are strictly annual; they decay for the most part as winter approaches, and are produced with the returning vigour of their parent in the spring. We are fully aware of the experiments of Mr. Knight and of the Rev. Mr. Keith, but their experiments attain to no other results than that all the fibrous roots are not dead at the same time. To this we assent; but we are of opinion, that they die in succession, and have, in no case, their existence prolonged much beyond a year. Mr. Keith says, "A partial decay, with a partial renovation, of these organs, seems to be occurring at all seasons; but a total denudation of the

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* In Prussia, it is said, the gardeners succeed in cultivating this subterraneous fungus; but their mode of treatment is a secret.

root occurs at no season." Hence the reason that plants are transplanted with most success during the season of the decay of those root-fibres: for, as the root almost exclusively imbibes nourishment by the mouths of these fibres, in proportion as they are injured by the removal, so is the plant deprived of the means of support; and if the removal be in the spring, or summer, the deprivation is at a time when all those fibres are most needed; and the sap which is employed in the formation of new fibres, would have served to increase the size of other parts.

The quantity of root we have always observed to increase with the poverty of the soil in which it is growing. Duhamel found the roots of some young Oaks, in a poor soil, to be nearly four feet long, though the stem was not more than six inches. Every one may have noticed this familiarly instanced in *Poa annua*, the grass most commonly growing on a gravel walk, its stem minute, its root a mass of widely-extending fibres. The cause of this is evident: the nourishment which is required for the growth of the plant, can only be obtained by an increased, widely-extending surface of root, and, to form this, more sap is often required than the plant, owing to the poverty of the earth, can obtain for itself; in that case, a soil is sterile, for the plant must evidently perish.

A root always proceeds in that direction where food is most abundant; and, from knowledge of this fact, we should be circumspect in our mode of applying manures, according to the crop and object we have in view. We know a soil which, being shallow, never produced a Carrot, or a Parsnip, of any size; but almost every root consisted of numerous forks thickly coated with fibres. Digging two spades deep produced no material advantage, the gardener applying, as usual, manure to the surface; but, by trenching as before, and turning in a small quantity of manure at the bottom, the roots always spindled well, grew clean, and had few lateral fibres. For late crops of Peas, which mildew chiefly from a deficiency of moisture to the root, it is an object to keep their radiculæ near the surface, for the sake of the light depositions of moisture incident to their season of growth; hence it will always be found of benefit to cover the earth over the roots with a little well-rotted dung, and to point it in lightly.

If it be desirable to prevent the roots of any plant travelling in a certain direction, the soil on that side should be excavated, and the cavity refilled with sand or some other unfertile earth; whilst the soil on those sides of the plant whither the roots are desired to tend should be made as fertile as is permissible with its habits.

To keep the roots of trees near the surface, gardeners make an impervious substratum beneath their borders, either by ramming a bed of chalk at the requisite distance from the surface, or by placing there an asphaltic mixture of hot coal tar and lime rubbish. Roots coming in contact with these do not turn aside, but immediately cease extending in length, and produce laterals.

It may be accepted as a general maxim, that whatever causes an excessive development of root prevents the production of seed; and *vice versâ*, the production of seed, especially in tuberous-rooted plants, reduces the amount of root developed. Thus, frequently transplanting the young plants of the Broccoli and Cauliflower causes the production of numerous fibrous roots, and is found effective in preventing the mature plants advancing early to seed. The early varieties of the Potato do not naturally produce seed; but if their tubers are removed as soon as they are formed, these early varieties blossom and bear seed as freely as the later kinds—a fact suggesting many experiments to the cultivators of shy-blooming tuberous-rooted flowers. Again, if the blossoms of those later varieties of the Potato are plucked off as they appear, the weight of tubers produced will be increased.

It is a common and very ancient opinion, that the roots of plants equal in extent that of their stems and branches. An opinion which we have already seen is fallacious in the case of plants growing in poor soils; and that it is a fallacy we shall have a future occasion to demonstrate.

That it was an ancient opinion is shown by these lines of Virgil—

> "Esculus in primis, quæ, quantum vertice, ad auras
> Aetherias, tantum, radice, in Tartara tendit."*—*Georg.* ii. 291.

"The Chestnut especially, whose root descends as low towards hell as its head extends in the air towards heaven."

Virgil may have only intended his description as a poetical mode of describing the deep rooting of the Chestnut and the Oak; yet it is a popular error still, that the roots sink down as high as the stem rises, and spread laterally as far as its branches. In the case of the Oak, we may mention one instance to the contrary. The well-known Rev. W. Bree, of Allesley Rectory, took up a year-old, self-sown seedling Oak. It was growing in a wheat stubble. The plant, thriving and vigorous, was four inches high, while the root below measured thirty-four inches and a half.—(*Gardeners' Magazine*, x. 439.)

Although there is no equality of extent between the branches and roots of plants, it is most important that there is a reciprocity in their action. If the roots are excited into activity before the branches and their leaves—or if these become active before the roots are powerfully imbibing food—disease, in some form, is the consequence.

That this should be so, might be anticipated even by the least thoughtful; for, if the sap is impelled upwards before the leaves are prepared for its reception and digestion, there must be bleeding, or other organic derangement; and if the leaves are developed before the root can supply them with sap, there must be

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* In Æneid iv., Virgil says exactly the same of the Oak.

gangrene, or decay, from the want of sustenance. Practice shows these events; and the best gardeners always take care, when forcing fruit, that by borders well drained and proportionately heated, the roots of the trees shall be growing and imbibing from the soil quite as soon as the buds begin to swell. It is useless to apply heat to the surface of a wet, undrained border; because the water with which it is charged will not conduct the heat downwards. On the other hand, if the border is well freed from stagnant moisture, heat applied to the surface will descend with sufficient rapidity. On this point we shall have occasion to speak more fully, and shall here only add a quotation from a recent communication from that scienced practitioner, Mr. Fish.

"I have found," he says, "that from twelve to fifteen inches of fermenting matter, such as tree leaves, will be sufficient to give a heat on the border, in moderate weather, of about 70°, three inches below the surface; 68° at the depth of six to eight inches; 66° at the depth of a foot; and about 57° at the depth of two feet—a heat quite as great as the roots would have in general seasons in summer from natural causes; and, therefore, when forced, placing the roots, as respects heat, in something like a natural position. These temperatures will vary according to the weather, and the state of the border, especially as respects freedom from stagnant moisture; but they will be found pretty near the mark on an average. The thermometers, if possible, should be placed in open tubes or drains, communicating with the end or front of the border, the end of the drains being shut; and then the thermometers will not be influenced by the fermenting matter placed over the border, farther than that communicates heat downwards.

"As heat rises most naturally, I cordially agree in the propriety of a heating medium in a chamber, or other contrivance, below the border—such as hot-water pipes—so that there would be no possibility of the roots coming in direct contact with the heating medium. But even then, for early forcing, there would be a necessity for littering the border, or covering it with glass, or some non-conducting medium, as wood, or asphalt shutters; or, in severe weather, there might be a very great difference between the heat at the bottom and the surface of the border. In unison with such border protection, one of the finest vineries I ever saw, had most of the heating surface in a chamber below the border,—the necessary heat for the atmosphere of the house being admitted by slides. In such a mode of heating, the border should not be too deep, as the heat will attract the roots down. On the other hand, throwing in a little heat from the surface will help to entice the roots upwards." *

According to the usual acceptation of the term, the roots of plants do not emit excrements; yet it is quite certain, that in common with all the other parts of a plant, they emit matters differing in their amount and composition. The earth in contact with the tubers of a Potato fully ripe contains mucilage, and has the peculiar odour of the root; that in contact with the roots of Peas is also mucilaginous, and smells very strongly of that vegetable; and the freshly up-turned soil where Cabbages have been growing always smells offensively.

In addition to this, every gardener knows that the vigour and luxuriance of a crop are influenced remarkably by that which immediately pre-occupied the ground on which it is growing; and this does not arise entirely from the previous crop having robbed the soil of constituents required by its successor, but from that crop having left something offensive. Thus, the Cabbage-worts will not grow healthily upon soil where the immediately-previous crop was of the same tribe; but if the ground be pared

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* We recommend, for attentive perusal, the entire essay from which this is extracted. See COTTAGE GARDENER, No. 542.

and burnt, they will grow luxuriantly. And the same occurs to ground exhausted by Strawberries: if it be burnt and manured, Strawberries will grow as vigorously as upon fresh ground; but they will not do so if manure only be applied. It has also been observed that the roots of plants placed in water give out their characteristic flavour to the liquid; but on this, as evidence that they emit excrements, no great reliance can be placed, for some of the roots, during removal from the soil, must be wounded.

The fact that the roots of plants do give out peculiar and varying matters to the soil which sustains them, aids to explain why one rotation of crops is superior to another, as well as why fallowing is beneficial.

Fallowing gets rid, by decomposition, of any offensive excrementitious matters, as well as accumulates that which is desirable to plants; and one crop succeeds better after some predecessors than others, because their exuviæ are more salutary.

These facts are all explicable by the supposition that roots emit into the soil various excrementitious substances. Let us next inquire whether they do so has been substantiated by direct experiment.

M. A. P. De Candolle, in his "Vegetable Organography," says that "these excretions of roots have been particularly seen by Bruemans;" but we are not acquainted with his researches. MM. Bacquerel and Macaire found when Barley and other grain were made to vegetate in pure chalk, acetate of lime was formed in it, evidently by acetic acid (vinegar) being emitted by the young roots, and this combining with the lime of the chalk.—(*Ann. de Chimie et de Phys.* iv.)

M. Braconnot washed the soil in which the Poppy (*Papaver somniferum*) had grown during ten years successively, and obtained from it a considerable quantity of acetate of lime.—(*Ibid.* lxxii.)

Mr. Lymburn says, "On lifting up a bed of two-year seedling Scotch Firs, or two-year seedling Spruces, the ground around the roots is filled with the excrement. In the Scotch Fir it assumes a white colour; in the Spruce it has a yellow colour; and in both is fibrous. I have found in practice, that, in sowing seed-beds, or transplanting trees into lines, Larch sown or planted after Spruce have nearly doubled the size of those planted after Larch at the same time, and from the same lot of seed or seedlings."—(*Gardeners' Magazine*, vi., N. S.)

Professor Johnston, from a series of deductions founded on chemical analyses, concludes by stating that they satisfied him "that the roots of plants do possess the power of excreting some of the substances which are held in solution by their sap on its return from the stem; and which, having performed their offices in the interior of the plant, are no longer fitted, in their existing condition, to minister to its sustenance or growth. The excretory power is not restricted to the emission of inorganic substances. Other soluble matters of organic origin, also, are permitted to escape into the soil—though whether of such a kind as must be injurious to the plant from which they have been given out, or to such a degree as *alone* to render a rotation of crops necessary, neither reasoning nor experiment has hitherto satisfactorily shown. All that we know with certainty is in favour of the opposite view. Mr. Gyde watered Bean plants, till fully ripe, with water containing the matter excreted from the roots of Beans; and these plants were slightly better in appearance than other Bean plants watered during the same time with rain water only. The excretions of the Bean's roots, therefore, do not seem to be injurious to the Bean."—(*Transac. Highland Soc.* 1845. *Johnston's Lectures on Agricultural Chemistry.*)

Liebig is clearly of opinion that the roots of plants throw out excrements. He says, "The experiments of Macaire-Princep have shown, that plants made to vegetate with their roots in a weak solution of acetate of lead (Goulard's extract), and then in rain water, yield to the latter all the salt of lead which they had previously absorbed. They return, therefore, to the soil all matters unnecessary to their existence. Again: when a plant, freely exposed to the atmosphere, rain, and sunshine, is sprinkled with a solution of nitrate of strontia, the salt is absorbed; but it is again separated by the roots, and removed further from them by every shower of rain which falls upon the soil; so that at last not a trace of it is to be found in the plant.—(*Daubeny.*)

"When bulbous plants, such as Hyacinths, are allowed to grow in plain water, this gradually acquires a brown colour. It, therefore, cannot be denied that excrements are actually given off by plants, although, very possibly, they do not produce them in the same degree. Through the expulsion of these matters unfitted for the plant's nutrition, yet containing a large proportion of carbon, the soil receives again with usury the carbon which it had, at first, yielded to the young plants as food in the form of carbonic acid. The soluble matter thus acquired by the soil is still capable of putrefaction, and then furnishes renewed sources of nutrition to another generation of plants: it becomes humus."—(*Liebig's Chemistry applied to Agriculture, &c.* 3rd ed.)

M. Walser endeavoured to show that no such excretions are formed (*Ann. des Sciences Naturelles*, xiv., 100. *Second series*), but Professor Gasparrini refutes his conclusions. We shall have occasion to refer to his experiments, tending to establish as a fact that the greater part of vascular plants absorb their food from the soil—not by the tips, or spongioles, of their fibrous rootlets, but by hairs formed at the base of those spongioles. These hairs, which the Professor calls suckers, become covered before they decay, which they do periodically, with grains, or clots, to which the soil around adheres. He witnessed these suckers on plants of Barley, Scurvy Grass, Rape, Rye, and Wheat, open at their ends, and discharge those clots which he had observed floating within those suckers in a limpid fluid. The discharge was preceded by a peculiar movement in the suckers, similar to that which occurs before a pollen-bag bursts. Warm water hastened the emission.—(*Ricerche sulla natura dei succiatori e la escrezione delle radici*, 1858.)

As it is certain that some plants grow more luxuriantly if following one kind of predecessors, than they do if in succession to some others; so is it probable that there are plants which flourish more in companionship with some tribes than they do if associated with other tribes.

This is no result of modern observation, but is asserted by some of the earliest writers on the cultivation of plants.

Thus, in 1570, Conrad Heresbach wrotes as follows:—" Because there is a natural friendship and love between certain trees, you must set them the nearer together, as the Vine and the Olive, the Pomegranate and the Myrtle. Others," he adds, " have a natural hatred, as the Vine with the Filbert and the Bay;" and Cato, about fifteen hundred years before Heresbach, said that the Vine is at enmity with the Cabbage.

That some plants are benefited by being grown in the vicinity of others seems established by observation, and might be rationally expected. Thus the blue-bottle (*Centaurea cyanus*) is rarely found flourishing, except in company with a corn crop. The benefit arising from such associations is, probably, the consequence of the cereal grasses emitting the usual gases in proportions, and at times grateful to the *Centaurea;* or from their excreting something in the soil that is acceptable to its roots. Then, again, the fragrance of the Rose is said to be increased by having the

Onion, or some other *allium*, grown in its vicinity. Phillips, in his poem entitled "Cider," alludes to this result:—

> ——— "The Pæstan Rose unfolds
> Her bud more lovely near the fœtid Leek,
> (Crest of stout Britons,) and enhances thence
> The price of her celestial scent."

This increase of fragrance, if it is a truth, probably arises from the same cause that ammonia increases the pungent perfume of snuff. Flavours and scents, we all know, are often made more intense by combination. Musk increases the aroma of all other perfumes.

This probable benefit, derived from association, is explicable very differently from what has been called "the sociality of plants." The social plants are those that are found herding only with members of their own species. We need only quote as an example the common Heath, which, as Meyen observes, "is the most social plant of all; and if all other plants were to occupy the surface of the earth in the same proportion, there would not be room for more than 5000 species." This sociality is regulated entirely by soil and climate. Thus, the Heath will only grow on a peculiarly siliceous soil, and it cannot endure cold like its frequent companions, the Andromeda and Juniper; therefore, it does not follow them within the Arctic zone.

As some plants are social, and are benefited by being grown grouped with their kindred, so there are others, the hermits of the vegetable world, which prefer being separated from all their relatives. Examples of these are the Sicilian Horehound (*Marrubium peregrinum*); the Blue-bottle Thistle (*Carduus cyanoides*); the Crimson Grass Vetch (*Lathyrus Nissolia*); the Elegant St. John's Wort (*Hypericum elegans*); and the Heath-leaved Sun Rose (*Helianthemum Fumana*). These and some others, it has been well observed, "stand quite insulated, and seem as if they would disappear, did not Nature, in a manner often inexplicable, provide for their continuance." But the most remarkable we have not yet mentioned,—namely, *Forstera sedifolia*, on the summits of the loftiest mountains of New Zealand; *Melastoma Tidorense*, on the crest of Mount Tidor, in the Molucca Islands; and *Disa cornuta*, on a few spots near the summit of Table Mountain.

Plants are very much benefited by having oxygen applied to their roots, being found to consume more than their own volume of that gas in twenty-four hours; and when applied by Mr. Hill to the roots of Melons, Hyacinths, &c., the first were found to be improved in flavour, the second in beauty, and all in vigour.

We will only quote the details of his experiments on the Hyacinth. They are as follows:—"I have been making experiments, during several winters, on the roots of Hyacinths, placed in glasses of New River water, by immersing, mouth downwards, in the glass, an ounce phial filled with oxygen. These Hyacinths were double varieties, seldom succeeding in water alone, yet not a single bulb failed. On the contrary, both flowers and leaves were bolder and larger than those of the same plants cultivated in the earth with the greatest care."—(*Horticultural Society's Transactions*, i.)

It has also been proved by experiments, that if the roots of a plant are growing in water which partly fills a vessel, the other part being occupied with atmospheric air, the oxygen of that air is gradually abstracted from it. The roots take it from the water as fast as this absorbs it from the air.

But we have evidence still stronger in proof of the absolute need there is for oxygen gas being supplied to the roots of plants. For if, instead of with atmospheric air, the space in the vessel mentioned in the last experiment be filled with carbonic acid gas, hydrogen gas, or nitrogen gas, the plant growing in the water rapidly droops, and dies in a few days.—(*Johnston's Lectures on Agricultural Chemistry.*)

Promoting the presentation of oxygen to the roots of plants therefore, must be beneficial; thus we find, that frequently stirring the ground about them promotes their growth; for, in proportion as the soil is loose can the atmosphere more easily penetrate it. Moist earth rapidly absorbs oxygen from the atmosphere, as Humboldt has demonstrated, but dry soil does not. This affords another reason for frequently stirring the earth about plants during the droughts of summer; for well-pulverised soils admit the evening dews more freely than others more consolidated; and, consequently, dews will be deposited more within their texture, and moisture is more firmly retained in such pulverised soils, inasmuch as that they are not so much heated by the sun's rays, being more pervaded by the air, which, like all gases, is one of the worst conductors of heat.

M. Schubler has more recently published experiments upon this subject, and their results confirm those of M. Humboldt. No earth, in the following table, absorbed any oxygen from the air in which they were confined, so long as they were dry; but when moist, and confined in a similar bulk of atmospheric air for thirty days, they had absorbed its oxygen in the following proportions:—

	Per cent.
Siliceous sand	1.6
Calcareous sand	5.6
Gypsum in powder	2.7
Sandy clay	9.3
Fine lime	10.8
Slaty marl	11.0
Arable soil	16.2
Garden mould	18.0
Loamy clay	11.0

	Per cent.
Stiff clay or brick earth	13.6
Grey pure clay	15.3
Magnesia	17.0
Humus	20.3

The decomposing parts of animals and vegetables contained in a soil are also highly absorbent of moisture: hence the more freely the air is exposed to them, the more effectually will they be enabled to exert this power. By being freely exposed to the influence of the air, such substances are more rapidly decomposed, which leads to a consideration of the practice of exposing soils as much as possible to the action of the atmosphere by ridging, &c. When a soil is tenacious, or abounding in stubborn vegetable matters, as in heath lands, it cannot be too completely exposed to the action of the air; but to light soils, which are, in general, deficient in organic decomposing matters, chemistry would say that ridging is accompanied by evils more injurious than can be compensated by the benefits obtained; for such light soils are easily pulverised whenever occasion requires, are so porous, as at all times freely to admit the pervasion of the atmosphere; and, therefore, by this extra exposure the vegetable and animal remains are hastened in decomposing, and much of their fertile constituents evolved in the state of gas, or carried away by the rains, &c., without there being any crop upon them to benefit by them. Thus theory argues, and practice certainly supports her doctrines. Switzer, one of our horticultural classics, says, "Rich, heavy ground cannot well be ploughed too often to make it light, and the better manure by killing the weeds; as poor, light ground cannot be ploughed too seldom, for fear of impoverishing it."—(*Ichnographia Rustica*, vol. iii. p. 237.)

The benefit derivable from the access of the atmospheric gases to the roots of plants, and the knowledge that fertile pulverised soil absorbs and retains from them moisture, explains why plants are benefited by having their lateral roots kept near the surface, and by having that surface frequently loosened by the fork. This is no mere imagination of theory; for, as long since as the days of Cato—half a century before the Christian era—the importance of pulverising the soil is recorded as a revelation of practice. "What is good husbandry?" inquires that writer. "To plough." "What is the second point?" "To plough." The third is "to manure." In later days, Mr. Barnes, one of the best practical gardeners of the present age, says,—"To secure good crops of Carrots, Parsnips, and Onions, I make it a standing rule to trench the ground well in winter, throwing it into rough ridges, forking and turning it over during frosty mornings, which not only sweetens and pulverises the earth, but eradicates insects—for I prefer a good preparation to early sowing; and practice has proved to me that a good season for sowing is any time between the 15th of March and the 10th of April. My practice is, sow every thing in drills; hoe as soon as the plants can be seen breaking the surface, continuing the hoeing throughout the season at every opportunity when the weather will permit, but not during rain, or when the ground is full of water,—not for the sake so much of destroying weeds and insects, which are rarely to be seen by following up hoeing with spirit, but with a desire of keeping one uniform pulverisation and moisture throughout, which is the means of not only continuing the present crop in the greatest of health and luxuriance, but at the same time is making a beautiful preparation for the succeeding crop.

"I keep all ground, as soon as a crop is done with, well trenched, burying all the refuse I possibly can in a green state; casting the earth into rough ridges; tumbling those ridges over with a strong fork on frosty mornings in winter and spring, and during hot sunny days in summer; continually changing the crops; keeping the hoe at work at all seasons in suitable weather; forking up all odd corners and spare ground without loss of time. By this management, I find the ground is always in good condition, and never tired by cropping; some judgment only being exercised in applying such properties again to the soil that have been taken from it, or that are likely to be required by the succeeding crop. To rest or fallow ground for any length of time is only loss of time and produce; more benefit will be obtained by trenching and forking, in frosty or hot sunny weather, in a few days, than a whole season of what is erroneously called rest or fallow. Trench, fork, and hoe; change every succeeding crop; return to the earth all refuse that is not otherwise useful in a green state, adding a change of other manures occasionally, especially charred refuse of any kind, at the time of putting the crop into the ground. Every succeeding crop will be found healthy and luxuriant, suffering but little either from drought, too much moisture, or vermin."

The benefit derived from keeping the roots near the surface is more apparent in fruit trees and other perennials than in our annual crops, inasmuch as that the roots of trees thus being kept within the influence of the solar rays, they always vegetate early and ripen well their young wood; yet the quantity of oxygen absorbed by the roots of annual plants is very large, being, in the instances of the Radish, Carrot, and others, not less than their own bulk in the course of twenty-four hours.

Saussure, having taken up some young plants of the Horse-chestnut, furnished with their leaves, and weighing about 460 grains, he introduced their roots, which were nearly a foot in length, into receivers of about sixty cubic inches in capacity, and luted the base of the stem to the neck of the receiver. Into one of the receivers — each of which contained a quantity of distilled water—he introduced twenty-eight cubic inches of nitrogen, which were in contact with the upper part of the root, while the under part was immersed in the water. Into another he introduced an equal quantity of hydrogen; and into a third an equal quantity of carbonic acid. The plant whose root was in contact with the carbonic acid died in the course of eight days: the others lived a fortnight, but had not diminished the volume of their atmosphere. But plants which were placed at the same time in a similar apparatus, furnished with atmospheric air, gave a very different result; for, at the end of three weeks when the experiment was stopped, they were still fresh and vigorous, and the volume of their atmosphere was diminished.—(*Sur la Veg.*, chap. iii., sect. vi.)

Perpendicular roots do not thrive so well, other circumstances being the same, in a stiff and wet soil as in a friable and dry soil; while plants with slender and divided roots thrive equally well in both; but this is, no doubt, owing to the obstacles that present themselves to the passage of the oxygen in the former case, on account of the greater depth and smaller surface of the root. It was further observed, that roots which penetrate into dung, or into pipes conducting water, divide into immense numbers of fibres, and form what is called the "fox-tail root;" but it is because they cannot continue to vegetate, except by increasing their points of contact, with the small quantity of oxygen found in such mediums. Lastly, it was observed that plants whose roots are suddenly overflowed with water remaining afterwards stagnant, suffer sooner than if the accident had happened by means of a continued current. It is because, in the former case, the oxygen contained in the water is soon exhausted; while in the latter it is not exhausted at all.—(*Keith*, ii.)

Digging, hoeing, and trenching, are employed for facilitating the access of the air to the roots of plants, by rendering the texture of the soil easily permeable, and they are practices requiring a separate consideration.

Very few people ever consider, in detail, the expenditure of labour required from the gardener when digging. It is a labour above most others, calling into exercise the muscles of the human frame; and how great is the amount of this exercise, may be estimated from the following facts :—

In digging a square perch of ground, in spite of the usual dimensions (seven inches by eight inches), the spade has to be thrust in 700 times: and as each spadeful of earth—if the spade penetrates nine inches, as it ought to do—will weigh, on the average, fully seventeen pounds, 11,900 pounds of earth have to be lifted; and the customary pay for doing this is 2½*d.*!

As there are 160 perches, or rods, in an acre—in digging the latter measure of ground, the garden labourer has to cut out 112,000 spadefuls of earth, weighing in the aggregate 17,000 cwt., or 850 tons; and during the work he moves over a distance of fourteen miles. As the spade weighs between eight and nine pounds, he has to lift, in fact, during the work, half as much more weight than that above specified, or 1278 tons. An able-bodied labourer can dig ten square perches a-day.

A four-pronged fork, with the prongs twelve inches long, and the whole together forming a head eight inches wide, is a more efficient tool for digging than the common spade. It requres the exertion of less power; breaks up the soil more effectually; and does not clog even when the soil is most wet. It is less costly than the spade; and, when worn, can be relaid at a less expense.

The following table, being the result of the experiments of M. Schublcr, exhibits the comparative labour required in digging various soils, and the same soil in various states. Thus, if to penetrate with a spade, when dry, grey pure clay, requires a force represented by 100; then, to penetrate an arable soil in the same state would require a force equal only to 33, or about one-third: so in a wet state the clay would adhere to the blade of the spade with a force equal to 27 lbs. the square foot; while the arable soil would only adhere to the same surface with the force of 6·4 lbs.

Of the results he obtained, he says, when speaking of the consistence of soil in the moist state, and its attachment, or adhesion, to agricultural implements, "When land is worked in a wet state, we have not only to overcome the cohesiveness of the particles among themselves, but, at the same time, their attachment and adhesion also to the agricultural implements employed. If we wish to subject this property to a comparative trial, we may effect it in the following manner. We fasten large round plates, equal in size, made of iron and wood (as the two materials commonly used for agricultural implements), underneath the scale-pan of a balance, and put weights into the other scale until both are equally balanced; we now bring the plate into exact contact with a moistened earth lying beneath it, and put weights into the other scale-pan until the plate is drawn away from the earth; the amount of such weights corresponds to the degree of adhesion, or to the difficulty of working the earth in its wet state. The degree of this adhesion is often more considerable than would have been expected—an adhesion plate, of three or four square inches, required upwards of two ounces of counter-weight in order to draw it away from the surface of garden mould: in the case of the heavier clays, the weight required was as much as five or six ounces. From the size of the plate employed in this experiment, it is, of course, easy to calculate the amount of adhesion for larger or smaller surfaces.

The "firmness" column in this table indicates the weight required to force into perfectly dry specimens of the earth a little blunt spade "of steel," one-thirty-sixth part of an inch in thickness, and one-third of an inch broad.

Kinds of Earth.	In the Dry State.	In the Wet State.	
	Firmness, that of Clay being 100.	Adhesion to Agricultural Implements, on a surface of one square foot; with	
		Iron.	Wood.
Siliceous sand	0	3·8 pounds	4·3 pounds
Calcareous sand	0	4·1 "	4·4 "
Fine lime	5·0	14·3 "	15·6 "
Gypsum powder	7·3	10·7 "	11·8 "
Humus	8·7	8·8 "	9·4 "
Magnesia	11·5	5·8 "	7·1 "
Sandy clay	57·3	7·9 "	8·9 "
Loamy clay	68·8	10·6 "	11·4 "
Stiff clay or brick-earth	83·3	17·2 "	18·9 "
Grey pure clay	100·0	27·0 "	29·2 "
Garden-mould	7·6	6·4 "	7·5 "
Arable soil	33·0	5·8 "	6·4 "
Slaty marl	23·0	4·9 "	5·5 "

—(*Journal Royal Agricultural Society*, i., 188.)

The preceding observations and facts are applicable to hoeing—an operation beneficial in consequence of its loosening the soil, as much, or more, as by its destroying weeds. Moisture abounds in the atmosphere during the hottest months, and it is absorbed and retained most abundantly by a soil which is in the most friable state. Professor Schubler found, that 1000 grains of stiff clay absorbed in twenty-four hours only thirty-six grains of moisture from the air; whilst garden mould absorbed in the same time forty-five grains; and fine magnesia seventy-six grains. Then, again, pulverising the soil enables it better to retain the moisture absorbed. This we demonstrated some years since; and the reason is, obviously, because a hard soil becomes heated by the sun's rays much more rapidly than one with a loosened texture. The latter is better permeated by the air, which is one of the worst conductors of heat. We are glad to find our opinions confirmed by so practical and so intelligent a man as Mr. Barnes, gardener to Lady Rolle, at Bicton Gardens, Devonshire. He says (*Gardeners' Magazine, September*, 1843), "I do not agree with those who tell us one good weeding is worth two hoeings, I say, never weed any crop in which a hoe can be got between the plants; not so much for the sake of destroying weeds and vermin, which must necessarily be the case if hoeing be done well, as for increasing the porosity of the soil, to allow the water and air to penetrate freely through it. I am well convinced, by long and close practice, that oftentimes there is more benefit derived by crops from keeping them well hoed, than there is from the manure applied. Weeds, or no weeds, still I keep stirring the soil; well knowing, from practice, the very beneficial effect which it has.

"Raking the surface fine, I have almost wholly dispensed with in every department. By hoeing with judgment and foresight, the surface can be left even, wholesome, and porous; and three hoeings can be accomplished to one hoeing and raking. Much injury is done by raking the surface so very much. It is not only the means of binding and caking the surface, but it clears the stones off as well.* The earth, in its natural state, has stones, &c., to keep it open and porous, &c. If the earth is sufficiently drained, either naturally or otherwise, and the surface kept open, there is no fear of suffering either from drought or moisture."

Exposing the soil in ridges during the winter is usually practised by gardeners for the purpose of destroying predatory vermin; but it is also beneficial by aiding the atmosphere to pervade its texture, which texture is also rendered much more friable by the frost. M. Schubler says, that freezing reduces the consistency of soils most remarkably; and that, in the case of clays and other adhesive soils, the diminution of this consistency amounts to at least fifty

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* A finely pulverised even surface cakes after rain much more than a surface rather rough.

per cent. In hoeing clay, he found it reduced from sixty-nine to forty-five of the scale already stated; and in the ordinary arable soil from thirty-three to twenty. He satisfactorily explains this phenomenon, by observing that the crystals of ice pervading the entire substance of the frozen soil necessarily separate the particles of earth, rendering their points of contact fewer.

We have seen that plants search after and acquire food by the agency of their roots; and that hair-like organs near their extremities appear to be the chief, if not the only parts, employed in the intro-susception of all food not in a gaseous state; for M. Duhamel observed, that that portion of a soil was soonest exhausted in which the greatest number of the extremities of the roots were assembled.—(*Physique des Arbres*, vol. iii., p. 276.)

The discoverer of the hair-like processes at the base of the spongioles being the organs for absorbing nutriment from the soil, is Professor Gasparini, of Naples. These hair-like organs he calls suckers. They are, at first, straight and smooth; but, when more mature, acquire a variously irregular and branched form. This irregularity and ramifying do not change the internal structure of the main body of the sucker, for this retains a cavity throughout its length, and throughout each of its branches. Each sucker imbibes from the soil by means of its entire surface. They are formed and decay periodically, to be again renewed and pass through the same changes.

MM. Sennebier and Carradori found that if roots of the Carrot, Scorzonera, and Radish, are placed in water—some with only their extremities immersed, and others with their entire surfaces plunged in, except the extremities—the former imbibe the water rapidly, and the plants continue vegetating; but the others imbibe no perceptible quantity, and speedily wither. This suggests, also, the reason why the gardener, in applying water, or manure, to trees, or shrubs, does so at a distance from their stems. A good rule for ascertaining the proper distance for such applications, seems to be to make them beneath the circumference of the head of the tree; for, as M. De Candolle observed, there is usually a relation between that and the length of the roots, so that the rain falling upon the foliage is poured off most abundantly at the distance most desirable for reaching their extremities.

This explains why the caudex, or main limb of the root, is continually extending in length. By this extension it each year shoots forth into a fresh soil. If the extremity of a root is cut off, it ceases to increase in length, but enlarges its circle of extension by lateral branches.

The original direction of the root is generally perpendicular, in which it descends to a considerable depth if not interrupted by some obstacle. In taking up some young Oak trees that had been planted in a poor soil, Du Hamel found that the root had descended almost four feet, while the height of the trunk was not more than six inches. If the root meets with an obstacle, it then takes a horizontal direction, not by the bending of the original shoot, but by the sending out of lateral shoots. The same effect also follows if the extremity of the root is cut off. It grows in length no longer. Du Hamel made some Cherry-stones, Almonds, and Acorns, to germinate in wet sponges; and when the roots had grown to the length of two inches, he then placed them in glasses, as bulbous roots are placed, so that the extremity of the root only touched the water. Some were previously shortened by the cutting off of a small bit from the point; others were put in entire. The former immediately sent out lateral shoots, but elongated no farther in a perpendicular direction; the latter descended perpendicularly to the bottom of the glass. He cut off also the tips of some roots vegetating in the earth, and had the same result; the wound citatrised, and the root sent out lateral divisions.

When a root ceases of its own accord to elongate, it sends out also lateral fibres, though less vigorously, and with less rapidity than in the above cases. The lateral branches of perpendicular roots are always the more vigorous the nearer they are to the trunk; but the lateral branches of horizontal roots are the less vigorous the nearer they are to the trunk. In the former case, the increased luxuriance is, perhaps, owing to the easy access of oxygen in the upper divisions; but in the latter case the increased luxuriance of the more distant divisions is not so easily accounted for, if it is not to be attributed to the more ample supply of nutriment which the fibres meet with as they recede from the trunk, particularly if you suppose a number of them lying horizontally, and diverging like the radii of a circle.

But the direction of roots is so liable to be effected by accidental causes, that there is often but little uniformity, even in roots of the same species. If plants were to be sown in a soil of the same density throughout, perhaps there might be at least as much uniformity in the figure and direction of their roots as of their branches; but this will seldom happen. For if the root is injured by the attacks of insects, or interrupted by stones, or earth of too dense a quality, it then sends out lateral branches, as in the above cases; sometimes extending also in length by following the direction of the obstacle, and sometimes ceasing to elongate, and forming a knot at the extremity. But where the soil has been loosened by digging, or otherwise, the root generally extends itself to an unusual length. This, Du Hamel has illustrated by the following cases:—If a trench is opened at a small distance from a young tree, and immediately filled up again with loose earth, the roots which enter the trench will continue to follow its direction, and will send out but few lateral branches. And if part of the trench is filled up with earth of a superior quality, or with earth mixed with manure, the greater number of divisions will be directed to that quarter. Trees, also, that are planted by the banks of a river extend their branches chiefly in the direction of the river, without sending out many lateral branches. Where the earth is very loose, the roots are generally weak; because, having no obstacle to overcome, they have extended to an undue length. Hence the roots of plants vegetating in pots, but especially in water, are the weakest; but where roots have some considerable obstacle to overcome, they will often acquire a strength proportioned to the difficulty: sometimes they will penetrate the hardest soil to get at a soil more nutritive, and sometimes they will insinuate their fibres into the crevices even of walls and rocks, which they will burst or overturn. This, of course, requires much time, and does much injury to the plant. Roots, consequently, thrive best in a soil that is neither too loose nor too dense.—(*Keith's Vegetable Physiology.*)

The distance to which the roots of a plant extend is much greater than is usually imagined; and one reason of the stunted growth of plants in a poor soil is, that the sap collected and elaborated by them has to be expended in the extension of the roots, which have to be larger in proportion as the pasturage near home is scanty. An Acorn, accidentally deposited on a wall, produced a young Oak; but this made no progress until its root had descended the whole height of the wall, and had penetrated the soil at its base.

In deep, poor, siliceous soils, we have traced the roots of trees from twelve to fourteen feet perpendicular without reaching their termination. Those of the Canada Thistle, seven feet; common Fern, eight feet; Wheat, thirty inches; Oats, twenty-four inches; Potatoes, eighteen inches; Onions, twenty inches; Carrots, Parsnips, and Beet, two feet.

Mr. Cary Tyso, the well-known florist at Wallingford, thus relates his observations on the distance to which the roots of

Mignonette will extend :—" I was invited by a gentleman of this town to inspect a plant of Mignonette, which had penetrated through several courses of bricks, and descended far into a wine-cellar. Over the cellar, which was outside the dwelling-house, was a brick pavement; between the joints of which Mignonette seed had been sown from year to year. A plant or two, where there was more soil, grew more vigorously than the rest, though not so luxuriantly as it often does in a common border. The roots off these plants had penetrated through eighteen inches of brickwork; and some of them were hanging inside the arched roof of the cellar, nourished by the damp atmosphere only. A few more favourably situated were attached to the end wall of the cellar, and had descended five feet five inches down the wall into the decaying sawdust of the wine-bin. Others were beautifully spread over the wall, with a thousand branching rootlets bespangled with minute crystal-like damp-drops, and extending over a space of five feet in width. It was difficult to trace the brittle roots in the sawdust; but I measured some upwards of seven feet below the surface of the brickwork in which the plants were growing."

The distance to which roots will travel, and their tenacity of life, render them, often, very obnoxious to the gardener. Thus the common Couch Grass (*Triticum repens*), is the most troublesome of weeds, for every fragment of its far-spreading-roots will vegetate; and the Sweet-scented Coltsfoot, the Periwinkle (*Vinca*), and Lemon Mint, are no less to be avoided, for the same cause renders them extremely difficult of extirpation, and they never can be kept within moderate bounds. Yet these creeping-rooted plants are not to be condemned without exception : for, whoever has grounds under his care bordering upon the sea-shore, the sands of which are troublesomely light and shifting, may have them effectually bound down by inoculating them with slips of the roots of these grasses, *Elymus arenarius*, *Carex arenaria*, and *Arundo arenaria*.

The roots of plants, unless frozen, are constantly imbibing nourishment, and even developing parts; for if the roots of trees planted during a mild winter be examined after an interval of a few weeks, they will be found to have emitted fresh radicles. The food they imbibe is slowly elaborated in the vessels of the stem and branches, and there deposited.

It is by hair-like perforated suckers near their extremities, as we have stated, that roots imbibe food; but the orifices of these suckers are so minute, that they can only admit food in a state of solution. Carbon, reduced to an impalpable powder, being insoluble in water, though offered to the roots of several plants, mingled with that fluid, has never been observed to be absorbed by them; yet it is one of their chief constituents, and is readily absorbed in any combination which renders it fluid.

Roots then must obtain from a soil nourishment to plants in a gaseous or liquid state: we shall have, therefore, to consider what constituents of soil are capable of being presented in such forms. Water can be the only solvent employed; indeed, so essential is this liquid itself, that no plant can exist where it is entirely absent; and, on the other hand, many will exist with their roots in vessels containing nothing but distilled water. Plants with a broad surface of leaves—as Mint, Beans, &c., we have always found increase in carbonaceous matter whilst thus vegetating; but Onions, Hyacinths, &c., with small surfaces of foliage, we, as invariably, have found to decrease in solid matters. The first, at all times, obtain nourishment by decomposing the carbonic acid gas of the atmosphere. The latter do so in a much smaller proportion: hence the reason why the latter are so much more impoverishing crops than the former, inasmuch as that they acquire nearly all their solid matter by means of their roots.

These observations explain the conflicting statements of Saussure and Hassenfratz on this point: the former experimented with broad-leaved plants; the latter on such as have small foliage. The first maintained that plants increase in solid content when their roots are supplied with water only; the latter denied the fact.

It has been advanced, that water is the sole food of plants; but all experiments are inconclusive which are presented as supporting the theory.

In the first place, all waters contain earthy, saline, and organic matters. Even distilled water is not pure, as Sir H. Davy has proved; and rain water has been demonstrated to be much less so. No plants, growing in water only, will ever perfect seed; and the facts, that different plants affect different soils, and that a soil will not bear through a series of years the same crop, whereas it will bear a rotation of different crops, demonstrate that they each take somewhat varying kinds of food from the earth, and not that universal one—water, which is ever present and renewed.

So far, indeed, from water being the sole food of plants, they are injured and destroyed by its superabundance in the soils sustaining them. Such soils are always colder than well-drained soils, inasmuch as that the same quantity of caloric (heat) which will warm the earth 4°, will only warm water 1°—or, to use the language of the chemist, the capacity for heat of water is four times greater than that of the earths.

The effect of drainage upon the temperature of the soil has been well shown by the observations recorded in Mr. H. Stephens' work on the Yester deep-land culture. Six thermometers were placed in the soil, at a depth of eighteen inches. This distance from the surface was chosen, since at that depth they were found not to be sensibly affected by the changes of the temperature of the atmosphere. Observations were made to ascertain the temperature of the ground before and after it was thoroughly drained and subsoil-ploughed. In the following table, column I. gives the month; II., the mean temperature in 1849 of the soil of a field at Yester Mains in its undrained state; III., that of another field in the same year after being thorough-drained; IV., that of No. II. in 1850, after thorough draining; V., that of the soil of the south border of a garden at Yester, in 1849:—

VEGETATING SEASON.	II.	III.	IV.	V.
March	36	37	37	42
April	40	38	39	43
May	48	47	42	51
June	54	53	54	58
July	55	54	59	62
August	56	46	54	62
September	50	54	55	59
October	35	37	50	50
Mean of vegetating season	46.75	45.75	48.75	53.37
NON-VEGETATING SEASON.				
November	34	37	44	46
December	34	36	39	41
January	32	32	32	43
February	34	38	36	53
Mean of non-veg. season .	33.05	35.75	37.75	45.75
Mean of both seasons. .	42.33	42.42	45.08	50.83

The celerity with which thorough draining may affect the temperature of the surface soil was observed, in one instance, at Broadwoodside. A thermometer placed one foot under the surface, on the crown of an eighteen-feet ridge, before a drain was cut, indicated a temperature of 48°; after a drain had been cut to the ordinary depth on each side, in the open furrow of the ridge, the temperature rose to 49.5°, that is 1½° in six hours.—(*Agricultural Gazette*, 1855, p. 651.)

The water removed from cultivated soils by the land-drains has been examined by Professor Way (*Journal Royal Agricultural*

Society, vol. xvii., p. 123), and as the substances found in such waters pretty well correspond with those contained in the moisture of the soils through which they percolate, and from which moisture the growing plant obtains at least all its mineral ingredients, it may be useful, as in the following table, to give, I., the substances found in 100 parts of the seed of the Hoptoun Wheat; II., in its straw and chaff (*Ibid*, vol. vii., p. 631); III. and IV., the matters (given in grains) contained in an imperial gallon of two (previously filtered) drain waters, from two fields on the farm of Mr. Paine, at Farnham, in Surrey (*Ibid*, vol. xvii., p. 133) :—

	I.	II.	III.	IV.
Silica	5.63	69.36	0.95	0.45
Phosphoric acid	43.98	5.24	trace.	0.12
Sulphuric acid	0.21	4.45	1.65	5.15
Chlorine	—	—	0.70	1.10
Lime	1.80	6.96	4.85	7.19
Magnesia	11.69	1.45	0.68	2.82
Peroxide of iron	0.29	0.73	—	—
Ditto and alumina	—	—	0.40	0.05
Potash	34.51	11.79	trace.	trace.
Soda	1.87	—	1.0	2.17

Then as to the soluble organic matter, ammonia, and nitric acid, found in land-drainage waters, in seven different specimens, from the lands of Mr. Paine, there were obtained (grains in imperial gallon) *see post.*, p. 54)—

	Soluble organic matter.	Nitric acid.	Ammonia.
1	7.00	7.17	0.018
2	7.40	14.74	0.018
3	12.50	12.72	0.018
4	5.60	1.95	0.012
5	5.70	3.45	0.018
6	5.80	8.05	0.018
7	7.40	11.45	0.006

The ammonia and nitric acid contained in the rain water which supplies this drainage water, varies considerably in different months. That falling at Rothamsted, in Hertfordshire, twenty miles from London, has been examined by Professor Way (*Ibid*, vol. xvii., p. 143). He found (grains) in an imperial gallon in—

	Ammonia.	Acid.		Ammonia.	Acid.
January	0.092	0.017	July	0.061	0.017
February	0.104	0.042	August	0.080	0.060
March	0.086	0.021	September	0.095	0.021
April	0.123	0.035	October	0.061	0.036
May	0.080	0.035	November	0.054	0.018
June	0.135	0.080	December	0.067	0.017

The advantages to the soil of removing the land water, which prevents the free circulation of the atmosphere, is self-evident. "Every acre of ground," adds the Professor, "which allows water to percolate freely, benefits equally by the nitric acid and ammonia of rain." But whence comes the additional luxuriance which vegetation puts on when the land is abundantly worked? whence the Lois Weedon crops? Obviously Mr. Smith cannot be satisfied with the ammonia of rain, he must have some from the air also; and he gets it from the air in a far greater quantity than the rain could furnish. In fact (adds Mr. Hoskyns), he habitually expresses his obligations to the dew, as a more steady benefactor than the rain, in much the same terms as might express the relation of "daily bread" to an occasional feast.

Liebig calculates (*Ibid*, p. 287) that the soil of an acre twelve inches deep can take up (lbs.) of ammonia, in addition to that contained in it from long exposure to the air—

Thin land of Dorsetshire	20.880
Light red soil, Berkshire	9.420
Stiff white clay	17.040

Secondly. The vegetable decomposing matters in a soil, where water is superabundant, give out carburetted hydrogen, acetic, gallic and other acids, instead of carbonic acid gas and ammonia —products essential to healthy vegetation. Palliatives are the application of lime, or its carbonate (chalk), to the soils in which these acids have been generated; and, indeed, after those acids have been formed, such an application is essential, though the radical cure and preventive of recurrence—thorough draining—be adopted.—(*Farmer's Almanac*, 1853.)

Thirdly. A soil filled with stagnant water cannot be penetrated by the rain, and this flows off from the surface. "If it be asked," says Mr. Cuthbert Johnson, "What difference is there between rain water and the water in the land which was once rain water too? Why should we covet an abundant supply of the first, and be anxious for the removal of the last?" The chemists of our time have given a ready answer. They have shown, amongst other causes of difference in their value, that rain water contains ammonia, of which land water is commonly destitute. This presence of ammonia in rain water has been placed, as Liebig remarks, beyond all doubt; it may also be detected in snow water. And it is worthy of observation, that the ammonia obtained by the chemical philosopher from these sources possesses an offensive smell of perspiration and animal excrements, a fact which leaves no doubt respecting its origin. And again, Hunefeld, and other German chemists, have proved the existence of carbonate and nitrate of ammonia in the water of many springs; in minute quantities it is, most probably, to be found in that of most springs, and this may tend to account for one of the observations of the skilful owners of the water meads of the great English chalk formation. They have remarked that the water of this stratum, as it issues, cold and bright as crystal, from the ground, is much better adapted for their purpose than when, in its course towards the sea, it has gradually acquired an increase of temperature, and a portion of finely-divided and other organic matters. They remark, too, that if the spring water is thus employed for the purpose of irrigation, that after it has passed over one meadow, it is almost useless to employ it a second time for a similar purpose. "Something is taken out of it by the first Grass," once remarked to me, an excellent owner of one of these great water meadows, "which the second meadow cannot find in it." The same able farmer who had noted these things in the case of the chalk springs of the upper portion of the valley of the Itchen, had also remarked, that the copious waters of that river, although deteriorated for the purposes of irrigation, by their employment in the meads above the city of Winchester, were nearly as valuable as ever after they had passed that city, and been mixed with the contents of its sewers.

It is to the presence of ammonia, then, in such waters, that one source of this effect may be attributed. It is true that the ammonia contained in rain water is in very minute proportions, and in spring water the proportion is, probably, still less; but then it must be remembered, what is not commonly very clearly understood, that the weight of water which annually falls upon the farmer's fields is very great. "If," remarks Liebig (*Organic Chem.*, p. 75), "a pound of rain water contains only one-fourth of a grain of ammonia, then a field of 40,000 square feet must receive annually upwards of 80 lbs. of ammonia, or 65 lbs. of nitrogen (ammonia is composed of nitrogen and hydrogen); for, by the observations of Schubler (made in Germany), about 700,000 lbs. of rain fall over this surface in four months, and, consequently, the annual fall must be 2,500 lbs. This is much more nitrogen than is contained in the form of vegetable albumen and gluten, in 2,650 lbs. of wood, 2,800 lbs. of hay, or twenty tons of Beet-root, which are the yearly produce of such a field; but it is less than the straw, roots, and grain of corn which might grow on the same surface would contain."

It is not an extravagant assertion, that there is scarcely a garden existing that would not be benefited by under-draining. Every gardener knows the absolute necessity for a good drainage under his wall-trees and Vines; but few gardeners ever think, for a moment, whether there is any escape, any outfall for the water he has drained from immediate contact with the roots of the above-named favoured trees. Every garden should have drains cut, varying in depth from two to three feet, according to the depth of the soil, with an interval of from twelve to eighteen feet between the drains. At the bottom of the drains should be placed one-inch pipes: these should be well puddled over, six inches deep, with clay, and then the earth returned. If the subsoil is clayey, the drains should be only twelve feet apart, and the draining tiles covered with stones. They should have an outfall into a ditch, at the least elevated side of the garden. By having the pipes with a bore no larger than an inch, moles cannot creep in, and they are large enough to carry off all the water, after even the heaviest rains.

The expense is, comparatively, nothing, varying from £3 to £5 per acre; and we shall not stop to argue with any one who doubts for an instant the advantage consequent upon removing all water from a soil not retainable by its own absorbent powers; and we will only state one other relative fact—viz., that at Lord Hatherton's residence, Teddesley Hay, in Staffordshire, 467 acres, formerly letting for an average rental of 12*s*. per acre, were all drained for an outlay of £3 4*s*. 7*d*. per acre, and their rental now averages more than 31*s*. per acre!

To plants in pots, good drainage is not less essential than to those in our borders.

To secure this, not only should at least two inches of broken potsherds and rubbly charcoal be placed beneath the soil put into pots, but the soil itself should be allowed to retain its pebbles, instead of having them sifted out, as was the ancient practice.

The soil must vary according to the nature of the plant; but whatever be its quality, instead of being sifted fine, as gardeners formerly directed, let all the small pebbles remain, and pieces of charcoal, none smaller than nuts, be mixed so as to pervade the earth at distances of about two inches. Let the whole rest upon a drainage composed entirely of charcoal, the pieces not less than small walnuts. This treatment, suggested by nature, but first recommended by Mr. Barnes, of Bicton Gardens, secures acceptable food to the roots, and prevents the occurrence to them of that fatal evil—stagnant water. Let the plants once a year be taken out of their pots, their heads reduced in size, and a portion of the exterior roots removed. Let them be returned into the same pots, with similar attention to the soil and drainage; for it is an inconvenience mostly growing out of error, to give them larger pots annually. Mr. Knight grew even a Nectarine tree for more than nine years in the same pot. This restriction to small-sized pots cannot be always effected; and when shifting is necessary, it is advisable to remove, as much as possible, the old soil, of course without injuring the roots. This is generally best effected by soaking the ball of earth in water: and thus it may be washed almost entirely away, and the roots be left coated with a mud that is beneficial to them, and preserves them from drying, until the fresh soil is well settled about them. The number of roots within a given space of soil is much larger than when the plants grow in the open soil; for, being restrained by the side of the pot, they fork into numerous fibres, spread over its surface and even turn inwards again in search of food, they being gifted with the power of forming an extra number of radicles whenever deficiency of food renders such compensatory power necessary. The gardener endeavours to render it needless, by supplying the plants with liquid manure. But this richness of pasture can only be permitted to a certain extent; for if a plant is so well supplied with food as not to render a certain consumption of its proper juices in forming roots requisite, so much more of those juices is stored in the stem and branches, rendering the plant over-luxuriant, and, consequently, unproductive of flowers and fruit.

Mr. Barnes observes that the common earth-worm is too generally regarded as an enemy; whereas, by its perforations of the earth, it facilitates the admission of air to the roots of plants: and we have found that thrusting a knitting needle down through the soil of potted plants, as well as stirring its surface, is highly beneficial.

Hunt's pots, supported by small feet, are well calculated to facilitate drainage; and, by permitting the passage of air beneath the pots, they also admit it more readily to the roots.

Drainage, however, is not the only desideratum to potted plants; for they have many other difficulties to contend against, from which those in the open soil are preserved. The soil, at a few inches below its surface, is always, during winter, some degrees warmer than the exterior air; but, owing to the evaporation from the sides of garden-pots, this is rarely the case with the soil in them. To preserve this salutary warmth to the roots, a double pot has been suggested, but placing the plant-pot within a larger pot, and stuffing moss in the interval between them, is a cheaper and readier safeguard.

The importance of following the dictates of nature in keeping the roots of plants, natives of the torrid and temperate zones, as warm or warmer than the branches, was too much neglected by the gardener in his forcing department. In the vinery, for example, the stem and roots are even now too often absurdly exposed to the rigour of winter; whilst the buds are expanding within the glass shelter in a temperature of 60°. A Vine so treated is like the felled Elm, which, allowed to retain its bark, though rootless, puts forth its leaves in the spring; expands its buds, and advances through the first stages of growth, merely from the sa stored within its stem and branches. This is no mere suggestio of fancy; for repeated experiments have shown that hot-hous Vines, with their roots thus kept torpid by exposure to cold were with buds unfolded; whilst other Vines, treated in al respects similarly, but with their roots kept genially warm, wer actually in bloom.

But a worse mischief arising from this absence of reciproca action between the roots and branches is the causing of disease. Thus the shanking and spot in Grapes occur apparently from th roots not supplying the sap so fast as the expanding fruit requires it. The application of more warmth and genial moisture to the soil usually arrests the progress of these diseases. They are really like mortification in the animal frame. If the necessary supply of blood is not given to any part of the human body, as by cutting in two a main artery, that part becomes cold, shrinks, ulcerates, and mortifies.

Although an excess of water applied to the roots of plants is injurious to them, yet all of them are benefited by a due supply of that liquid, and the supply has to be regulated by the amount of their daily transpiration. The gardener knows that this differs in every species, and during different seasons. For instance, in a dry hot day, a Sunflower, three feet and a half high, transpired 1 lb. 4 ozs., being seventeen times more than the human body; during a hot, dry night, it transpired 3 ozs.; during a dewy night there was no transpiration; and during a rainy night the plant absorbed 3 ozs.

Therefore, the gardener finds it best to apply water during dry weather, early in the morning, just before the chief demand occurs, which is from six A.M. till two in the afternoon, or in the evening whilst hot weather continues, for the dews then supply the chief natural moisture at night; and during moist weather he refrains from the application entirely. Then, again, the gardener keeps his Agaves and other fleshy-leaved plants in a dry stove, for they transpire but sparingly in proportion to their mass, and require watering but seldom, and then abundantly; for they take up, as in their native siliceous soils, a large supply of moisture, and retain it pertinaciously in defiance of the long-protracted droughts to which they are exposed.

In the same species we have always found varieties transpire abundantly, and require a larger supply of water in proportion to the extent of their transpiring surface. Thus the broad-leaved Fuchsias and Pelargoniums transpire from two to three times as much as those varieties which have smaller and less abundant foliage.

Returning to the consideration of the food obtained by a plant from the soil by the agency of its roots, we find that silica, or the pure substance of flint, is present in all soils; is soluble in water, requiring one thousand times its weight of this liquid to dissolve it (*Kirwan's Mineralogy*, vol. i., p. 10); is found in many plants, and in all the grasses that have been analysed.

It was the opinion of Lampadius that the earths contained in plants are merely the effect of vegetation, and altogether independent of the soil in which they grow. The experiment was as follows:—Five beds, four feet square by one foot in depth, each containing a pure earth,—alumina, silica, lime, magnesia, garden mould, and each mixed with eight pounds of cowdung, were sown with rye. The produce of each was separately reduced to ashes, and the same principles were found in them all, particularly a portion of silica. Whence came the silica in the bed of alumina? According to Lampadius it was the result of vegetation. But Saussure, after Ruckert, has shown that cowdung contains a portion of silica. (*Sur la Veg.*, chap. ix. sect. 3.) Hence the substance which Lampadius could not account for but by means of vegetation he had supplied with his own hands. It is now known that the earths are partially soluble, some of them in pure water, and all of them with the aid of acids; so that we may fairly presume that they are taken up in solution by the root, and converted to the purposes of vegetation. Not that they are capable of affording any considerable degree of nourishment to the plant, but that some plants seem to be benefited by absorbing them. The grasses have their stems thus strengthened, and the Equisetaceæ and the Palms have their stems or leaves better fitted for the purposes of art. The leaves of Palms make a substantial thatch for covering houses owing to the silica they contain; and the Dutch Rush is made use of to polish even brass.

Alumina, or the basis of clay, present in all soils, is so soluble in water as to be inseparable by the filter, and is much more so when any of the acids are present (*Sennebier's Physiolog. Veget.* vol. iii., p. 18); it is found in plants in minute quantities, especially in the grain of barley, Oats, Wheat, &c. (*Schrœder, in Gehlen's Journ.*, vol. iii., p. 525). The chief value of Alumina in a soil is by enabling it to retain moisture and the soluble portions of organic manures as they decompose. It also retains their ammonia; and it is believed that it even absorbs this great promoter of vegetation from the atmosphere.

"Peroxide of iron and alumina," says Liebig, "are distinguished from all other metallic oxides by their power of forming solid compounds with ammonia. The precipitates obtained by the addition of ammonia to salts of alumina or iron are true salts, in which the ammonia is contained as a base. Minerals containing alumina or oxide of iron also possess, in an eminent degree, the remarkable property of attracting ammonia from the atmosphere, and of retaining it. Vauquelin, whilst engaged in the trial of a criminal case, discovered that all rust of iron contains a certain quantity of ammonia. Chevalier afterwards found that ammonia is a constituent of all minerals containing iron; that even hematite, a mineral which is not at all porous, contains one per cent. of it. Bouis showed also, that the peculiar odour observed on moistening minerals containing alumina is partly owing to their exhaling ammonia. Indeed, many kinds of gypsum and some varieties of alumina, pipeclay for example, emit so much ammonia when moistened with caustic potash, even after they have been exposed for two days, that reddened litmus paper held over them becomes blue. Soils, therefore, containing oxides of iron and burned clay must absorb ammonia, an action which is favoured by their porous condition; they further prevent, by their chemical properties, the escape of the ammonia once absorbed. Such soils, in fact, act precisely as a mineral acid would do if extensively spread over their surface.

"The ammonia absorbed by the clay or ferruginous oxides is separated by every shower of rain, and conveyed in solution to the soil."

Lime is found in almost all soils; it is easily soluble in water, and there is but one plant that is not known to contain some of it as a constituent—the *Salsola Soda* (*Ann. de Chimie*, vol. xviii. p. 76). Thus a crop of Beans, twenty-five bushels per acre, contains in those twenty-five bushels 36½ lbs. of lime,—namely, 2½ lbs. in the seed, and 34 lbs. in the stems and leaves. Twenty tons of Turnips from the same space of ground contain 118 lbs. of lime—46 lbs. in the bulbs, and 72 lbs. in the leaves. Eight tons of Potatoes from an acre contain 39 lbs. of lime—8 lbs. in the tubers, and 31 lbs. in the haulm.

Another important suggestion is thus thrown out by the late Professor Johnston:—"Can lime take the place of potash or soda in the living plant? We have no series of anaylses of *entire* plants which are fitted to throw much sure light upon this point. In regard, indeed, to certain parts of the plants it appears that the proportion of lime they contain may vary very much, and that as the lime increases the alkaline matter diminishes. Thus, in—

"*a. The Tobacco leaf.*—The mean relative proportions of the alkaline matter and of lime found in a series of tobacco leaves grown in two different localities were as follows:—

	I.	II.
Potash and soda	27.02	12.21
Lime.........................	27.87	45.90

"Each of these results is the mean of four analyses; and they appear to show satisfactorily that in the leaf of this plant the lime may increase while the potash diminishes. In other words, the lime may take the place of a part at least of the potash. So

"*b. The twigs of the Vine*, from two localities, gave an ash which contained of alkaline matter and of lime respectively—

	I.	II.
Alkalies	45.82	27.98
Lime.........................	29.75	40.75

from which it would appear as if lime in this plant might also take the place of potash and soda.

"Such facts as these seem to render it probable that lime may supply the place of alkaline matter to a certain extent—may perform some of its functions in some plants. We know too little, however, of the changes which take place in the relative proportions of the inorganic substances in the same part of a plant at different periods of its growth, or of how much of that which is found in the leaf or twigs is really essential to its healthy existence, to be able to estimate the amount of reliance which ought to be placed upon the conclusions to which the above facts seem to lead.

"It is not likely that lime should serve the purpose of the alkalies in rendering silica soluble, and thus making its entrance into the roots of plants more easy—though even here our knowledge is by no means certain. As lime is so very abundant, it would be both interesting and important to make out by experiment to what extent it may perform the functions and supply the place of alkaline matter in our cultivated crops."—(*Lectures on Agricultural Chemistry.*)

When caustic lime, or, as it is commonly called, quicklime is added to a soil it decomposes the salts of ammonia which the soil contains, driving off the ammonia, but which is absorbed and retained by the alumina in the soil. Caustic lime also promotes the rapid decay of vegetable and animal bodies in the soil; and is especially useful in rendering fertile boggy soils full of woody matters, and containing an excess of the salts of iron.

Magnesia, generally present in soils, is soluble in water, and is found in many plants. Indeed, lime and magnesia in combination with phosphoric acid exist in all plants. They resemble each other very much; and some facts are known which seem to show that they may take the place of each other. In all our published analyses of Wheat, Oats, and Barley, the proportion of magnesia greatly predominates in the grain, while that of lime is larger in the straw. This is not in favour of the view that they are capable of taking the place of each other in the several parts of healthy plants.

On the other hand, in the Tobacco leaves from the Bannat, Will and Fresenius found the potash much less than in other varieties, while the magnesia was much greater—as if magnesia as well as lime could take the place of potash. The same was found by Hruschauer in the stem of Indian Corn. Of the inorganic matter present in the mature leaf and stem, however, we do not really know how much is accidentally present, and how much is essential to its healthy existence. We must, therefore, defer our judgment in regard to this point.

The most apparently decisive experiments on this relation of lime and magnesia are those upon the composition of Linseed. German Linseed, of which the ash was analysed by Leuchtweiss, and specimens of Riga and Dutch seed examined in Professor Johnstone's laboratory by his assistant, Mr. Cameron, contained respectively of lime and magnesia in their ash—

	German.		Riga.		Dutch.
Lime	25.27	...	8.46	...	8.12
Magnesia......	0.22	...	14.83	...	14.52

These analyses, if they are to be depended upon, show that magnesia may either be almost entirely wanting in these seeds, or that it may be present in large proportion, and that, when magnesia is scarce in them, lime is abundant. In other words, that these two earthy bases may, to a certain extent, replace each other.

Iron is present in all soils, in all natural waters, and in all plants.

Manganese is found in some soils, is soluble in water containing acids, &c., and is found in a few plants.

But none of those substances in a state of purity, either simply or combined, have ever been found capable of perfecting a plant through all its stages of growth when moistened only with distilled water; the contrary is the case, however, when the water contains in solution vegetable or animal matters, as the dung of animals. Now these matters contain carbon, hydrogen, oxygen, nitrogen, and various salts: the three first are absolutely necessary for the existence of all plants, every part of which is chiefly composed of them. Nitrogen is found in most plants; and the importance of salts to vegetation is demonstrated by the facts that Clover will not flourish where there is no sulphate of lime; that Nettles follow the footsteps of man for the nitrate of potass, which always abounds near the walls of his habitation; and that marine plants linger for the common salt of their native haunts. Salts of some kind or other are found in every species of plant, but none of which the constituents have not also been detected in soils. During decay, vegetable and animal matters also exhale various gases. Carbonic acid, hydrogen, carburetted hydrogen, ammonia, &c. are of the number; all of which have been applied to the roots of plants with great benefit by Sir H. Davy and others.

Although plants will not grow upon soils composed of the earths only, yet these have a great influence over plants, not merely by their secondary powers of regulating the amount of moisture, heat, &c., but by entering directly into the constitution of the plant; for it is a result of experience, to which we know of no exception, that a plant contains more of any given earth, if grown in a soil where it predominates, than if grown in a soil where it is in less profusion. We have already stated some examples; but the fact was first pointed out by Saussure, who found that the *Rhododendron ferrugineum*, when growing on the calcareous formation of Mount Jura, contained in its ashes 43.25 per cent. of carbonate of lime, but only 0.75 of silica. On the other hand, the ashes of the same plant, from the granitic district of Mount Brevere, contained, 2.0 per cent. of silica, but only 16.75 of carbonate of lime.

However varying in the proportions, yet every soil is composed of silica, alumina, lime, magnesia, oxide of iron, salts, and animal and vegetable remains. The most important consideration is, what proportions those are which constitute a fertile soil.

The *beau ideal* of a fertile soil is one which contains such a proportion of decomposing matter, and of moisture, as to keep the crop growing upon it always supplied with food in a state fit for its consumption, yet not so superabundantly as to render the plants too luxuriant, if the object in view is the production of flowers or seed; but, for the production of those plants whose foliage is the part in request, as Spinach and Rhubarb, or of edible bulbous roots, as Onions, which have a small expanse of leaves, so as to be almost entirely dependent upon the soil for nourishment, there can scarcely be an excess of decomposed matter presented to their roots. Spinach, on rich soils, will yield successive cuttings the same as Asparagus; the latter, especially, demands abundant applications of nourishment to its roots; since, like the Onion, it has little foliage and slightly fibrous roots, at the same time that, like the Spinach, it has to afford repeated cuttings; and thus, requiring a repeated development of parts, needs abundant food in its immediate neighbourhood.

A soil with a just proportion of decomposing matter will be capable of absorbing moisture during the droughts of summer from the atmosphere, for the most fertile soils are always the most absorbent: yet it must not be too retentive of moisture, which is the case in such soils as contain too much alumina; neither must it too easily part with moisture—a fault which is a characteristic of those soils which contain an excess of silica. A subsoil of gravel mixed with clay is the best, if not abounding in oxide of iron; for clay alone retains the moisture on the arable surface in too great an excess; and sand, on the contrary, carries it away too rapidly. Chalk is a cool subsoil; and if the surface soil is of average quality and depth, crops upon it are not liable to suffer from drought. It is, however, evident, that to ensure these good qualities in any soil at all seasons is impossible; and it is as manifest that a soil that would do so in one climate would fail in another, if the mean annual temperature of them differs, as well as the amount in inches of rain which falls during the same period. For example: in the western parts of England more than twice as much rain occurs as in the most eastern counties, or in the proportion of 42 to 19; therefore, a soil in the east of England, for any given crop, may be richer and more tenacious than the soil required for it on the western coast.

Alumina, or clay, imparts tenacity to a soil when applied; silica, or sand, diminishes that power; whilst chalk and lime have an intermediate effect. They render heavy soils more friable, light soils more retentive. These simple facts are important; two neighbouring gardens, by an interchange of soils, being often rendered fertile, which, before, were in the extremes of heaviness and lightness.

From these statements it is evident that no universal standard, or recipe, can be given for the formation of a fertile soil; but a soil, the constituents of which approach in their proportions to those of the following, cannot be unproductive in any climate. It is a rich alluvial soil which Mr. Sinclair, in his "Hortus Gramineus Woburnensis," gives as being the most fertile for the grasses:—

"Fine sand, 115; aluminous stones, 70; carbonate of lime, 23; decomposing animal and vegetable matter, 34; silica, 100; alumina, 28; oxide of iron, 13; sulphate of lime, 2; soluble, vegetable, and saline matter, 7; loss 8. Total, 400."

It may be added, that, to constitute a soil eminently fertile, much of its earthy particles must be in a minute state of division. In the above analysis, 185 parts only were separable by sifting through a fine searce; 215 parts were impalpable; whereas poorer soils will often have 300 parts of coarse matter to every 100 of finely pulverised constituents.

We have noticed the ready mode, so usually within the gardener's power, of improving the staple of a soil by the mere admixture with it of some other soil in its immediate vicinity. As a guide in forming such mixtures, by showing how the earths and their compounds differ in their physical qualities, the following researches of M. Schubler, epitomised by Mr. Cuthbert Johnson in his "Modern Agricultural Improvements," will be found useful.

"The weight of the earths and their compounds differs very materially, according to their degree of dryness. In the following tables, the *wet* state is regarded as being that when a soil thoroughly moistened is laid in a wet state on a filter, and no longer allows any water to drop through.

"Several of the earths exhibited the following differences in reference to this point :—

Kinds of earth.	Specific gravity, that of water being taken as = 1.	Weight of a cubic foot.	
		In the dry state.	In the wet state.
		Pounds.	Pounds.
Calcareous sand	2.722	113.6	141.3
Siliceous sand	2.653	111.3	136.1
Gypsum powder	2.331	91.9	127.6
Sandy clay	2.601	97.8	129.7
Loamy clay	2.581	88.5	124.1
Stiff clay, or brick earth	2.560	80.3	119.6
Pure grey clay	2.533	75.2	115.8
Fine white clay (pipe clay)	2.440	47.9	102.1
Fine carbonate of lime	2.468	53.7	103.5
Fine carbonate of magnesia	2.194	15.8	76.3
Humus	1.370	34.8	81.7
Garden mould	2.332	68.7	102.7
Arable soil	2.401	84.5	119.1
Fine slaty marl	2.631	112.0	140.3

"*Weight of Artificial Mixtures of Earths.*—When different earths are artificially mixed together, a cubic inch of the earthy mixture obtained gives a weight greater than the arithmetical mean (or common average) of the earths entering into the mixture, whether mixed in equal portions according to weight or volume, or in other quantities. 'I took,' says M. Schubler, 'in different proportions, a common siliceous sand, a rich clay, and a fine clay-marl, of which I had previously ascertained the absolute weights, and mixed them together, when I determined the weight of the mixture and obtained the following results :—

Kinds of earth.	Weight of 5.7 cubic inches.	Arithmetical mean.	Increase of weight.
	Grains.	Grains.	Grains.
Common siliceous sand	2840		
Stiff clay, or brick earth	2020		
Fine clay-marl	1790		
Clay and sand in equal proportions by weight	2545	2430	115
Clay and sand in equal proportions by volume	2685	2430	255
2 parts clay and 1 part sand by weight	2390	2293	97
2 parts clay and 1 part sand by volume	2470	2293	177
2 parts sand and 1 part clay by weight	2740	2566	174
2 parts sand and 1 part clay by volume	2825	2566	259
Equal parts of marl and sand by weight	2315	2267	48

"'This phenomenon is only to be explained by supposing a more intimate approach in the interstices of the contiguous earthy particles; something similar, therefore, seems here to happen with this mechanical commixture to what takes place in a still higher degree with natural mixtures of earthy and rocky materials: for instance, with the dolomite sand and stony marls, in which cases not only the absolute weight, but the real specific gravity also, is greater than in the separate earths.'

" Such researches as these all tend to promote the *permanent* improvement of the soil by the admixture of earths; and there is no doubt of the great advantage of this mode of improving land. 'The best natural soils,' said Davy, 'are those of which the materials have been derived from different strata; which have been minutely divided by air and water, and are intimately blended together; and in improving soils artificially, the farmer cannot do better than imitate the processes of Nature. The materials necessary for the purpose are seldom far distant; coarse sand is often found immediately on chalk, and beds of sand and gravel are common below clay; the labour of improving the texture or constitution of the soil is repaid by a great permanent advantage; less manure is required, and its fertility insured; and capital laid out in this way secures for ever the productiveness, and, consequently, the value of the land.'—(*Elem. Agric. Chem.*, p. 204.)

"A very important question to the cultivator of the soil is the amount of water, both by weight and volume, which various soils are capable of containing: this we shall find determined in the following table. To obtain these results considerable care is required.

"It might appear that this determination could be made by the mere comparison of the weights of a cubic inch of dry and wet soil, or from the absolute weight of a volume of the dry soil, and its power of containing water; we should, however, in this way obtain no correct result, because many soils, especially those containing clay and humus abundantly, contract considerably in drying, a cubic inch of such dry soils generally occupying a greater space in their wet state.

Kinds of earth.	Power of containing water.		A cubic foot of the wet earth contains of water.
	According to weight.	According to volume.	
	Per cent.	Per cent.	Pounds.
Siliceous sand	25	37.9	27.3
Calcareous sand	29	44.1	31.8
Gypsum powder	27	38.2	27.4
Lime, precipitated	47	54.5	39.1
Fine lime	85	66.1	47.5
Fine magnesia	256	76.1	62.6
Sandy clay	40	51.4	38 8
Loamy clay	50	57.3	41.4
Stiff clay, or brick earth	61	62.9	45.4
Pure grey clay	70	66.2	48.3
White clay (pipe clay)	87	66.0	47.4
Humus	181	69.8	50.1
Garden mould	89	67.3	48.4
Arable soil	52	57.3	40.8
Slaty marl	34	49.9	35.6

"The rapidity with which the water contained in various soils evaporates, by exposure to the atmosphere, varies very considerably. The following table contains the results of the experiments made by M. Schubler, in reference to this point, with 200 grains of the several earths at a temperature of 65¾°: they were spread out over a surface of ten square inches. The second column of the table contains in one view the portions of time in which the several earths respectively became dry under exposure to the same temperature: he did not require a perfect state of dryness, as this, at a temperature of 65¾ F. and in the open air, could not be expected.

Kinds of earth.	Capability of drying.		
	Evaporation from 100 parts of absorbed water, at 65¾° F. in 4 hours.	Times required for 90 parts of water to evaporate (at 65¾° F.) from 100 parts absorbed.	
	Parts.	Hours.	Minutes.
Siliceous sand	88.4	4	4
Calcareous sand	75.9	4	44
Gypsum powder	71.7	5	1
Sandy clay	52.0	6	55
Loamy clay	45.7	7	52
Stiff clay, or brick earth	34.9	10	19
Pure grey clay	31.9	11	17
Fine lime	28.0	12	51
Humus	20.5	17	33
Magnesia	10.8	33	20
Garden mould	24.3	14	49
Arable soil	32.0	11	15
Slaty marl	68.0	5	53

"The degree of *contraction* which soils undergo by being dried also varies very considerably. The subjoined table give the extent of this in the cases of the common earths :—

Kinds of earth.	1000 cubic lines became diminished in volume to	1000 parts therefore diminished in volume by
Siliceous sand	(no change)	—
Calcareous sand		
Fine lime	950 cubic lines	50 parts.
Sandy clay	940 „	60 „
Loamy clay	911 „	89 „
Stiff clay, or brick earth	886 „	114 „
Pure grey clay	817 „	183 „
Carbonate of magnesia	846 „	154 „
Humus	800 „	200 „
Garden mould	851 „	149 „
Arable soil	880 „	120 „
Slaty marl	965 „	35 „

"The extent to which various soils absorb the insensible vapour of the atmosphere was first endeavoured to be ascertained by Sir H. Davy (*Agric. Chem.*, p. 183). It is a power, as he truly enough described it, much connected with fertility. M. Schubler has much extended the experiments of Davy. (*Jour. R. A. S.*, vol. i. p. 196). The following table gives the results of these valuable researches, which were made by exposing the various earths in an atmosphere contained in an inverted vessel, resting in a surface of water, in a temperature of 59° to 65¾°. Under these circumstances the confined air, having free access to water, may be regarded as having been saturated with moisture.

Kinds of earth.	1000 grains of earth on a surface of 50 square inches, absorbed in—			
	12 hours.	24 hours.	48 hours.	72 hours.
	Grains.	Grains.	Grains.	Grains.
Siliceous sand	0	0	0	0
Calcareous sand	2	3	3	3
Gypsum powder	1	1	1	1
Sandy clay	21	26	28	28
Loamy clay	25	30	34	35
Stiff clay	30	36	40	41
Pure grey clay	37	42	48	49
Fine lime	26	31	35	35
Fine magnesia	69	76	80	82
Humus	80	97	110	120
Garden mould	35	45	50	52
Arable soil	16	22	23	23
Slaty marl	24	29	32	33

"It is a common error to regard the subsoil as being always similar in its *earthy* composition to the surface soil; and thus not to look for assistance to that source. This erroneous conclusion long misled, for instance, the cultivators of some of the thin clays of the north of Hampshire, resting upon the chalk formation; the chalk being there so very near the surface soil, no one imagined that a dressing with that could possibly fertilise the thin clay soil which merely covered it to the depth of a few inches; they have found, however, upon a correct examination, such a deficiency of carbonate of lime (chalk) in this thin surface of clay that they have now generally adopted, with great advantage, the plan of manuring these soils with copious dressings of chalk, brought to the surface, in some instances, by sinking dry wells to a considerable depth. And in another adjoining portion of the same county—the *deep* clays of the district around Strathfieldsaye, it has been found, by the analysis of Professor Phillips, that this apparently uniform clay differs very materially in composition at different depths. He found (to give an instance) in one hundred parts of two varieties of clay, at twenty-two inches and at four feet six inches, per cent.

	At 22 ins.	At 54 ins.
Silica	59.0	72.9
Alumina	23.5	13.4
Peroxide of iron	8.1	6.6
Carbonate of lime	1.0	0.8
Water, sulphate of lime, &c.	4.8	5.5
Carbonate of magnesia	0.0	9.8

—(*Jour. R. A. S.* vol. vii. p. 258.)

"The cultivators of the northern portion of our island, who principally obtain their lime from limestone, are, generally speaking, hardly sufficiently particular as to the quality of the stone they employ—this varies very considerably. Thus, some of the limestones of Argyleshire, have been found by Professor Johnston to contain—

Carbonate of lime	90.14
Carbonate of magnesia	0.31
Alumina, and oxide of iron	0.51
Insoluble siliceous matter	9.08

"The lime obtained from such limestone would not contain so large a portion of magnesia as to be injurious to vegetables; other limestones, however, are of a very different description; specimens from Berwickshire contained—

	From Langton Park.	Langton Wood.	Grueldykes.
Carbonate of lime	43.85	47.00	43.81
Carbonate of magnesia ...	33.34	38.04	39.50
Alumina and oxide of iron	1.59	1.99	3.57
Insoluble siliceous matter	21.41	12.97	13.09

—(*Trans. High. Soc.*, 1847, p. 574—577.)"

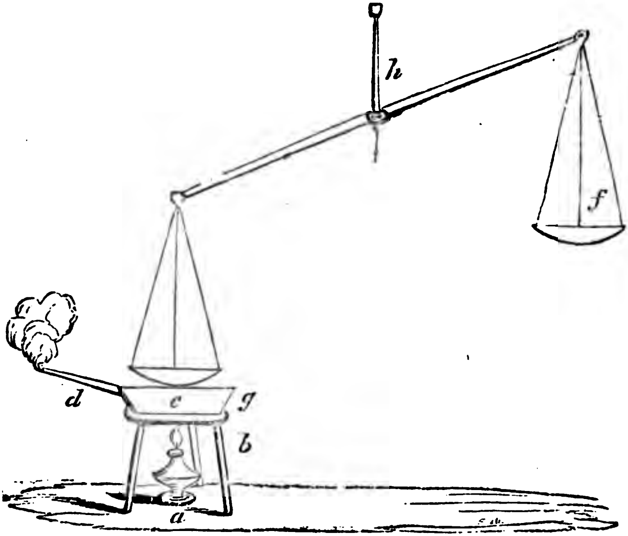
Before leaving this branch of our subject—the constitution of soils, we must detail that of the soil so valuable to the gardener, *peat earth* or *bog mould.* This is not that mass of moss or sphagnum dug out of wet, fenny places for fuel; but a sharp, sandy soil, mixed with the dead, fibrous roots of heath, and usually of a dark-grey colour, such as is found upon the surface beneath the heath on Wimbledon, Bagshot, and many other dry commons. Peat of the best description is thus constituted. Of 400 parts—

Fine siliceous sand	156
Unaltered vegetable fibre	2
Decomposing vegetable matter . . .	110
Silica (flint)	102
Alumina (clay)	16
Oxide of iron	4
Soluble, vegetable, and saline matter . .	4
Muriate of lime	4
Loss	2

From the preceding notes upon the constituents and properties of soils, it will be obvious that to be able readily to ascertain those constituents and properties in a soil must often be singularly useful to its cultivator. The requisite experiments are easily tried; and it is a very erroneous impression that, for such researches, an expensive and well-furnished laboratory is needed.

The late Dr. Henry, of Manchester, whose experiments were so numerous and so varied, so intricate yet so accurate, "was at no period of his life in possession of a well-furnished laboratory, or of nice and delicate instruments of analysis or research;" but his ingenuity "was especially displayed in the neatness and success with which he adapted to the purposes of experiment the simple implements that chance threw in his way."—(*Quarterly Journal of Science, &c.*, vol. viii. p. 17.) If to make experiments in nearly the whole range of chemistry required no paraphernalia of apparatus, much less does it require such for the analysis of soils, to which we shall in this place confine our directions for the attention of the horticulturist; not that such alone is desirable to be pursued by him, but because, in the present state of chemical knowledge among the cultivators of the soil generally, it is absurd to expect that he would pursue some of its most intricate researches. There is no field of science in which lie hid at present more brilliant objects for examination, none that will redound more to the fame of their discoverer, none that will be more generally beneficial to mankind, than that which embraces agricultural and horticultural chemistry. It is yet in its infancy; but the day will come when every cultivator will prepare his soil for each crop in a more scientific way than at present manifested in one unvarying course of culture. The day will come when manures will be distributed in greater variety and with more discrimination than stable manure and chalk are at present by the load; and when science, confirming him in the judicious application of manures, and the necessity of a clean course of cultivation, will, at the same time, demonstrate that even dungs and composts may be selected and compounded with beneficial discrimination; and that economy is not misplaced in regulating abundance.

The following sketch represents the apparatus we have found the best for ascertaining the retentive and absorbent power of soils. *a* Represents a small lamp; *b*, a tripod for supporting a small tin vessel *c*, which has a small hole and plug at *g*, for the purpose of filling it with water; and a small pipe *d* for the escape of the steam when the water is brought to a boiling



temperature; *h* is a small pair of grain scales. To ascertain the moisture-retentive power of a soil, put ten grains of it, previously dried by exposure to a temperature of 212° (the boiling point of water) for half an hour, by having it laid upon *c*, whilst the water within it is kept boiling for that period. On the ten grains of previously dried soil put, by means of a small quill, three drops of clean water; ascertain the exact weight of these, usually four grains; then suspend the beam, so that the pan of the scales containing the soil may rest upon *c*, as represented in the sketch, the weight of the water having previously been removed from the other scale-pan, *f*. The water in *c* must be kept boiling, and the exact number of minutes noted that is required to evaporate the added moisture, so as to return the beam into equilibrium.

Two hundred grains are as eligible a quantity of any soil to analyse as can be selected. Previously to analysis a proportion should have been kept, slightly covered, in the dry atmosphere of a room for several days, to allow it to part with all the moisture that can be obtained from it by mere atmospheric exposure. Two hundred grains of the soil thus dried should then be placed on a small plate, and held, by means of a pair of pincers, over the flame of a candle or lamp, with a small shaving of deal upon it, until this shaving begins to scorch. The process is then to cease, and the loss of weight, sustained by the soil being thus dried, ascèrtained. We will suppose that it amounts to thirty grains and a half. The residue must then be gently triturated in a mortar, which, properly, should be of agate, and sifted through a piece of fine muslin; what remains in the muslin will consist of stones and vegetable fibres; the weight of these must be ascertained, and this we will suppose amounts to fifteen grains and a half and five grains respectively. The stones must be examined by dropping some sulphuric acid (oil of vitriol) upon them: if they effervesce, they contain chalk; if not, they are siliceous, and will be sufficiently hard to scratch glass, and will feel gritty; or they are clay stones, will feel soft, and be with little difficulty cut with a knife. That part which passed through the muslin must now be boiled in a small teacup full of clean water for about five minutes; being allowed to cool, and a piece of clean blotting-paper, previously dried before the fire and its weight ascertained, employed to strain the liquor through, care must be taken to get every particle of the soil into the strainer from the vessel in which it was boiled by repeated washings with clean water. When the liquor is all strained away, place the blotting-paper on a plate over the candle, with a shaving of deal on the plate, and dry it until the shaving begins to scorch.

When perfectly dry, weigh the whole; and then, the weight of the paper being subtracted, the weight of the residue, and, consequently, the quantity of matter dissolved by the water, will be afforded; this, which consists of salts and vegetable extract, we will suppose, amounts to four grains and a half. The watery solution must be carefully set on one side, and the analysis of the solid parts proceeded with. Half an ounce, by measure, of muriatic acid (spirit of salt) must be poured upon this in a saucer, and allowed to remain for full an hour, being occasionally stirred with a piece of glass or porcelain; this must now be strained by means of a piece of blotting-paper as before, the matter left upon it being frequently washed with clean water, and the washings allowed to pass through the paper to mingle with the other acid liquor; the matter left upon the paper being perfectly dried and weighed, and the loss ascertained—we will suppose this to be twenty grains. Into the liquor must be dropped, gradually, a solution of prussiate of iron. The blue precipitate which this will occasion being collected by filtering through paper, and washed as before, heated red-hot by means of an iron spoon in the fire, and then weighed—we will suppose it to weigh two grains and a half; this is oxide of iron. This deducted from the twenty previously ascertained to be in the solution, leaves seventeen grains and a half, which may be considered as carbonate of lime (chalk), though probably with the admixture of a little carbonate of magnesia. The solid matter must now be heated to redness in a spoon, until, upon cooling, it does not appear at all black; this must then be weighed, and the loss noted; that loss consisted of animal and vegetable matters—we will suppose it amounted to seven grains. The remainder must be boiled for about two hours with two drachms, by measure, of sulphuric acid, mixed with eight drachms of water, and, when cooled, strained through blotting-paper as before, and washed; when dried at a red heat in the iron spoon, the loss sustained will be alumina (clay); what remains will be silica (flint). We will suppose the first to weigh fifteen grains, and the latter a hundred and two grains and a half.

The analysis will then stand thus:—

Water	30.5
Stones and coarse sand	15.5
Vegetable fibres	5.0
Saline matters	4.5
Oxide of iron	2.5
Carbonate of lime	17.5
Decomposing matter, destructible by heat	7.0
Alumina	15.0
Silica	102.5
	200.0

The first watery lixiviation, employed to obtain the saline matter, may now be evaporated to dryness; if of a brown colour, it is chiefly vegetable extract; if of a whitish colour, it is principally saline, and probably consists of chloride of sodium (common salt), with the admixture of a little sulphate of lime (gypsum).

The above mode of analysis we have made as simple as possible, and it requires no other apparatus than a set of grain scales and weights, a little sulphuric and muriatic acids, and some prussiate of potash—the whole of which, sufficient for examining every soil upon a large estate, may be obtained for 30*s*.

In the above are no processes requiring adroitness in the manipulation, extreme nicety in the operation, or the practised eye of science and experience to conduct. All is simple, requiring nothing but the employment of the ordinary carefulness, and the common sense, of the experimenter.

The portion of soil which it is proposed to analyse should be, taken at about three inches from the surface. Neither should the surface soil only be examined, but the substratum also. For it often will occur that the subsoil is of a better staple than that which reposes on it; or is of a quality that is capable of correcting some deficiency in it. Thus a light siliceous soil will often lie upon a stratum abounding in alumina, which, by digging or trenching, may be brought to the surface and mingled with it.

The foregoing plan of analysis, it must be observed, is not one so particular as a practised chemist would pursue; but it is one easy and capable of affording all the facts usually required to be known by a cultivator—viz., the moisture-retaining power of a soil; the quantity of soluble and decomposable matter it contains; and the proportions of its earthy constituents.

It has been urged by some that a great deal of information may be compendiously obtained by ascertaining the specific gravity of a soil; but of this we could never feel conviction. That a peat soil—that is, one containing a great excess of vegetable matter—is much lighter in weight than such as contain more of earthy constituents is certain; but such do not require their specific gravity to be taken to detect them. If a soil is but rather above or under the average specific gravity, we do not see how the knowledge of that can determine whether the excess of weight arises from silica or carbonate of lime; or the deficiency of weight from vegetable matters, alumina, or other light constituent. The specific gravity of silica is 2.66; of carbonate of lime, 2.7; of alumina only 2.

In affording warmth to plants, we have seen that the earth is of considerable importance; and the power of accumulating and retaining heat varies as much in soils as the proportions of their constituents. Sir Humphrey Davy found that a rich black mould, containing one-fourth of vegetable matter, had its temperature increased in an hour from 65° to 88° by exposure to the sunshine, whilst a chalk soil was heated only to 69° under similar circumstances; but the first, when removed into the shade, cooled in half an hour 15°, whereas the latter lost only 4°. This explains why the crops on light-coloured tenacious soils are, in general, so much more backward in spring, but are retained longer in verdure during autumn, than those on black, light soils;

the latter attain a general warmth the more readily, but part from it with equal speed.

M. Schubler has examined these phenomena more, and published the following tables. "The first," he says, "contains the results of a series of experiments which I made on the different degrees in which earths acquire warmth from the sun in fine weather. I placed these earths in vessels of four square inches in surface, and half an inch deep, and exposed them to the rays of the sun, coloured differently on the surface, and furnished with thermometers. The observations were made in the latter part of August, and between 11 and 3 o'clock in the day, while the temperature of the air varied in the shade from 72½° to 77° F. As all the observations could not be made at once, the temperature which sand acquired on the same occasion was in each case taken as the standard of comparison, to which all the several observations have been reduced.

Kinds of earth.	Mean of highest temperature of the upper surfaces of the earths. (77° F. in the shade.)			
	With a surface of the natural colour.		With dry earth.	
	Wet.	Dry.	With a white surface.	With a black surface.
	Degrees.	Degrees.	Degrees.	Degrees.
Siliceous sand, bright yellowish grey	99.1	112.6	109.9	123.6
Calcareous sand, whitish grey	99.3	112.1	109.9	124.0
Gypsum, bright white-grey	97.3	110.5	110.3	124.3
Sandy clay, yellowish	98.2	111.4	108.3	121.6
Loamy clay, yellowish	99.1	112.1	107.8	121.1
Stiff clay, or brick earth, yellowish grey	99.3	112.3	107.4	120.4
Fine bluish grey clay	99.5	113.0	106.3	120.0
Lime, white	96.1	109.4	109.2	122.9
Magnesia, pure white	95.2	108.7	108.7	121.3
Humus, brownish black	103.6	117.3	108.5	120.9
Garden mould, blackish grey	99.5	113.5	108.3	122.5
Arable soil, grey	97.1	111.7	107.6	122.0
Slaty marl, brownish red	101.8	115.3	108.3	123.4

"The next table contains the results of trials made to determine the extent of the power possessed by different soils of giving out to surrounding bodies, in different lengths of time, the warmth communicated to them by the sun or the temperature of the atmosphere:—

Kinds of earth.	Power of retaining heat, that of calcareous sand being = 100.0	Length of time required by 30 cubic inches of earth to cool down from a temperature of 144½° to 70¼° F. in a surrounding temperature of 61¼°.
Calcareous sand	100.0	in 3 hours, 30 min.
Siliceous sand	95.6	3 — 20 —
Gypsum powder	73.8	2 — 34 —
Sandy clay	76.9	2 — 41 —
Loamy clay	71.8	2 — 30 —
Stiff clay, or brick earth	68.4	2 — 24 —
Pure grey clay	66.7	2 — 19 —
Fine lime	61.3	2 — 10 —
Humus	49.0	1 — 43 —
Fine magnesia	38.0	1 — 20 —
Garden mould	64.8	2 — 16 —
Arable soil	70.1	2 — 27 —
Slaty marl	98.1	3 — 26 —

Different plants affect different soils. Every gardener must have observed that there is scarcely a kitchen garden but has some particular crop which it sustains in luxuriance far superior to any other garden in its neighbourhood, or to any other crop that can be grown on it. A garden we once cultivated would not produce, without the preparation of an artificial soil, the common garden Cress (*Lepidium sativum*), whilst the Raspberry was remarkably luxuriant; and we have seen that the composition of a soil has a main influence in these peculiarities.

It is certain that a soil is often considered unproductive, and the unproductiveness attributed to some deficiency in its staple, when, in truth, the defect arises from erroneous management. We have before stated an instance of tap-rooted plants being produced of superior size and form, by means of applying the manure deep below the surface. In another instance, some Parsnips being of necessity sown in a poor soil, some manure was turned in by trenching full twelve inches deep, but none applied to the surface; but, at the time of thinning, half the plants were left at an average of twelve inches distance between the plants, the other half at nine inches; when taken up for storing the whole were alike perfectly fusiform, but those grown at twelve inches apart were the finest, as four and a half is to three. If manure had been applied to the surface, the fibrous roots, it was calculated, would be multiplied at the expense of the caudex, to its much greater detriment, than by making the few, usually produced by this root, extend in length by enlarging the circuit of their pasturage.

Again, a more siliceous, darker-coloured soil should be employed for the growth of an early crop of any given plant than is required by the main crop; because such soil will more readily get rid of the superfluous moisture, and earlier acquire a genial warmth—two great desiderata for vegetation in spring. On the contrary, in autumn, for a late crop of Peas, for instance, the soil should be more aluminous; because in August and September, atmospheric moisture, in the form of night-dews, abounds: the foliage is, therefore, perpetually subject to alternate extremes of moisture and dryness, whilst the root is liable to a state of exceeding drought. The soil, therefore, should be rich, and kept in a minute state of division by frequent hoeing, that moisture may be absorbed; and it should be more aluminous, that such moisture may be retained.

We may now proceed to consider manures—a class of bodies of the first importance to the cultivator of the soil, yet of the economy of which he is generally most ignorant, inasmuch as that their judicious employment requires considerable chemical acquirements. Every substance increasing the fertility of a soil, when incorporated with it, is a manure; hence the earths, when applied to regulate its retentive powers, are actually manures.

Manures are derived from animals, vegetables, and minerals; they *directly* assist the growth of plants; *firstly*, by entering into their composition; *secondly*, by absorbing and retaining moisture from the atmosphere; *thirdly*, by absorbing the gases of the atmosphere; and, *fourthly*, by stimulating the vascular system of the plants.

Manures *approximately* assist vegetation: *firstly*, by killing predatory vermin and weeds; *secondly*, by promoting the decomposition of stubborn organic remains in the soil; *thirdly*, by protecting plants from violent changes of temperature.

All these properties seldom, if ever, occur in one species of manure, but each is usually particularised by possessing one or more in a superior degree. That is the most generally applicable manure which is composed of matters essential to the growth of plants; the chief of these are carbon, hydrogen, and oxygen; therefore, all animal and vegetable substances are excellent manures. It would evidently be of great benefit, if every plant could be manured with the decaying parts of its own species. The ancients made this a particular object. We read that those Vines were the most fruitful, which were manured with their own leaves and prunings, and the skins of expressed Grapes.* This rule might be so far followed, as that the stems of Potatoes, Peas, &c., could be dug respectively into the compartments where those crops are intended to be grown in the following year.

Farmyard Manure.—M. Boussingault made many experiments upon farmyard manure; and when formed by the excretions of thirty horses, thirty oxen, and from ten to twenty pigs,

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* Crescentius Agric., sect. 2, c. 6.

on the average of three years, it contained 20.7 per cent. of dry matters, and 79.3 per cent. of water.

When analysed more completely after being dried at a temperature of 238°, the same manure was found to contain on the average,—

Carbon	35.8
Hydrogen	4.2
Oxygen	25.8
Azote	2.0
Salts and earths	32.2
	100.0

When moist, its composition is represented by:—

Carbon	7.41
Hydrogen	0.87
Oxygen	5.34
Azote	0.41
Salts and earths	6.67
Water	79.30
	100.0

EXCRETIONS OF THE HORSE.—A moderate-sized farm horse was fed upon hay and Oats. The urine and the excrements together contained 76.2 per cent. of moisture. In twenty-four hours the excretions weighed—moist, 34.2 lbs.; dry, 8.1 lbs.

Their composition was found to be:—

	In the dry state.		Moist ditto.
Carbon	38.6	...	9.19
Hydrogen	5.0	...	1.20
Oxygen	36.4	...	8.66
Azote	2.7	...	4.13
Salts and earths	17.3	...	4.13
Water	„	...	76.17
	100.0	...	100.0

EXCRETIONS OF THE COW.—A cow was fed upon hay and raw Potatoes. The urine and excrements together contained

86.4 of moisture. The weight of the excretions in twenty-four hours was—moist, 80.5 lbs.; dry, 10.9 lbs.

Their composition by analysis was:—

	Dry.		Wet.
Carbon	39.8	...	5.39
Hydrogen	4.7	...	0.64
Oxygen	35.5	...	4.81
Azote	2.6	...	0.36
Salts and earths	17.4	...	2.36
Water	„	...	86.44
	100.0	...	100.0

EXCRETIONS OF THE PIG.—The pigs, upon which the observations were made, were from six to eight months old. They were fed upon steamed Potatoes. The urine and the excrements lost by drying 82 per cent. of moisture. The average of the excretions yielded by one pig in twenty-four hours was—moist, 9.1 lbs.; dry, 1.6 lbs. Composition:—

	Dry.		Moist.
Carbon	38.7	...	6.97
Hydrogen	4.8	...	0.86
Oxygen	32.5	...	5.85
Azote	3.4	...	0.61
Salts and earths	20.6	...	3.71
Water	„	...	82.00
	100.0	...	100.0

The litter that is generally employed is wheat-straw. This straw, in the condition in which it is used, contains twenty-six per cent. of moisture. Its composition is:—

	Dried.		Undried.
Carbon	48.4	...	35.8
Hydrogen	5.3	...	3.9
Oxygen	38.9	...	28.8
Azote	0.4	...	00.3
Salts and earths	7.0	...	5.2
Water	„	...	26.0
	100.0	...	100.0

Each horse received daily as litter 4.4 lbs.; each cow, 6.6 lbs.; each pig, 4.1 lbs. of straw.

To the stables and the cowhouses together were given every twenty-four hours 132.0 lbs. of straw for thirty horses; 198.0 lbs. for thirty horned cattle; 66.0 lbs. for sixteen pigs; making 396.0 lbs. of straw, estimated when dry at 292.6 lbs.

The composition of the materials which constitute the dung produced in one day are set forth in the following table :—

Excretions yielded in 24 hours by	Weight when dry.	Weight in the wet state.	Elements of the dry matter.					Water constituting the wet matter.
			Carb.	Hydr.	Oxyg.	Azote.	Salts and earths	
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Thirty horses ...	245.08	1028.28	94.60	12.32	89.10	6.60	42.46	783.20
Thirty horned cattle	327.36	2416.48	130.24	15.40	116.16	8.58	56.98	2089.12
Sixteen pigs......	26.40	146.74	10.12	1.32	8.58	0.88	5.50	120 34
Straw used in litter	292.60	396.00	141.68	15.62	113.74	1.10	20.46	103.40

The average or mean composition of this mixture may be taken as follows :—

In the dry state.					In the wet state.					
Carb.	Hydr.	Oxyg.	Azote.	Salts.	Carb.	Hydr.	Oxyg.	Azote.	Salt.	Water.
42.3	5.0	36.7	1.9	14.1	9.4	1.2	8.2	0.4	3.2	77.6

That of the resulting dung :—

35.8	4.2	25.8	2.0	32.2	7.4	0.9	5.3	0.4	6.7	79.3

On comparing the composition of the dung-heap with that of the different kinds of litter collected in a day, little difference is observed; the larger quantity of saline and earthy matters discovered in the fermented manure is readily explained from the additions of ashes incorporated with it, and also by the accidental admixture of earthy matters proceeding from the sweepings of the court, the earth adhering to the roots consumed as food, &c.—refuse of every kind, the residue after cleansing the various kinds of fodder for the stable and stall, &c., all went to the dung-heap. Lastly, and with reference to the elements that are liable to be dissipated in the state of gas, or which may be changed into water, the azote is perceptibly in larger quantity in the prepared manure than in the unfermented litter and excretions. This is at once seen on comparing the composition of these two products after the saline and earthy matters have been deducted.

	Carbon.	Hydr.	Oxyg.	Azote.
The composition of fresh litter, is	49.3	5.8	42.7	2
That of dung	52.8	6.1	33.1	3.0

Dung is, therefore, somewhat richer in azote and carbon than litter, and it contains less oxygen. It is the property of lignine undergoing decomposition, that it yield a product which relatively abounds more in carbon than the original matter, in spite of the carbonic acid which is formed and thrown off during the alterations undergone; this is owing to the elements of water being thrown off in relatively still larger quantity at the same time.—(*Boussingault's Rural Economy.*)

NIGHT SOIL is the most fertilising and most economical of all manures. We know of more than one garden characterised by the abundance and excellence of their produce which are manured almost exclusively with the house-sewage. In China, and in continental Europe, a much juster estimate is formed of this manure than in our own country. How fully that high estimate is justified may be at once understood by a reference to the following analyses.

Liebig, quoting Playfair, says that human fæces are composed as follows:—

Water	300.00
Carbon	45.24
Hydrogen	6.88
Azote Oxygen	34.73
Salts and earths	13.15
	400.00

Human urine, according to Berzelius, contains—

Urea	3.01
Uric acid	.10
Animal matter, lactic acid, and lactate of ammonia	1.71
Mucus	.03
Sulphate of potash	.37
" soda	.32
Phosphate of soda	.29
Chloride of sodium	.45
Phosphate of ammonia	.17
Chloro-hydrate of ammonia	.15
Phosphate of lime and magnesia	.10
Silica, a trace	......
Water	93.30
	100.00

There is no validity in an objection to night soil on account of its offensive smell, because that smell is rendered very slight when diluted with the other sewage and rain water from the house, and is perfectly deodorised in a few minutes by the earth upon which it is poured.

It is rendered still less offensive before application, if required in a solid state, by mixing it with coal ashes, earth, and gypsum. The best proportions we have found to be two barrows full of ashes, three of earth, and one of gypsum. Enough of this mixture must be incorporated with the night soil to render it so dry as to be easily spread by the shovel. The mixture was suggested by a knowledge of the chemical facts that gypsum (sulphate of lime) unites with the ammonia of the night soil; whilst the carbon in the ashes, and the alumina in the earth, act as deodorisers.

GUANO—the excrements of sea fowl, and the remains of marine animals—is another most powerful manure. It is composed chiefly of carbon, hydrogen, azote, and oxygen; but is rendered especially valuable by some of these being combined in the form of ammonia, and by containing earthy phosphates in a soluble form.

The following analyses are by Professor J. F. Johnston:—

Kinds.	Water.	Ammoniacal matter.	Earthy phosphates.
Peruvian	7 to 9	56 to 66	16 to 23
Chilian	10 13	50 56	22 30
Bolivian	6	65 64	25 29
Ichaboe	18 26	36 44	21 29
Saldanha, light	17 27	14 22	43 56
,, dark	33 44		
Algoa Bay	2.26 23.93	22.37 23.16	70.20 43.15
Halifax	24.47	20.61	22.67
Bird's Island	25 49	19 to 21	22.43
,, ,,	14.18		5.37
Patagonian, light	40.99	20 25	24 to 32
,, dark	20.55		

Dr. Fownes found, in one analysis, the ammoniacal constituents and earthy phosphates were in the following proportions, but they vary very much in their relative quantities:—

Oxatate of ammonia Uric acid Carbonate of ammonia, &c.	66.2
Phosphates of lime and of magnesia	29.2
Alkaline phosphates, chlorides, and sulphates	4.6
	100.0

The dungs of pigeons and domestic fowls are somewhat like guano, but they contain more of the earthy phosphates and less of the ammoniacal constituents.

The Drainage from a Dunghill contains some of its soluble and most fertilising constituents. Therefore, it is best made under a shed in a waterproof pit, and communicating with a well, into which the drainage may pass, and from which it may be readily obtained. It is a powerful liquid manure requiring to be largely diluted with water.

A specimen of such drainage from heaps of cowdung exposed to rain were found by Professor Johnston to be dark-coloured, and, of course, contained only what rain water is capable of washing out of such dungheaps. An imperial gallon of these drainings, when evaporated to dryness, left about 480 grains, or an ounce weight of dry solid matter. This solid matter consisted of—

	Grains.
Ammonia	9.6
Organic matter	200.8
Inorganic (ash)	268.8
	479.2

The inorganic portion contained—

	Grains.
Alkaline salts	207.8
Phosphates of lime and magnesia	25.1
Carbonate of lime (chalk)	18.2
Carbonate of magnesia and loss	4.3
Silica, and a little alumina	13.4
	268.8

Those, therefore (observes the Professor), who, besides allowing the urine of their byres to run to waste, permit the rain to wash their dunghills, suffer a double loss; they lose the ammonia-producing substances, and much alkaline matter in the urine and the phosphates, and a large additional portion of alkaline matter in the washings.

Wood charcoal reduced to powder, charred sawdust, and charred peat, are all capable of being used with advantage in extracting the ammoniacal and other salts which give their value to the liquid of the farmyards. Experiment has shown that, when filtered through a bed of such charcoal, the liquid escapes without colour, and almost without taste, while the charred peat or sawdust is itself converted into fertilising manure. Wherever, therefore, such charcoal can be obtained in abundance, and at little cost, this mode of employing it may be both useful and profitable.—(*Trans. High. Soc.*, 1846, p. 191.)

The following table shows some of the constituents of common stable manure that are constituents also of our usual crops :—

Stable manure.	
Carbon	These are the chief components of all plants.
Hydrogen	
Oxygen	
Nitrogen	In some vegetables.
Carbonate of lime	In almost all plants.
Muriate of potash	In Cucumbers, Garlic, &c.
Muriate of Soda	Perhaps in all.
Sulphate of potash	In Cucumbers, Garlic, &c.
Magnesia	In all corn and many other plants.
Phosphate of lime	Potatoes, Onions, and most other crops.
Oxide of iron	In most plants.
Alumina	In most plants.
Silica	

Stable manure, and for the same reason every other manure composed of animal or vegetable remains, is evidently valuable to plants, by affording them such matters as they are composed of. But this is not the only reason that manures are beneficial; for in that case mere decayed parts of their own species should be the most fertilising applications. There is no doubt that plants are essentially benefited by such applications; but why do Potatoes, for example, grow more luxuriantly on ground manured by sprats than on ground manured with the dung of horses, and still more superior to the same crop grown on a plot manured with the decayed parts of their own species? Apparently, but only partly, because the manures mentioned decompose with a rapidity exactly proportioned to the order of benefit. Sprats decompose, and their parts become soluble and capable of use by the plants, first and most rapidly; then the dung of animals; lastly, the vegetable remains. All the less solid animal matters decompose with greater rapidity than vegetable matters: hence the dung of such animals as are carnivorous is the most prompt in benefiting vegetation. Witness night soil, pigs' dung, &c.; but such manures are not the most permanent. Hassenfratz manured two portions of the same soil, No. 1, with a mixture of dung and straw highly putrefied; No. 2, with a similar mixture, newly made. He observed, that during the first year the plants in No. 1 produced the best crop; but the second and third years (no more dung being added), No. 2 produced the best crop; after which, both seemed alike exhausted.—(*Ann. de Chimie*, xiv., 57.) The same chemist found that a soil manured with wood-shavings did not, during the two succeeding years, produce a superior vegetation to the same soil without any manure; the third, year, however, it was better, but it was not until the fifth year that it reached the maximum of fertility. The site of a wood-stack, and the newly cleared lands of America, are eminently fertile from the gradually decomposing vegetable remains they contain.

These facts and observations teach us that the most prompt manures are the reverse of economical. Vegetable remains, incorporated with a soil, will ensure an average produce during several years; animal matters and dungs highly putrescent are powerfully but transiently beneficial. Putrefaction is evidently the means of rendering these substances available to plants: hence, thoroughly decayed stable manure is usually employed by gardeners, as being of immediate benefit, admitting of clean husbandry; and because economy is not, in private establishments the generally presiding genius of the gardens. If stable dung or other manure be allowed to putrefy in an unenclosed heap, the loss is immense; all the gases which pass off during decomposition, all the soluble matters which drain away, are highly nutritious to plants, as has been proved by Davy and others. If the decomposition be thus allowed to proceed until the heap becomes a soap-like mass, the loss cannot be less than fifty per cent. Notwithstanding all the reasoning of chemists, however, putrefied dung will continue to be used; it admits of clean workmanship with less labour, and ensures a good immediate crop: to prevent as much loss as possible, therefore, the dung-heap should be in a brick cistern, and covered over with earth at least nine inches deep, with a well at one corner to retain the drainage, which from time to time, should be returned over the heap.

The chief component of plants is carbon, and we shall not be far wrong if we estimate it as constituting 50 per cent. of every vegetable; it is the decayed organic remains of the soil which supply a considerable portion of this to the growing plants. It is a subject of debate amongst chemists how the carbon of manures is imbibed by plants. Carbon, say they, is insoluble, and experiment has demonstrated that the roots cannot absorb it in a solid state. Sennebier, having observed that water impregnated with carbonic acid, when applied to the roots of plants, was beneficial, concluded that the carbon of manures is converted into carbonic acid, and is in that state imbibed by them.—(*Phys. Vég.*, v. iii., p. 55.)

We consider that the facts of which we are in possession, if progressively estimated, place the subject in a very clear light. Saussure found that a soil deprived of its soluble matters, by repeated boiling in water, would not support vegetation so well as that portion of the same soil not so deprived of its soluble constituents (*Recherch. sur la Vég.*, cv., sect. 11., p. 170.) The extract thus obtained was evidently composed of saccharine matter, mucilage, extractive principle, &c. These we know are nutritive to plants, and are elaborated and assimilated by them after being absorbed by their roots. Now, vegetable substances. as straw, &c., gradually yield these soluble matters as they decay, Straw, wood, leaves, &c., consist chiefly of woody fibre; to convert this into saccharine and mucilaginous matters is the work of putrefaction; to effect this, oxygen must be absorbed, and the extra proportions of carbon be got rid of, as is evident from the following table of constituents:—

	Woody Fibre.	Gum.	Sugar.
Carbon	52.53	42.23	27.5
Oxygen	41.78	50.84	64.7
Hydrogen	5.69	6.93	7.8
	100.00	100.00	100.0

That such processes actually do occur Saussure has demonstrated by experiment: he found that moist wood exposed to the air absorbed oxygen, evolved carbonic acid, and water was evidently decomposed. Thus, then, putrefaction seems to render organic matters fit for the nourishment of plants by converting them into saccharine and mucilaginous compounds, capable of solution in water. Hence the phenomenon of wood, which is slow of decomposition, being a permanent manure; animal matters which rapidly putrefy, being transient, though temporarily powerful: hence the economy of using partially decomposed composts is also explained; when completely decomposed, their soluble matters, being more than can be consumed at the time by the crop, pass away with the drainage water, much is lost in the state of gas, and all that is left are a few earthy, saline, and carbonaceous particles of comparatively little value.

The quantity of soluble matter obtainable from a soil at any one time is very small, seldom exceeding the one-thousandth part of its weight; and even pure vegetable mould, the *débris* of entirely putrefied plants, was found by Saussure to yield only one-eleventh of soluble matter. This mould was too rich for horticultural purposes, Peas and Beans grown in it being too luxuriant, and they were more productive in a soil containing only one-twentieth of organic constituents dissolvable by water. Small in amount, however, as are the soluble constituents of the most fertile soils, they are necessary for the vigorous vegétation of plants; for when a soil is deprived of those constituents by frequent washings with boiling water, it is much less fertile than before. Liebig and others have most illogically concluded, from the smallness of the soluble extract contained in a soil, that, therefore, it is of trivial importance; but they forget that, as fast as this extract is removed from a soil by the roots of the crop, it is generated again by the decomposition of the animal and vegetable remains contained in the soil. This is one reason why fallowing is beneficial, the more easily decomposing matters have been exhausted by successive crops; and by a year's rest, and exposure to the putrefactive agency of the air, the more stubborn and more slowly decomposing organic remains have time to resolve into and accumulate soluble compounds in the soil.

The mucilaginous and saccharine matters formed by manures during their decomposition in the soil are unquestionably absorbed by the roots along with its moisture; for if the whole of the branches of a Vine or Maple be cut away close to the surface of the ground, it will continue to bleed for many days, and to the last its sap will continue to afford the same amount of those matters. But their saps, and that of all plants as yet subjected to analysis, abound with carbonic acid gas; and there is no doubt that decomposing organic manures are very largely beneficial to plants by affording that gas to their roots, a subject which will be further considered when we are examining the phenomena attendant upon vegetable decomposition.

Of the less general manures, which benefit plants by entering into their composition, a few words will suffice. Sulphate of lime (gypsum) is a component of Clover, Lucerne, Turnips, &c.; hence it has been applied with benefit to these crops on such soils as did not already contain it. Bones, broken small, have lately become a very general manure; their benefit, which is very permanent, is easily accounted for. The bones of oxen contain about fifty per cent. of gelatine, which is soluble in water, and rapidly becomes putrescent; the remainder is chiefly phosphate and carbonate of lime, salts which are components of Wheat, Rye, Barley, Oats, Peas, Beans, Vines, Cucumbers, Potatoes, Garlic, Onions, Truffles, &c. Common salt, also, is employed as a manure, and is beneficial, partly in consequence of entering into the constitution of plants.

The day has long passed when it was disputed whether saline bodies are promotive of vegetable growth. It is now determined that some plants will not even live without the means of procuring certain salts. Borage, the Nettle, and Parietaria will not exist except where nitrate of potash is in the soil; Turnips, Lucerne, and some other plants will not succeed where there is no sulphate of lime. These are facts that have silenced disputation. Still there are found persons who maintain that salts are not essential parts of a plant's structure: they assert that such bodies are beneficial to a plant by absorbing moisture to the vicinity of its roots; or by improving the staple of the soil; or by some other secondary mode. This, however, is refuted by the fact that salts enter as intimately into the constitution of plants as do phosphate of lime into that of bones and carbonate of lime into that of egg-shells. They are part of their very fabric, universally present, remaining after the longest washing, and to be found in the ashes of all and any of their parts, when subjected to incineration. Thus Saussure observes, that the phosphate of lime is *universally* present in plants.—(*Sur la Véget.*, c. 8, s. 4.) The *sap* of all trees contains acetate of potash; *Beetroot* contains malate and oxalate of potash, ammonia, and lime; *Rhubarb* oxalate of potash and lime; *Horseradish*, sulphur; *Asparagus*, super-malates, chlorides, acetates, and phosphates of potash and lime; *Potatoes*, magnesia, citrates, and phosphates of potash and lime; *Jerusalem Artichoke*, citrate, malate, sulphate, chloride, and phosphate of potash; *Garlic*, sulphate of potash, magnesia, and phosphate of lime; *Geraniums*, tartrate of lime, phosphates of lime, and magnesia; *Peas*, phosphate of lime; *Kidney Beans*, phosphate of lime and potash; *Oranges*, carbonate, sulphate, and muriate of potash; *Apples* and *Pears*, malate of potash; *Grapes*, tartrate of lime; *Capsicums*, citrate, muriate, and phosphate of potash; *Oak*, carbonate of potash; and the *Lilac*, nitrate of potash. Let no one fancy that the salts are a very trivial portion of the fabric of plants. In the Capsicum, they constitute one-tenth of its fruit; of Carrot juice, one-hundredth; of Rhubarb, one-eleventh; of Potatoes, one-twentieth; whilst of the seed of the *Lithospermum officinale* they actually form more than one-half. Their constituents being as follows:—

Carbonate of lime	43.7
Silica	16.5
Vegetable matter, phosphate of lime, &c. . .	39.8
	100.0

These amounts of earthy saline matters are nearly as much as exist in human bones; but if we turn to the marrow, it only contains one-twentieth of saline matters; the blood only one-hundredth; muscle only one-thirty-fourth; yet no one will argue that these saline constituents, though smaller than those in vegetables, are trivial and unimportant.

Having shown that saline compounds enter universally into the composition of plants, let us next examine more in detail some of the salts which have been proved to be most beneficial as manures.

Foremost among these is *superphosphate of lime*, prepared by the addition of sulphuric acid (oil of vitriol) to crushed bones. It is more useful as a manure than bones, because it is more soluble in water. If we bury a bone it will remain almost unaltered for years; but if we break it into small pieces it decays much sooner; and if put round the roots of Cabbages, will soon make them grow more fine and vigorously. Cabbages, however, are not the only garden vegetables benefited by bone manure; for, as we have just said, phosphate of lime is one of the most constant constituents of all plants. Of this phosphate, therefore, the soil is deprived by every crop it bears; and to restore this phosphate to the soil is an object with every cultivator. It was long since shown by chemists that phosphate of lime is the chief ingredient in all bones, and, consequently, these by degrees have become one of the most extensively used manures.

In every 100 lbs. of sheeps' bones there are 70 lbs. of phosphate of lime; in 100 lbs. of horses' bones, sixty-eight of that phosphate; and in the same quantity of ox bones, 55 lbs.

Now, as phosphate of lime is insoluble in water, and even bone dust is slow in decaying, it was suggested that by dissolving it in a strong acid, superphosphate of lime, a substance soluble in water, would be formed, and also all the other constituents of the bone be presented to the roots of the crop in a most available form. This process is said to have been first adopted by Mr. Fleming, of Borrochan, N.B., in the year 1841. He employed muriatic acid (spirit of salt) to dissolve the bones, and the result of his experiments, per acre, on Turnips and Potatoes, was as follows:—

	Swede Turnips. Ton.	Swede Turnips. cwt.		Potatoes. Ton.	Potatoes. cwt.
Bones (16 tons, no acid) . . .	14	17	...	9	15
Bones (10 tons, with acid) .	18	11	...	12	15

Subsequent experiments have demonstrated that oil of vitriol (sulphuric acid) can be used much more advantageously for dissolving bones than the muriatic acid, and for reasons thus epitomised by Mr. W. C. Spooner, in his "Treatise on Manures:" —"Sulphuric acid is stronger, cheaper, has a greater specific gravity, and, therefore, is not so bulky; and contains much less water. On mixing it with water a much higher temperature is obtained, which conduces to the dissolving of the bones. But, above all, we find that in the trials which have been made, bones dissolved in muriatic acid have been found somewhat less beneficial than others dissolved in sulphuric acid." Mr. Spooner's conclusions, after lengthened experience, are—

1. That superphosphate of lime is the essential manure for Turnips, and particularly for Swedes. (We can add, that it is most excellent for every kind of Cabbage, Broccoli, and Cauliflower.) That with it alone a good crop can be raised; but without it the Turnip will not thrive, however rich the manure may otherwise be.

2. In preparing the mixture, the bones should be in as fine a state as possible.

3. That sulphuric acid, from its greater strength and cheapness, is preferable to muriatic acid.

4. That water, in the proportion of one-half the weight of the acid, should be first sprinkled over the bones.

5. The proportion of sulphuric acid most economical to employ should not be less than one-third, nor more than one-

half the weight of the bones, and that probably the medium between these two quantities is most advantageous.

6. That the mixture can be applied either with the addition of a considerable quantity of water, or with ashes, by means of an ordinary drill. That though mixed with water it may be more speedy in its effects, yet when mixed with ashes it can be more conveniently applied, and has the advantage of admitting the addition of a large quantity of ashes.

7. That vitriolised bones may be used either alone or with other manures; and that when the latter are at hand, it is more advantageous to use the former in combination with them.

Mr. Spooner remarks that, in his experiments with superphosphate of lime applied at the time of sowing seeds, these invariably sprouted more quickly than other seeds sown without the addition of the phosphate. It seems to have the power generally of hastening the progress of vegetation; and the following from Mr. R. White shows its effect upon the Rose tree.

"In the autumn of 1845 I transplanted about twenty Rose trees; and in consequence of seeing this substance mentioned as one to be used with advantage in such a case, I tried the experiment on eight out of that number, by sprinkling about a handful on and about the roots at the time of planting. Early in March of this year the difference was very perceptible; the eight plants in question were in leaf, and quite as forward as those which had not been removed, while the remainder (with one exception) had not then started into growth. I think this may be taken as a proof that superphosphate of lime has a beneficial influence in causing the more ready formation of roots."—(*Gardeners' Chronicle.*)

Bone manure, whether merely ground bones or those dissolved in sulphuric acid, is not only beneficial to Cabbages and Turnips, but to all garden crops and flowers. We have noticed very great benefits ourselves from applying it to Peas, Beans, Asparagus, and Strawberries.

Mr. Cuthbert Johnson, in his essay "On the Uses of Bones as a Manure," observes, "There is yet another source from whence the phosphate of lime might be obtained in large quantities for the use of the farmer, viz., the fossil bones, or native phosphate of lime, which is found in various districts of this country in very considerable quantities, and would only require crushing or powdering to render it nearly as useful to the farmer as the recent bones; for that the cartilage, or oily matter of the bone, does not constitute the chief fertilising quality is shown by the fact, that the farmers who use bone dust will as readily employ that which has first been used, and all its fatty portion extracted by the preparers of cart-grease, as they will the unused fresh bones. The mineral substance called the apatite, found in the Cornish tin mines, is nothing but phosphate of lime; 100 parts being composed of—

Phosphoric acid	45
Lime	55

"The phosphate of lime is also found in many parts of the north of England, in Hungary, and in immense beds in Spanish Estremadura, where it is said to be so common in many places, that the peasants make their walls and fences of it. One hundred parts of this substance, called by mineralogists the phosphorite, contain—

	Parts.
Phosphoric acid and lime	93.0
Carbonate acid	1.0
Muriatic acid	0.5
Fluoric acid	2.5
Silica	2.0
Oxide of iron	1.0

"The inquiry as to the quantity in which this native phosphate of Spain exists having engaged the attention of the Royal Agricultural Society of England, Dr. Daubeny and Captain Widdrington were induced, in 1845, to make a voyage into Spain to examine it, and they have since published the result of their inquiries.—(*Journal Royal Agricultural Society*, vol. v., p. 406.) They found the phosphorite rock existing in large masses a short distance from Logroson, a considerable village about seven Spanish leagues to the south-east of Truxillo, in Estremadura. It forms 'a rock varying from seven to sixteen feet in breadth, traceable for nearly two miles along the ground, and extending into the earth to a great, though as yet an unascertained, depth.'" Some specimens, analysed by these highly usefully employed voyagers, consisted per cent. of—

Silica	1.70
Peroxide of iron	3.15
Fluoride of calcium (fluor spar)	14.00
Phosphate of lime	81.15

How much phosphate of lime is required by our common garden crops, may be estimated by the following results of some of the experiments of various chemists:—

100,000 lbs. of	Phosphoric acid. lbs.	Lime. lbs.
Potatoes contain	40	33
Beans "	292	165
Peas "	190	58
Cabbage "	436	1822
Beet "	167	285
Turnips "	73	127
Carrots "	395	505

Even the most delicate of our flowering stove plants contain phosphate of lime; for in 10,000 grains of a *Catasetum* bulb Mr. Solly found 183 grains of earthy phosphates, and 222 grains in a bulb of a *Bletia*.

Salts of Ammonia.—These, without any exception, are powerful manures, though varying in their amounts of benefit to the crops for the increase of which they are applied. More than thirty years since we pointed out that dung-manures are good fertilisers in proportion to the amount of ammonia they contain, and we endeavoured to account for it upon the known stimulating properties of ammonia. There was, also, the known fact, that such highly ammoniated dung-manures decompose and become soluble more rapidly than other organic manures containing less ammonia. Since then, chemical analysis has shown that azote, or nitrogen, a chief constituent of ammonia, is also a constituent of vegetables more prevalent than had been ascertained at the time we wrote.

The pungent smell in stables, and which arises from the fermenting dung of hotbeds, is caused by the ammonia which is escaping. To prevent this escape, it is not unusual to sprinkle powdered gypsum (sulphate of lime), among the dung and over the pavement of stables. Gypsum spread over a soil at the time dung is dug in also prevents the escape from it of the ammonia. It is then spoken of as *fixing* the ammonia.

This process consists in the combination of the sulphuric acid of the sulphate of lime with the ammonia, and the consequent formation of sulphate of ammonia, a salt which is said to be thus *fixed* in the soil, because it is not volatile, or vaporised in a temperature in which several other of the salts of ammonia are completely removed from the soil. This salt, in common with other salts of ammonia, is a powerful fertiliser, and is one of those valuable additions to the list of the cultivator's agents for which he is indebted to modern chemistry. Ammonia consists of hydrogen seventy-four per cent., nitrogen or azote twenty-six per cent. The following is the composition of its three chief salts, which are easily purchaseable:—

	Acid.	Ammonia.	Water.
Sulphate . . .	54.66 ...	14.24 ...	31.10
Carbonate . . .	45.00 ...	43.00 ...	12.00
Muriate . . .	49.55 ...	31.95 ...	18.50

In 1840, Liebig, when speaking of the source from whence plants obtain the greatest portion of nitrogen, combated pretty successfully the old opinion that they derived it chiefly from the atmosphere. He remarked (*Organic Chemistry*, p. 69), "We cannot suppose that a plant would attain maturity, even in the richest mould, without the presence of matter containing nitrogen, since we know that nitrogen exists in every part of the vegetable structure. The first and most important question to be solved therefore is, How, and in what form, does Nature furnish nitrogen to vegetable albumen, and gluten to fruits and seeds?" After giving a variety of facts in support of the opinion that it is ammonia which affords all vegetables, without exception, the nitrogen which enters into the composition of their constituent substances, he adds the way in which plants supply themselves with ammonia :—"The nitrogen of putrefied animals is contained in the atmosphere, as ammonia, in the form of a gas which is capable of entering into combination with carbonic acid gas, and forming a volatile salt. Ammonia in its gaseous form, as well as all its volatile compounds, is of extreme solubility in water; ammonia, therefore, cannot remain long in the atmosphere, as every shower of rain must condense it and convey it to the surface of the earth. Hence, also, rain water must at all times contain ammonia, though not always in equal quantity. It must be greater in summer than in spring or in winter, because the intervals of time between the showers are greater; and when several wet days occur the rain of the first must contain more of it than of the second. The rain of a thunder-storm, therefore, after a long protracted drought, ought, for this reason, to contain the greatest quantity which is conveyed to the earth at one time. But all the analyses of atmospheric air *hitherto made have failed to demonstrate the presence of ammonia;* although, according to our view," says M. Liebig, "it can never be absent. Experiments made in the laboratory of Giessen, with the greatest care and exactness, have placed," continues Liebig, "the presence of ammonia in rain water beyond all doubt. It had hitherto escaped observation, because no one thought of searching for it. All the rain water employed in this inquiry was collected 600 paces south-west of Giessen, whilst the wind was blowing in the direction of the town. When several hundred pounds of it were distilled in a copper still, and the first two or three pounds evaporated, with the addition of a little muriatic acid, a very distinct crystallisation of sal ammoniac was obtained. The crystals had always a brown or a yellow colour. Ammonia may also always be detected in snow water. Crystals of sal ammoniac were obtained by evaporating in a vessel with muriatic acid several pounds of snow, which were gathered from the surface of the ground in March, when the snow had a depth of ten inches. The *inferior* layers of snow which rested upon the ground contained a quantity decidedly greater than those which formed the surface. It is worthy of observation, that the ammonia contained in rain and snow water possessed an offensive smell of perspiration and animal excrements, a fact which leaves no doubt respecting its origin. The products of the distillation of flowers, herbs, and roots, with water, and all extracts of plants made for medicinal purposes, contain ammonia. The unripe transparent and gelatinous pulp of the Almond and Peach emit much ammonia when treated with alkalies. The water which exudes from a cut Vine, when evaporated with a few drops of muriatic acid, also yields a gummy deliquescent mass, which evolves much ammonia on the addition of lime. Ammonia exists in every part of plants, in the roots (as in Beet-root), in the stem (of the Maple tree), and in all blossoms, and fruit in an unripe condition. Putrid urine is employed in Flanders as a manure with the best results. During the putrefaction of urine, ammoniacal salts are formed in large quantity, it may be said exclusively; for, under the influence of heat and moisture, urea, the most prominent ingredient of the urine, is converted into carbonate of ammonia."

"'Ammonia,'" says Professor Johnston (*Elem. of Chemistry*, p. 22), "'is naturally formed during the decay of vegetable substances in the soil. This happens either, as in animal bodies, by the direct union of nitrogen with a portion of the hydrogen of which they consist, or by a combination of a portion of their hydrogen with the nitrogen of the air; or, when they decompose, in contact with air and water; at the same time, by their taking the oxygen of a quantity of the water, and disposing its hydrogen at the moment of liberation to combine with the nitrogen of the air, and form ammonia. In the two latter modes, ammonia is formed most abundantly when the oxygen of the air does not gain the readiest access. Hence, in open subsoils in which vegetable matter abounds, it is most likely to be produced; and thus one of the benefits which follow from thorough draining and subsoil ploughing is, that the roots penetrate and fill the subsoil with vegetable matter, which, by its decay in the confined atmosphere of the subsoil, gives rise to this production of ammonia.'"—(*C. Johnson's Modern Agricultural Improvements.*)

That the salts of ammonia are very powerful manures has been established by the experience of many practical men; and whether applied in the form either of gas ammoniacal liquor or sulphate of ammonia, they have been found to benefit very largely Potatoes, Asparagus, Peas, Turnips, Fuchsias, Pelargoniums, and Hollyhocks. We believe that there are few, if any, plants cultivated in our gardens that would not be benefited by these ammoniacal applications, care being taken not to apply them too liberally. Half an ounce of sulphate of ammonia to a gallon of water is quite enough.

Many other saline manures have been employed by cultivators with various degrees of benefit, such as *common salt* (chloride of sodium); *bleachers' refuse*, principally composed of sulphate of soda and common salt; *cubic petre* (nitrate of soda); *gypsum* (sulphate of lime); *saltpetre* (nitrate of potash); and *soda ash*, containing, among other salts, carbonate of soda, common salt, and sulphate of soda.

As already stated, some salts are essential, and still more are useful, for promoting the growth of plants; an important consideration, therefore, is contained in the answer to the query so often put—How should saline manures be applied? The answer is, that, when practicable, they ought to be in very small quantities and frequently, *during the time of the plant's growth.* No plan can be worse than soaking seed in a saline solution for the purpose of giving such salt to the plant of which it will be the parent. It is soddening the embryo with a superfluity totally useless to it; and, if the solution does not injure the germination, it will be washed away most probably before the roots begin to absorb such nutriment.

We may observe here, appropriately, that, to arrive at a correct knowledge of manures by means of experiments, far more forethought and care are requisite than are usually bestowed upon them.

1. A space should be left without any manure being applied, otherwise there will be no satisfactory basis of comparison.

2. The larger the space subjected to experiment for each manure, the more entitled to confidence will be the result. The reason for this is, obviously, that no two seeds will produce plants of precisely equal prolificacy. Imperfect ripening of the parent seed, variance in the depth at which the seed is buried, and many other circumstances, will be more liable to have a controlling effect over the weight of the produce from a small plot

of crop than from a larger. A dozen super-prolific or defective plants, on a square rod of ground, will have an influence on the result when calculated per acre, that would be scarcely appreciated if the experiment were made on an eighth of an acre.

3. If manures in solution are employed for soaking the seed, a similar quantity of seed of the same sample should be soaked for a similar length of time in simple water. If liquid manures are given experimentally to plants during their growth, other plants of like number and growth, and in every respect treated similarly, should at precisely the same time have simple water applied to them.

4. There should be a certainty that the manure employed is pure. No wonder that experiments are discrepant when Mr. E. Solly has detected adulterations in fertilisers to the amount of 97 per cent.! Even when the dung of animals is employed, it varies most essentially, and according to the food on which they are kept. The richer their nourishment the more abounding are their excrements in the salts of ammonia and other fertilising matters.

Some manures are beneficial by absorbing moisture from the atmosphere. This property is, at least, as useful to ground that is aluminous as to that which is siliceous; for it is equally useless to either during such periods of the year as are characterised by a plentiful deposition of rain; but in the drought of summer, when moisture is much wanting to plants, it is beneficial to both: in very dry seasons it is even of greater importance to clayey than to light soils; for vegetation on the former suffers more from long-continued drought than on the latter, inasmuch as that moisture being equally exhaled from each, the surface of the clayey soil becomes caked and impervious to the air—the only grand source of compensatory moisture that is available to the languishing plants, and which is more open to those which grow on light and, consequently, more pervious soils.

The following table of the comparative absorbent powers of many manures is extracted chiefly from "An Essay on the Uses of Salt in Agriculture," by Mr. Cuthbert Johnson:—

1000 parts of	Parts.
Horsedung evaporated previously to dryness, at a temperature of 100°, absorbed during an exposure of three hours to air saturated with moisture at 62°	145
Putrefied tanners' bark, under similar circumstances (66°)	145
Unputrefied tanners' bark	115
Cowdung	130
Pig ditto	120
Sheep ditto	81
Pigeon ditto	50
Refuse marine salt (60°)	49½
Soot (68°)	36
Burnt clay	29
The richest soil (in one hour)	23*
Coal ashes	14
Lime (part carbonate)	11
Crushed rock salt	10
Gypsum	9
Chalk	4

The absorbing power of a manure is much influenced by the state in which it is presented to the atmosphere. In a finely-divided state mere capillary attraction assists it; hence, as before insisted, the importance of keeping the soil frequently stirred by hoeing, &c. But a mere mass of cotton, by means of capillary attraction, will absorb moisture from the air, yet it parts with it at a very slight elevation of temperature; it is of importance, therefore, to ascertain which are the manures that not only *absorb* but *retain* moisture powerfully. The following results of my experiments throw some light on this point:—

[*] Sir H. Davy.

100 parts of	Minutes
Pigdung evaporated to dryness at a temperature of 106°, and then moistened with 6 parts of water, required for being reduced to dryness again, at the above temperature	135
Horsedung, under similar circumstances	90
Common salt	75
Soot	75
Rich soil	32
Chalk	29
Poor soil (siliceous)	23
Gypsum	18

These experiments point out a criterion by which we easily ascertain the comparative richness of any two given soils or manures; the most fertile will be the most absorbent and retentive.

Some persons have argued that the moisture-retentive powers of manures must be injurious to plants by withholding that moisture from their roots; but these theorists argue without an acquaintance with facts. Such manures have a greater attraction for moisture than is possessed by atmospheric air; but it is much less powerful than the power of suction possessed by roots. There is no saline body which these will not deprive of the moisture it has absorbed—nor will any be surprised at this, when they know that the root of a Pear tree, half an inch in diameter, absorbs water with such force and rapidity as to cause mercury to rise up an attached tube eight inches in six minutes.—(*Hale's Veg. Statics.*, Exp. xxi.)

Some manures increase the growth and vigour of plants by stimulating their absorbent and assimilating organs. This will only be admitted by those who allow that plants are gifted with sensation—a topic to be more fully discussed hereafter; but a few illustrative facts may be here stated. The Venus's Fly-trap (*Dionæa muscipula*) has jointed leaves, which are furnished on their edges with a row of strong prickles. Flies, attracted by honey which is secreted in glands on their surface, venture to alight upon them; no sooner do their legs touch these parts than the sides of the leaves spring up, and locking their rows of prickles together, squeeze the insects to death. The well-known sensitive plant (*Mimosa sensitiva*) shrinks from the slightest touch. *Oxalis sensitiva* and *Smithia sensitiva* are similarly irritable, as are the filaments of the stamens of the Berberry. One of this irritable tribe, *Hedysarum gyrans*, has a spontaneous motion; its leaves are frequently moving in various directions, without order or co-operation. When an insect inserts its proboscis between the converging anthers of a kind of Dog's-bane (*Apocynum androsæmifolium*) they close with a power usually sufficient to detain the intruder until death. How often have we heard a farmer reply to an observation upon the tardy growth of Turnips, "They will not grow apace, until their leaves are large enough for the wind to take hold of them;" and this is only because plants cannot be healthy and vigorous without exercise. Mr. Knight found that trees which were regularly shaken every day in his greenhouse grew more rapidly and were stronger than others which were kept still.

The stimulating powers of excrementitious manures arise from the salts of ammonia they contain. Sir H. Davy found vegetation assisted by solutions of muriate of ammonia (sal-ammoniac), carbonate of ammonia (volatile salt), and acetate of ammonia. Night soil, one of the most beneficial of manures, surpasses all others in the abundance of its ammoniacal constituents in the proportion of three to one. It may be observed, that the nearer any animal approaches to man in the nature of its food, the more fertilising is the manure it affords. We believe that a languishing plant—one, for example, that has been kept very long with its roots out of the earth, as an Orange tree recently imported from Italy, might be most rapidly recovered if its stem and branches were steeped in a tepid, weak solution of carbonate of ammonia, and, when planted, an uncorked phial of the solution were suspended to one of the branches, to impregnate the atmosphere slightly with its stimulating fumes.

Manures are also of benefit to plants by affording some of the gases of the atmosphere to their roots in a concentrated form. A soil, when first turned up by the spade or plough, has generally a red tint, of various intensity, which, by a few hours' exposure to the air, subsides into a grey or black hue. The first colour appears to arise from the oxide of iron, which all soils contain, being in the state of the red or protoxide; by absorbing more oxygen during the exposure it is converted into the black or peroxide. Hence one of the benefits of frequently stirring soils: the roots of incumbent plants abstract the extra dose of oxygen, and reconvert it to the protoxide. Coal ashes, in common with all carbonaceous matters, have the power of strongly attracting oxygen. Every gardener may have observed how rapidly a bright spade of iron left foul with coal ashes becomes covered with rust, or red oxide. All animal and vegetable manures absorb oxygen from the air during putrefaction. If it be inquired of what benefit this property is to plants, since the gases are frequently presented to them in the atmosphere, it admits the ready answer, that they enjoy the additional quantity which is thus collected to the vicinity of their roots, without the latter source being diminished; and, that plants are benefited by such additional application to their rootlets has been proved by the experiments of Mr. Hill, already quoted.

Again, if the water in which the roots of a plant are immersed be contained in a close bottle only partially filled with the water, while the remainder is occupied by atmospheric air, the oxygen in this air will slowly diminish, being absorbed by the roots through the medium of the water. The roots extracting it from the water, and the water absorbing it from the air. If carbonic acid, nitrogen, or hydrogen, is substituted for the atmospheric air in the bottle, the plant droops and dies in a few days.

These facts evince that oxygen is required by the roots of plants; but practice also suggests that different plants require different quantities of that gas. This suggestion arises from the fact, that some genera, as the grasses and bulbous-rooted plants, require an open, light soil, easily penetrated by the air; whilst Beans, Clover, and other plants require a stiff soil less penetrable by the air.—(*Johnston's Lectures on Agricultural Chemistry.*)

The question may also be asked, whether the roots have the power to extract the oxygen from its combination. That they have this power admits of little doubt, since Saussure found that they were able to extract various saline bodies from their combinations; not only extracting, but selecting in those cases where several salts were in the same solution. Dr. Daubeny, the Oxford Professor of Agriculture, has also shown that strontian is rejected by Barley, Pelargoniums, and the winged Pea.

"In 1829, the seeds of various plants, such as the garden Radish (*Raphanus sativus*), the Cabbage (*Brassica oleracea*), the garden Bean (*Vicia Faba*), Hemp (*Cannabis sativa*), &c., were sown in soils containing various proportions of sulphate of strontian, with or without manure, and, amongst the rest, one in which no other ingredient except this earth was present in any quantity. The plants grew up; and when they had arrived at maturity were collected, burnt, and their ashes examined. No strontian, however, could be detected in any one of them; not even in that where the matrix consisted almost wholly of the earth in question. In 1831, the experiments were conducted with rather more attention to accuracy. One thousand one hundred and twenty-four grains of Scarlet Kidney Beans (*Phaseolus multiflorus*) were sown in a box containing about 290 lbs. of powdered sulphate of strontian, which has been ascertained to be free from alkaline matter, but to contain two per cent. of carbonate of lime, and about one-half per cent. of alumina. The box was placed in an open situation, exposed to sun and rain; and when the plants reared from these seeds had come to maturity, they were cut down and burnt. An account was then taken of the weight of the ashes remaining after the combustion had been completed, and of the fixed principles obtained from them; first, by lixiviation in water; secondly, by digestion in nitric acid; and, thirdly, by treating the remainder with an alkaline carbonate, and then again with the same acid as before. A similar process was gone through with the same quantity of the Kidney Beans as that of which the plants examined had been the produce.

It may be asked, whether the strontian is taken first into the system, and afterwards excreted from it, or whether the spongioles of the roots refuse it admission. The latter supposition seems the more probable one; since, if we adopt the former, we ought to be able always to find traces of the earth diffused throughout the vegetable tissue; and I may relate an experiment of my own, which seems to confirm it, undertaken after the plan of those by means of which the ingenious M. Macaire, of Geneva, established his important doctrine with respect to the excretory function discharged by the roots of plants. A small Pelargonium was taken out of its pot, and its roots divided into two nearly equal bundles; one of which had its extremities immersed in a glass containing a weak solution of nitrate of strontian, the other in one containing pure distilled water. After a week had elapsed, the water contained in the second glass was tested; but no strontian could be discovered in it, though a single grain in one pint of water would have been readily detected by my method. Hence it would seem that the strontian is not excreted by the roots. Yet this power of rejecting the earth in question, if possessed by the plant, must be held compatible with that of absorbing the water containing it, with which its roots are in contact. I took out of the ground a small Lilac (*Syringa vulgaris*), and introduced its roots into a glass globe containing seven pints of a weak solution of nitrate of strontian. In about a fortnight the quantity was reduced to three pints—the remainder having, for the most part, been absorbed by the roots; for evaporation was prevented by covering the surface of the water with a stratum of Olive oil, and the mouth of the vessel with a cork. Unluckily, the original quantity of salt had not been estimated; but it was found that what remained in the water, at the close of the experiment, yielded 69.4 grains of sulphate of strontian, equivalent to 39.2 grains of the earth. The four pints of water, therefore, consumed, if they had passed through the organs of the vegetable charged with their original quantity of nitrate of strontian, would have carried into its circulation 22.4 grains of this earth; and, as the water was absorbed at the average rate of about four ounces and a half per diem, it follows that more than one grain and a half would have been carried daily through the substance of the plant, supposing the salt to have been taken up in the same ratio as the water. Now, on burning the plant, and examining its ashes, a trace of strontian certainly was detected; but its whole amount did not reach the one-fifth of a grain, that is, two per cent. of the whole quantity of earthy matter present; my analysis indicating, of lime 2.70 grains; strontian, 0.18; total quantity of earth, 7.48.

Upon the whole, then, I see nothing, so far as experiments have yet gone, to invalidate the conclusion, to which the preceding facts appear to lead, that the roots of plants do, to a certain extent at least, possess a power of selection; and that the earthy constituents which form the basis of their solid parts are determined as to *quality* by some primary law of nature, although their amount may depend upon the more or less abundant supply of the principles presented to them from without."—(*Edinburgh New Philosophical Journal.*)

Manures may also be beneficial to plants by affording carbonic acid gas to their roots. Animal and vegetable matters evolve this gas whilst putrefying; but we are not aware of any manure that absorbs it from the atmosphere, so as to be for that reason beneficial to vegetation. Lime attracts carbonic acid gas from the air rapidly, but combines with it so strongly, that it is useless to the plant until the carbonate of lime so formed is imbibed and elaborated by that plant.

It is to its power of gradually forming carbonic acid gas that *charcoal* partly owes its value as a manure. The chemical operation of charcoal, when employed for this purpose, is by no means so well understood as that of most other fertilising additions to the land. That the carbon of the charcoal operates so beneficially upon plants, amongst other modes by a gradual combination with oxygen, hardly admits of a doubt. Liebig gives the results of a series of experiments by Lukas on the use of charcoal as a manure, which seem to corrobarate his opinion. From the facts which these chemists, however, adduce, it is evident that the beneficial action of charcoal, as a fertiliser, depends upon the presence of other substances besides carbon. Liebig notes (*Organic Chem.*, p. 62) that "plants thrive in powdered charcoal, and may be brought to blossom, and bear fruit, if exposed to the influence of the rain and the atmosphere. Plants do not, however, attain maturity under ordinary circumstances in charcoal powder when they are moistened with pure distilled water instead of rain or river water. Rain water must, therefore, contain within it one of the essentials of vegetable life; and it has been shown that this is the presence of a compound containing nitrogen: the exclusion of which entirely deprives humus and charcoal of their influence on vegetation." It is ammonia, to whose presence in rain water Professor Liebig thus refers, in whose valuable work (p. 207) the experiments of Lukas will be found. From these we learn that in a division of a low hothouse, in the Botanic Garden at Munich, a bed was set apart for young tropical plants; but instead of being filled with tan, as is usually the case, it was filled with powdered charcoal, the large pieces of charcoal having been previously separated by means of a sieve. The heat was conducted by means of a tube of white iron into a hollow space in this bed, and distributed a gentle warmth, sufficient to have caused tan to enter into a state of fermentation. The plants placed in this bed of charcoal quickly vegetated and acquired a healthy appearance. As always is the case in such beds, the roots of many of the plants penetrated through the holes in the bottom of the pots, and then spread themselves out; but these plants evidently surpassed in vigour and general luxuriance plants grown in the common way; for example, in tan.

M. Lukas then gives a list of several of the exotic plants upon which charcoal appears to have produced the most beneficial effects. It appeared also to promote the rapid germination of seeds. He then proceeded to try the effects of charcoal when mixed with vegetable mould, all of which answered very well. "The charcoal," continues M. Lukas, "used in these experiments was the dust-like powder of charcoal from Firs and Pines. It was found to have most effect when allowed to lie during the winter exposed to the action of the air. In order to ascertain the effects of different kinds of charcoal, experiments were also made upon that obtained from the hard woods and peat, and also upon animal charcoal; although I foresaw the probability that none of them could answer so well as that of Pine wood, both on account of its porosity and the ease with which it is decomposed. The action of charcoal consists primarily in its preserving the parts of plants with which it is contact, whether they be roots, branches, leaves, &c., unchanged in their vital power for a long space of time, so that the plant obtains time to develope the organs for its further support and propagation. There can scarcely be a doubt, also, that the charcoal undergoes decomposition; for, after being used five or six years, it becomes a coaly earth. It exercises likewise a favourable influence by absorbing and decomposing the matters excreted by the roots of plants, so as to keep the soil free from the putrefying substances, which are often the cause of the death of the spongioles. Every experiment," concludes M. Lukas, "was crowned with success, although plants belonging to a great many different families were subjected to trial."—(*Ibid.*, p. 211.)

Professor J. F. Johnston (*Elm. of Ag. Chem.*, p. 142) recognises the good properties of charcoal as "a valuable mixture with liquid manure, night-soil, farmyard manure, ammoniacal liquor, or other rich applications to the soil." And, as he observes in another place, when speaking of the fertilising portions of farmyard drainage (*Trans. High. Soc.*, 1846, p. 190), "The only substance at present known, by which the separation of all the valuable ingredients from liquid manure can be fully effected, is animal charcoal. A sufficient supply of this substance, when intimately mixed with the liquid manure, will take up nearly the whole of the saline and colouring matters it holds in solution, will carry down the substances it holds in suspension, and will leave the water nearly pure and colourless. The refuse of the prussiate of potash manufactories will have this effect, and what remains when ivory-black is digested in spirit of salt (muriatic acid), will do still better; but this kind of charcoal is neither cheap nor abundant, and, therefore, cannot be recommended for general use. The refuse animal charcoal of our manufactories is now sold for manure at the price of several pounds a ton:

either those who sell it, or those who use it, might render it still more valuable by causing fermenting liquid manure to filter through it before it is applied to the land.

"But other kinds of charcoal possess this property to a certain extent: wood charcoal, reduced to powder, charred sawdust, and charred peat, are all capable of being used with advantage in extracting the ammoniacal and other salts, which give its value to the liquid of our farmyards. Experiment has shown that when filtered through a bed of such charcoal, the liquid escapes without colour, and almost without taste, while the charred peat or sawdust is converted into fertilising manure. A great portion of the loss now incurred may be prevented by the use of such kinds of charcoal; and the fertilising substance may, through their means, be applied to our crops at seasons of the year for which, in their liquid form, they are not suited. It is even capable itself of yielding slow supplies of nourishment to plants; and it is said in many cases, even when unmixed, to be used with advantage as a top dressing. In moist charcoal the seeds of the gardener are found to sprout with remarkable quickness and certainty, but after they have sprouted they do not continue to grow well in charcoal alone."—(*C. W. Johnson's Modern Agricultural Improvements.*)

Manures sometimes assist plants by destroying predatory vermin and weeds. This is not a property of animal and vegetable manures; they foster both those enemies of our crops. Salt and lime are very efficient destroyers of slugs, snails, grubs, &c. It is astonishing how ignorantly neglectful are the cultivators of the soil, when their crops are devastated by the slug, not to dress them with caustic lime, so as to render the surface of the soil quite white during the promise of a few days' dry weather: it is instant destruction to every slug it falls upon; and those that it misses are destroyed by their coming in contact with it when moving in search of food.

It is a common practice to burn Couch-grass, Docks, Gorse, and other vegetables, which are very retentive of life, or slow in decay: a more uneconomical, unscientific method of reducing them to a state beneficial to the land of which they were the refuse cannot be devised. In breaking up heaths, such exuviæ are very abundant; but, in all cases, if the weeds, leaves, &c., were conveyed to a hole or pit, and, with every single horse-load, and with barrow-loads in proportion, a bushel of salt and half a bushel of lime were incorporated, it would, in a few months, form a mass of decayed compost of the most fertilising quality; the lime retaining many of the gases evolved during the putrefaction of the vegetable matter, and the salt combining with the lime to destroy noxious animals, which might form a nidus in the mass. By this plan nearly all the carbonaceous matters of the refuse vegetables are retained; by burning, nearly all of them are dissipated. The forming of a compost, such as that recommended, is justified and approved by the experience of many.

Stable-manure, and all decomposing animal and vegetable substances, have a tendency to promote the decay of stubborn organic remains in the soil, on the principle that putrescent substances hasten the process of putrefaction in other organic bodies with which they come in contact. Salt, in a small proportion, has been demonstrated by Sir I. Pringle to be gifted with a similar septic property; and that lime rapidly breaks down the texture of organised matters is well known.

There is no doubt that rich soils, or those abounding in animal and vegetable remains, are less liable to change in temperature with that of the incumbent atmosphere than those of a poorer constitution. This partly arises from causes already explained when treating of the influence of the colour of soils upon vegetation. Some manures, as salt, protect plants from suffering by sudden reductions of temperature by entering into their system, stimulating and rendering them more vigorous, impregnating their sap, and consequently rendering it less liable to be congealed.

Other saline manures are beneficial to plants from similar causes; but, as is justly observed by Professor Johnston, "we have also seen that all our cultivated crops require the ingredients of several saline compounds to form a healthy plant. Hence we naturally draw the inference, that artificial mixtures of two or more saline substances are likely to be still more useful, and more generally so, than any one substance applied alone.

"This has been confirmed by numerous experiments. Thus,—

"1°. *Sulphate with nitrate of soda.*—If instead of dressing Potatoes with dry sulphate of soda alone, a mixture of this salt with an equal proportion of the nitrate of soda be applied at the rate of 2 cwt. per imperial acre, the produce is in the same circumstances much greater. Thus Mr. Fleming, in 1841, obtained in the same Potato field, all equally manured with farmyard dung, the following different results—

	Produce per imp. acre.
With dung alone	16½ tons.
Dressed with nitrate of soda . . .	20 „
With sulphate and nitrate mixed . . .	26¾ „

"Again, in 1842, he obtained on another field of Potatoes top dressed on the 1st of June—

	Produce per imp. acre.
1. Dung alone gave	12¾ tons.
2. Dressed with 2 cwt. sulphate . . .	12¾ „
3. Dressed with 1½ cwt. nitrate . . .	16 „
4. Dressed with ¾ cwt. nitrate and 1¼ cwt. of dry sulphate of soda	18 „

"Still such results are not constant. It is only where the soil is deficient in the constituents of both salts, that the application of the mixture of the two is likely to be more useful than either of them put on alone. It may even happen, as in the case of the sulphate in this experiment, that one substance when applied alone may produce no increase of crop, and yet may increase the good effect of another which is applied along with it.

"2°. *Sulphate of soda with sulphate of ammonia.*—The same mutually-increasing effect of two substances was seen by other experiments in the same field. Thus—

	Per imp. acre.
Dung alone gave	12¾ tons.
2 cwt. sulphate of soda in addition . .	12¾ „
1½ cwt. sulphate of ammonia	12½ „

"The produce being sensibly equal in the three cases, and the top dressings apparently thrown away. But a mixture of

1½ cwt. sulphate of soda, with ¾ cwt. sulphate of ammonia	gave 18¾ tons.

"3°. *Sulphate of magnesia with nitrate of soda.*—In the same field also—

1½ cwt. of nitrate of soda gave. . .	16 tons.
1½ cwt. of sulphate of magnesia . .	13¼ „

"While a mixture of

1 cwt. of each of the two gave . .	22½ tons.

"4°. *Sulphate of lime* (gypsum) *with common salt.*—Gypsum and common salt are known to have been often used with advantage alone. Mixed and applied at the rate of 2 cwt. of gypsum to 1 cwt. of common salt, Mr. Alexander, of Ballochmyle, found it to invigorate an apparently worthless Bean crop to such degree that it became the admiration of the district." — (*Lectures on Agricultural Chemistry, by Professor Johnston.*)

Every cultivator of the soil, by certain empirical signs, may be able to determine that certain appliances are required to render his land productive. For example, he knows when chalk may be applied to advantage; but no lengthened practice has yet enabled any one to judge of the quality of a chalk by its exterior appearance. Chemistry alone can do this. The farmers of a district in Yorkshire having experienced the benefit of lime, procured some from a neighbouring kiln, and were astonished to behold the injury it caused to their crops; and it remained an anomaly of their experience, until chemistry demonstrated that the lime near home contained a very large proportion of magnesia, which, absorbing carbonic acid very slowly, remained in a caustic state, to the injury of the roots of the plants, and the diminution of benefit from the carbonic acid evolved by the decomposing constituents of the soil.

The experiments of Saussure demonstrate the benefit accruing to cultivated plants from animal and vegetable manures decomposing in the soil; but they do more, for they afford additional evidence to that already given how erroneously those persons argue who recommend the seed to be soaked in powerfully stimulating manures, for no other reason than because they are grateful to the adult plant. Carbonic acid gas, though an efficient promoter of a plant's growth when mature, is a check to its progress whilst the root is forming. Saussure placed Peas so that their just-developed radicles were immersed, some in distilled water, and others in water impregnated with carbonic acid. The radicles when the experiments commenced were two lines and a half in length, and in ten days those in distilled water were five inches longer than those in the acidulated water, and the stalks and leaves were equally superior. But when a month had passed, the relative superiority was reversed, and in six weeks the plants fed with carbonic acid were in every respect most vigorous. Ruckert obtained nearly the same result when Beans were grown in earth, some being watered with distilled water, and the others with water impregnated with carbonic acid.

Every cultivator in districts where marl is to be obtained is aware that it is highly beneficial when applied to the land; few of them, however, know that this various-coloured compound of earths contains always chalk, often to the amount of 50 per cent. They learn from experience that the marl of one district is most beneficial to their heavy soils; that of a second district is productive of most benefit upon light land: yet they they are ignorant, in the first instance, that the first marl contains silica, or sand; that the second has alumina, or clay, as a component; and if a new pit of marl is opened, they have to wait the result of some years' practice before they can ascertain its quality. The chemist can inform them in an hour.

THE STEM AND BRANCHES.

ALTHOUGH every member of the vegetable form, from the minutest root to the most fragile spray, has its epidermis, cellular integument, bark, woody fibre, and medullary matter, yet as these are most apparent in the stem and branches, they can be commented upon most readily in this chapter, devoted to the consideration of those vegetable members.

The first of these, the *epidermis*, is analogous to the human cuticle, or scarf skin, being the external envelope of the whole surface. It is commonly transparent and smooth, sometimes hairy; in other instances hard and rugged, occasionally so abounding with silica, or flint, as to be employed as a polisher for wood, and even brass. In every instance it is a network of fibres, the meshes of which are filled with a fine membrane. The epidermis appears to be designed as a preservative from the injurious effects of the atmosphere, to regulate the quantity of gaseous matter and moisture respired, and as a shield from the attacks of animals, &c. It is certainly devoid of sensation. The texture of the membrane between the meshes varies much in different species of plants. In very succulent plants it is so contrived that it readily allows the absorption of moisture, but prevents perspiration. Such plants are, consequently, well qualified to inhabit hot climates and dry soils. Neither is it at all impossible that it possesses the quality of allowing the passage of some gases, and rejecting others, as the bladder of animals permits water to pass through its texture, but is impervious to alcohol. In old trees it cracks, and in many cases becomes obliterated, the dead layers of bark performing its offices. Its growth is slower than that of other parts, and its powers of expansion, though great, occasionally cannot equal the rapid enlargement of the parts it encloses and defends. This is very frequently the case with the stem and branches of the Cherry; the tree is then said by gardeners to be hide-bound, and is relieved by making longitudinal incisions. It is still more apparent in the fruit of the Cherry and Plum: when rain falls abundantly during their state of ripeness, their pulp swells so rapidly, that in an hour or two the epidermis of every ripe drupe upon a tree will be cracked.

Gardeners are very prone to scrape with no gentle hand the bark of their fruit trees; whereas every care should be taken not to wound its surface unnecessarily, and never to reduce its thickness until all danger of severe frosts is passed.

The epidermis regulates the evaporation from a plant, and preserves it in some degree from the detrimental sudden changes of temperature to which our climate is liable. The Birch (*Betulus alba*), has more films of epidermis than any other European tree; and it ascends to greater heights in the Alps, and approaches nearer to the frozen zone than other trees of the same climates.

It is quite certain that stems and branches can imbibe nourishment through their epidermis. If a branch be cut off, and a wetted towel be wrapped round the bark, yet without touching either the cut end or the leaves, that branch will retain its foliage verdant much longer than another branch similarly cut off, but not enfolded by a wetted towel. So all gardeners know, that enclosing the stems of newly-transplanted large trees with moss or hay-bands, and keeping these moist, is an efficient mode of enabling them to bear the removal. A branch, or a whole tree, may be killed by painting over its entire epidermis with gas tar. Showing either that the admission and emission of gases and moisture being prevented, or that creosote or other poisonous matter is absorbed from the tar, death is the consequence.

We could give many similar results of experience, but will only add further that Mr. Hales states, as the result of many experiments, "that the air enters very slowly at the back (bark?) of young shoots and branches, but much more freely through old bark; and in different kinds of trees it has very different degrees of more or less free entrance."—(*Vegetable Statics*, i. 160.)

Knowing these facts, and knowing also the benefit a tree derives from keeping its epidermis freed from lichens, we have never doubted that its clean and healthy state is of as much importance to a plant as is a clean and healthy skin to an animal.

Some phytologists, however, have viewed the epidermis in a light altogether different, and have regarded it as being the effect of mere accident or position—that is, as being nothing more than a scurf formed on the exterior of the pulpy parenchyma, and indurated by the action of the air. This was the opinion of Grew and Malpighi, which, though it does not seem to have met with any very general reception, has been revived of late years by M. Mirbel, who, professing to be dissatisfied with the analogy that has generally been thought to exist between the epidermis of the animal and the vegetable, contends that the latter is nothing more than the indurated surface of the parenchyma, from which it differs only in such circumstances as are occasioned by position. If it is more or less transparent,—if it is tougher or firmer in its texture than the parenchyma or any of its parts, it is only because it is constantly exposed to the influence of light and air, and to the contact of such bodies as float in the atmosphere; but it is not to be regarded as constituting a distinct organ or membrane, or as exhibiting any proof of its being analogous to the epidermis of animals.—(*Trait. d'Anat. et de Phys. Vég.*, i. 87.)

Yet, if it is true that the epidermis is nothing more than the pellicle formed on the external surface of the parenchyma, indurated by the action of the air, then it will follow that an epidermis can never be completely formed till such time as it has been exposed to that action. But it is known that the epidermis exists in a state of complete perfection in cases where it could not possibly be affected by the external air. If you take a Rose-bud, or bud of any other flower, before it expands, and strip it of its external covering, you will find that the petals and other enclosed parts of the fructification are as completely furnished with their epidermis as any other parts of the plant, and yet they have never been exposed to the action of the air. The same may be said of the epidermis of the seed while yet in the seed-vessel, or of the root, or of the Paper Birch, which still continues to form and to detach itself, even though defended from the action of the air by the exterior layers.—(*Keith's Lexicon.*)

Liebig has gone a step further even than Mirbel. He obtained the following analyses :—

	Ashes of Wood of the Fir HERTWIG.	Ashes of the Bark of the Fir HERTWIG.
	1000 wood gave 3.28 ashes.	1000 bark gave 17.85 ashes
Soluble Salts 18.72.		
Carbonate of soda	7.42	
Carbonate of potash	11.30	Soluble salts 2.95
Chloride of sodium Sulphate of potash	Traces.	
Insoluble Salts.		Insoluble Salts 97.05.
Carbonate of lime	50.94	64.98
Magnesia	5.60	0.93
Phosphate of lime	3.43	5.03
„ magnesia	2.90	4.18
„ manganese	Traces.	
„ peroxide of iron	1.04	1.04
„ alumina	1.75	2.42
Silica	13.37	17.28
Loss	2.26	1.79
	100.00	100.00

Because the wood and the bark "differ essentially from each other, both in their composition and characters," Liebig concludes that "the inorganic ingredients of the bark are obviously inorganic substances, expelled by the living organism," and "are in so far true excrements, that they arise from living plants and play no further part in their vital functions; they may even be removed from them without thereby endangering their existence. It is known that certain trees throw off annually their barks: this circumstance, viewed in its proper light, shows that, during the formation of certain products formed by the vital processes, materials arise which are incapable of experiencing a further change."

This conclusion is certainly illogical; for, from similar premises it might be concluded that the shell of the lobster and of other crustaceæ are "true excrements;" and, moreover, it is a conclusion refuted by all experiments upon its functions, and by the fact, that to denude a plant of its epidermis, and to keep it so denuded, is a treatment certainly followed by disease and decay.

Immediately below the epidermis occurs the *cellular integument* (otherwise known as the *parenchyma* and *pulp*). It is a juicy substance; and, being the seat of colour, is analogous to the *rete mucosum* of man, which is red in the white, and black in the negro. The flesh of fruits is composed of it. Leaves are chiefly formed of a plate of it, enclosed by epidermis. In herbs, succulent plants, leaves and fruits, if it is destroyed, like the epidermis of the same, it remains unrestored; but in the case of trees and shrubs, it is regenerated after each removal. In leaves it is generally green; in flowers and fruits of every hue. It is always cellular, and evidently acts a part in the secretory system of plants.

The cellular tissue, says M. A. de Candolle, considered collectively, is a membranous tissue composed of a great number of cellules or cavities, closed on all sides. The froth of beer, or a piece of honeycomb, gives a rude but pretty accurate idea of it; each wall of water or wax represents the membrane, and the place of the air or the honey gives the idea of the cavity or cellules.

The walls which form the cells are of transparent membrane; these easily swell up by maceration in water, and rapidly shrivel and become obliterated by exposure to the air; so that their examination requires some care. These membranes are generally without colour when they are properly deprived of the sap stored up in the cellules.

The diameter of the cellules varies much; in general, the larger it is, the more the part to which it belongs has a loose texture, or the more rapidly it grows. Kieser calculates that the largest cellules—those of the Gourd, for instance, or of the Balsam, under a magnifying power of 130 times their diameter, are from five to six millimetres;* and that the diameter of the smallest, as, for example, those of the leaves of the Wallflower, is not, under the same magnifying power, more than one millimetre; so that there are 5100 cellules under a millimetre square of the natural size.

The cellules, being closed on all sides, can only receive the sap by means of the hygroscopicity of their walls. Those which are round suck up the juices which surround them, and elaborate them in their interior; and it is thus that, by a vital process, they form the feculent and mucilaginous substances, and the resinous matter which gives them their colour. We also see these different substances abound in all parts of plants which are essentially composed of round cellules; as the parenchyma of

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* A millimetre is about equal to 1-26th of an inch. It is the thousandth part of a metre, a French measure, which is equal to about thirty-nine inches English.

the external covering of leaves and fruits.—(*De Candolle's Vegetable Organography.*)

These cells are filled with *chromule*, or as some chemists term it, *chlorophyll;* which we shall consider fully when remarking upon the leaves of plants.

Under the cellular integument occurs *the bark*, which, in annual plants, or branches of one year's growth, consists of a single layer, scarcely distinguishable from the wood; in older stems and branches it is composed of as many layers as they are years of age. It is in the innermost of these, which is called the *liber*, that the vital returning circulation and secretions are carried on for the time being almost exclusively. These layers are concentric, or, as they are usually termed, *cortical layers;* they are thicker in feeble plants than in more vigorous plants of the same species; they are formed of waving, longitudinal fibres, the meshes of the net-work they thus constitute being filled with pulp. If the outer bark is destroyed, but the wound does not penetrate below the liber, the wound is healed up, otherwise the removed part is unregenerated. In some roots, although only annuals, the bark is composed entirely of liber, and is very thick, as in the Carrot and Parsnip, in which it is remarkably separated by a light-coloured annular mark, from the central or woody part. The liber is composed of various longitudinal tubes, in which the true sap of the individual descends after elaboration in the leaves; consequently here are found in the most concentrated state the substances that are the peculiar products of each plant, as the resin of the Fir, the bitter principle of the Cinchona, or Peruvian bark, &c.

It is called *liber*, the Latin for a book, because it was used for writing upon in ancient times before paper was invented. It is the finest and most delicate of the layers, being often reticulated most beautifully, as in the liber of *Daphne lagetto.*

These facts relative to the functions of the bark at once suggest a warning against the injury inflicted by stopping the pores of the epidermis, on the stem and branches of a tree. Through those pores oxygen and water are absorbed, and carbonic acid is evolved, the same as in the leaves, which operations are all parts of the process of elaborating the sap. It is no trivial inspiration of oxygen; for in twenty-four hours, the branch of an Apple tree has been found to inhale five times its own volume.

If the fibres emitted by the Ivy, by which they cling to other trees for support, do not aid it in obtaining nourishment, yet by filling their respiratory pores, they are injurious, and should never be allowed to cling around serviceable trees.

Immediately beneath the bark is situated *the wood*, which forms the chief bulk of trees and shrubs. In all exogens it is formed of concentric layers, one of which at least is added annually. These layers are formed of a tissue of longitudinal fibres resembling network, the interstices of which are filled up with soluble matter, differing in each vegetable genus, but closely resembling its parenchyma. The layer immediately in contact with the bark is the softest and palest in colour, and thence is called the *alburnum*. It is in this that the vessels which convey the sap from the roots to the leaves are chiefly situated. This layer is annually renewed, that of the previous year becoming more complete wood. Although the chief part of the sap-vessels, as just observed, is situated in the alburnum, yet others, though more scantily, are dispersed through other parts of the wood. Wherever situated, they extend from the extremity of the minutest root to the leaves.

In some trees, and especially in those which are not very hard, the line of demarcation of the wood and alburnum is hardly perceptible; we see this in the Poplar, the Willow, the Chestnut, the Bombax, &c.; on the contrary, in hard woods, this line is readily distinguished by the hardness and colour of the organs; thus, in the Ebony, the wood is, as every one knows, perfectly black, whilst the alburnum is white; in *Cercis siliquastrum* the wood is yellow and the alburnum white; in *Phillyrea* the wood is brownish yellow, the alburnum white; but in this last species the perfect wood is only found in very old trees; and as many as fifty layers of the alburnum were remarked by De Candolle in *Phillyreas* about 200 years old.

The relation of the thickness of the alburnum to the wood varies in different species and different individuals, not only from the preceding causes, but, moreover, from the age of the tree. Thus, the alburnum is equal to the wood in an oak six inches in diameter; it is as two to seven in a trunk of a foot; as one to nine in one of two feet, &c.; still these proportions given by Duhamel are very variable. Mustel has observed that different parts of the same layer of the alburnum may be transformed into perfect wood at different periods; thus, he has seen some Oaks which had, on one side, fourteen layers of the alburnum, on the other, twenty; or, on one side seven, on the other twenty-two, &c. The layers of the alburnum are almost always thicker on the side where they are less numerous; that is to say, in other terms, that when a root meets a good stratum of earth, it nourishes the corresponding part of the tree more abundantly. Those parts which are most nourished have the woody layers thicker, and they arrive more quickly to the state of perfect wood, whilst the roots which fall in with poor strata badly nourish the corresponding parts; and, consequently, these have the layers thinner, and they remain a longer time before they attain their complete hardness.

All workmen know very well that the alburnum is less solid than the wood, and take care to separate it from the latter when they use it for building purposes, &c. Buffon, who performed with Duhamel some important experiments upon this subject, found that in the Oak the difference of solidity of the alburnum and the wood, is as six to seven. But the principal cause for which the alburnum is carefully rejected from the wood in building, is that on account of its looser tissue it is more liable than the latter to be affected by moisture, worms, and insects. We often find stakes placed in wet situations, with the alburnum either entirely decayed, or perceptibly changed, while the wood is still very sound.—(*A. De Candolle's Organography*).

The idea that the annular layer of wood is rendered more dense and firm by severe winters is denied by reason, and demonstrated to be false by actual observation. The layers are thickest on those sides of a tree where the largest roots and branches occur, and are throughout of a greater size in such years as afford the most genial period to vegetation.

Each of the woody layers is, during its first year, a kind of very elongated cone, which surrounds the pith; during the second year it forms a second cone, which surrounds the terminal prolongation of the pith, and which is prolonged at the base in such a manner as to cover over the cone of the first year; and thus cone after cone is formed in succession, until the destruction of the trunk. It evidently results from this, that each cone, or woody layer, only increases during the first year of its life; and that it is afterwards covered over by subsequent cones, and is, as it were, shut up by them in such a manner as not to be able to lengthen or thicken any more; it remains, after some years, in an almost passive state, and does not seem any longer to form part of the living organs of the plant. It results from this state of things, that the woody layers serve successively as coverings to each other; and if one of them has received any injury—as, by the action of frost, having letters cut in its tissue, or cavities hollowed out in its thickness, having nails driven into it, &c.—all

these injuries, covered by subsequent layers, may be again found after any number of years; experiments have demonstrated this, and it serves to explain several facts to which marvellous ideas would be attached. Thus the layers of the alburnum, being full of sap, are liable to be frozen when the cold is very intense. When this accident takes place, and the frost does not reach the liber and the alburnum, the tree continues to live; the frozen layer is covered over by a sound one—afterwards by several others; and thus covered, it is found in the centre of trees; this accident is named in French, *Gélivure.* We can, by counting the number of layers formed since the accident took place, know in what year it happened. Thus, in 1800, M. De Candolle had cut down in the Forest of Fontainbleau, a trunk of a Juniper (*Juniperus communis*), which was found to present, near its centre, a layer which had been affected by frost, covered over by ninety-one woody layers, and which dated, therefore, from the severe winter of 1709.

An inscription written upon the trunk of a tree, and which penetrates to the alburnum, is covered over by the new woody layers, and may be found entire as long as that part of the trunk remains so. It was thus that Reisel found, in 1675, some capital letters in the middle of a Beech; that Mayer, in 1688, found in the woody body of a Beech a kind of sculpture representing a gallows, and a person hanging; that Albrechti, in 1697, found in the same tree the letter H, surmounted by a cross; that Adami found, under nineteen layers of the alburnum, the letters J. C. H. M. It is thus that in certain trees in India there have been found inscriptions in the Portuguese language, which had been written there some centuries before, when the country was discovered by those navigators. It is thus that different spots, or regular stars, have been artificially formed in the middle of several trees. Two Mémoires by Fougeroux de Bondaroy, inserted among those of the Académie de Paris for 1777, may be particularly consulted upon this subject.

When any accidental cause, as the hand of man, the teeth of animals, or simply a morbid change, hollows out a cavity in the alburnum, the orifice of which is sufficiently narrow to be covered over by the subsequent woody layers, the cavity is preserved entire, as well as any object shut up in it. De Candolle found in the middle of a large piece of Oak, which appeared perfectly sound, a cavity partly filled with nuts and acorns, which had probably been carried there by dormice or squirrels before it was covered over by new woody layers. In the same manner bones, stones, &c., are found in similar cavities.

When a nail is driven into a tree, so as to reach the alburnum, it remains fixed, and, by degrees, the new woody layers which are formed around it surround its base, so that it appears as if it had been driven into them; sooner or later it is entirely covered over: it is thus that we find nails and other instruments, or the horns of stags, infixed, or completely sunk, in the wood of exogenous trees. It is by the same process that the base of the Mistletoe appears each year to sink into the tree, because the woody layers rise up around it.—(*A. De Candolle's Organography.*)

Wood is consolidated fastest in those plants which are most freely exposed to the influence of light and air, and those plants grow in height the slowest. This teaches a lesson to the gardener he often may remember with advantage; for it is often desirable to have specimens of the same shrub, varying in height; and he may often increase their stature, yet preserve them in health, by keeping them in a moist, shaded locality, during the early stages of growth; and he may as certainly render them more dwarf, by exposing them to a drier, and the brightest atmosphere that they will healthily endure, and he can command. By the former treatment we have seen Heliotropes clustering round the pillars of a conservatory to the height of fifteen feet.

From the extension of the woody fibre being greater and longer continued on one side of a stem or branch than on its opposite side, it frequently becomes contorted. Gardeners usually endeavour to remedy this by making an incision on the inner side of the curvature, and then employing force to restore it to a rectilinear form, causing a gaping wound, and mostly failing to attain the object. If the incision be made on the outer side of the curve, thus dividing the woody fibres that continue to elongate most rapidly, the branch or stem, with but slight assistance, will recover its due form, and there will be no open wound.

From the fact that there is invariably more woody matter deposited on the side of a stem or branch which is most exposed to the air and light, gardeners have explained to them why those sides of their trained trees which are nearest the wall, ripen, as they term it, most slowly; and are benefited by being loosened from the wall so soon as they are relieved from their fruit. If they require any demonstration that this explanation is correct, they need only examine the trees in clumps and avenues; their external sides will be found to enlarge much more rapidly than their internal or most shaded sides.

Although the sap rises chiefly through the alburnum, yet it is not at all certain that the interior wood has become entirely inert. Indeed, the facts of its long continuing to increase in density, to change its colour, and to retain much both of liquid and gaseous matters, are evidences to the contrary.

These gaseous substances, according to Boucherie, are in some cases equal in bulk to one-twentieth part of the entire trunk of the tree in which they exist. They, probably, move upwards along with the sap, and are more or less completely discharged into the atmosphere through the pores of the leaves.

That these gaseous substances not only differ in quantity, but in kind also with the age and species of the tree, and with the season of the year, may be considered as almost amounting to a proof that they have not been inhaled directly by the roots, but are the result of chemical decompositions which have taken place in the stem itself, as the sap mounted upwards towards the leaves.

We have seen that the roots exercise a kind of discriminating power in admitting to the circulation of the plant the various substances which are present in the soil. The vessels of the stem exhibit an analogous power of admitting or rejecting the solutions of different substances into which they may be immersed. Thus Boucherie states that, when the trunks of several trees of the same species are cut off above the roots, and the lower extremities are immediately plunged into solutions of different substances,—some of these solutions will quickly ascend into, and penetrate the entire substance of, the tree immersed in them, while others will not be admitted at all, or with extreme slowness only, by the vessels of the stems to which they are respectively presented. On the other hand, that which is rejected by one species of tree will be readily admitted by another. Whether this partial stoppage of certain substances, or total refusal to admit them, is a mere *contractile* effort on the part of the vessels, or is the result of a chemical change of the substance itself, or of the fibre or sap with which it comes into contact, by which-change their exclusion is effected or resisted, does not as yet clearly appear. That it does not depend upon the lightness and porosity of the wood, as might be supposed, is shown by the observation that the Poplar is less easily penetrated in this way than the Beech, and the Willow than the Pear tree, the Maple, or the Plane.—(*Johnston's Lectures on Agricultural Chemistry.*)

Young wood contains more moisture and cellular tissue than old wood; in the latter the moisture and the cells being gradually filled with woody matter, or lignum. Chemists have endeavoured to analyse, separated the cellular tissue and the woody matter, but with no satisfactory results, inasmuch as that there is reason to believe that soaking the woods in caustic potash, and other corrosive liquids, formed the compounds which they detected during their investigations. We, therefore, give the analyses of the woods, without any attempt to distinguish one of their parts from another; nor in these analyses is there any allowance made for their saline components. These, however, do not exceed two parts in every thousand, and the oxygen in the following table may be reduced that much. The analyses were made in Liebig's laboratory.—(*Annal. de Pharm.*, xvii. 139.)

Woods.	Carbon.	Hydrogen	Oxygen.
Oak (*Quercus robur*)	49.432	6.069	44.499
Beech, red (*Fagus sylvatica*)	48.184	6.277	45.539
Beech, white	48.533	6.301	45.166
Birch (*Betula alba*).......................	48.602	6.375	45.023
Alder (*Betula alnus*)	49.148	6.217	44.587
Larch (*Pinus larix*).......................	50.106	6.310	43.584
Spruce Fir (*Pinus abies*)	49.946	6.407	43.647
Silver Fir (*P. picea*).......................	49.591	6.384	44.025
Scotch Fir (*P. sylvestris*)	49.937	6.250	43.813
Wild Plum (*Prunus domestica*)	49.311	5.964	44.725
Wild Cherry (*Prunus cerasus*).........	48.824	6.276	44.900
Crab Apple (*Pyrus malus*)	48.902	6.267	44.831
Wild Pear (*Pyrus communis*)	49.395	6.351	44.254
Ebony (*Diospyrus ebenum*)	49.838	5.352	44.810
Box (*Buxus sempervirens*)	49.368	6.521	44.111
Cork-barked Elm (*Ulnus suberosa*)	50.186	6.425	43.389
Black Poplar (*Populus nigra*).........	49.699	6.312	43.989
Ash (*Fraxinus excelsior*)	49.356	6.075	44.569
Walnut (*Juglans regia*).................	49.113	6.443	44.444
Locust (*Robinia pseudacacia*)	48.669	6.272	45.059
Lime (*Tilia Europæa*)	49.408	6.861	43.731
Horse-chestnut(*Æsculus hippocastanum*)	49.077	6.714	44.209
Crack Willow (*Salix fragilis*).........	48.839	6.360	44.801
Maple (*Acer campestris*)	49.803	6.307	43.890

In the centre of the wood is situated the *medulla* or *pith*. It only exists in dicotyledonous plants; and in them is a soft, cellular, membranous substance, juicy when young, and extending from the ends of the roots to the extremities of the branches. In the first stages of vegetation it occupies but a small space: it gradually dilates; and in shoots of a year old, and in young trees, it is of considerable diameter; as their age increases it gradually diminishes, and at length becomes totally or nearly extinct, its place being occupied by perfect wood. Its functions are little understood. It appears to be connected with the production of young shoots and buds; for, as soon as it becomes extinct in a branch, that member loses, in a great degree, the power of producing them; that power apparently being transferred to those younger branches which still retain their pith in perfection.

Much has been said concerning the function of the pith, and many opinions hazarded. In the earlier ages of phytological inquiry, or rather in ages when phytological opinions were taken up without inquiry, one of the vulgar errors of the time seems to have been an opinion that the function of the pith was that of generating the stone of fruit, and that if a Plum tree were to be deprived of its pith, it would produce fruit without a stone. This opinion receives some countenance from Evelyn (*Pomona*, chap. i.), but we presume that it is now exploded. Another early opinion is that by which the pith was regarded as being analogous to the brain and heart of animals; though we cannot see in what respect it is analogous to either. Malpighi believed it to be, like the cellular tissue, the viscera in which the sap is elaborated for the nourishment of the plant, and the protrusion of future buds. Magnol thought that it produces the flower and fruit, but not the wood. Duhamel thought it was not destined to perform any important function at all in the vegetable economy; and Linnæus revived the old doctrine of its analogy to the brain and spinal marrow. Thus all was uncertainty or contradiction among the earlier phytologists with regard to the function of the pith; and we believe that no function has been yet assigned to it, even among modern phytologists, calculated to do away all doubt.

Mr. Knight, in one of his papers published in the "Philosophical Transactions" for 1801, regards it as destined by Nature to be a reservoir of moisture to supply the leaves when exhausted by excess of perspiration; which opinion Sir J. E. Smith combated, contending that the cause assigned is wholly inadequate to the effect, as the moisture of the pith would, in many cases, be insufficient to supply even one hour's perspiration of a single leaf. Thus he overthrows the hypothesis of Mr. Knight; but we cannot think that he succeeds in establishing his own, which is merely a modification of that of Linnæus, by which he regards the pith, not as a source of nourishment, but as a reservoir of vital energy or life, analogous to the spinal marrow or nerves of animals. Yet surely the analogy will not hold good. If the spinal marrow is injured, the parts below are immediately paralysed; and if it is broken the animal dies; but Mr. Knight, after Theophrastus, has shown that a portion of the pith may be abstracted from the shoot, so as to occasion a disruption of continuity, without doing any material injury to the plant.

When the functions of the pith, whatever they may be, have ceased, nothing remains but a mass of the purest cellular tissue, so light and so full of cells as usually to float even on the surface of alcohol (*spirits of wine*). Dr. John endeavoured to establish it as a peculiar vegetable principle, under the name of *Medulline*, and he chose as examples, among others, the pith of the Sunflower (*Helianthus annuus*), and that of the Lilac (*Syringa vulgaris*). He says its characteristics are being insoluble in water, ether, alcohol, and oils; being destitute of taste and smell; being soluble in nitric acid, and thereby furnishing oxalic acid; furnishing ammonia when distilled, and leaving a charcoal having a bronzy metallic lustre (*Chemische Taballen der Pflanzem Analysen*). But nearly all these characteristics are furnished by cotton and other mere woody fibres.

The stem is by no means an essential part of the plant, since many are destitute of it; to such trees as naturally are gifted with one, it is somewhat injurious to prevent its formation. Standard fruit trees, under similar circumstances of soil, season, and culture, generally produce finer-flavoured fruit than either dwarf standards or espaliers. This fact appears to be accounted for by the discoveries of the indefatigable Knight, which evince that plants, during the latter part of the summer, are employed in preparing nourishment for the production of the foliage and blossom in the succeeding spring; this nourishment is perfected and deposited in the alburnum, and mixes with the sap during its ascent in that season. Of a consequence it is found to increase in density proportionate to the height at which it is extracted.

THE LEAVES.

THE *leaves* are highly vascular organs, in which are performed some of the most important functions of a plant. They are very general, but not absolutely necessary organs, since the branches sometimes perform their offices; such plants, however, as naturally possess them are destroyed, or greatly injured by being deprived of them. The duration of a leaf is, in general, but for a year, though in some plants, they survive for twice or thrice that period. These organs are generally of a green colour. Light seems to have a powerful influence in causing this; since, if kept in the dark, they become of a pale yellow, or even white hue, unless uncombined hydrogen is present, in which case they retain their verdure though light be absent. Hence their blanching would seem to arise from their being unable to obtain this gas, under ordinary circumstances, except when light is present. Now, the only source from which they can obtain hydrogen is by decomposing water; and how light assists in the decomposition may perhaps be explained by the disoxygenising power with which it is gifted. The violet rays of the spectrum have this power in the greatest degree; and Sennebier has ascertained by experiment that those rays have the greatest influence in producing the green colour of plants.

Sennebier has observed that, when plants are made to vegetate in the dark, their blanching is much diminished by mixing a little hydrogen gas with the air that surrounds them. Ingenhousz had already remarked that when a little hydrogen gas is added to the air in which plants vegetate, even in the light, it renders their verdure deeper; and he seems to think, also, that he has proved by experiments that plants absorb hydrogen gas when so circumstanced. M. Humboldt has observed that the *Poa annua* and *compressa*, *Plantago lanceolata*, *Trifolium arvense*, *Cheiranthus cheiri*, *Lichen verticillatus*, and several other plants which grow in the galleries of mines, retain their green colour even in the dark, and that in these cases the air around them contains a quantity of hydrogen gas. This philosopher concludes, from his observations, that the white colour of blanched plants is occasioned by their retaining an unusual proportion of oxygen, and that this is prevented by surrounding them with hydrogen gas. This may, perhaps, be true in certain cases; but the experiments of Mr. Gough are sufficient to prove that the retention of oxygen is not the only difference between green and blanched plants.

The green colouring matter of plants has been shown by Rouelle to be of a resinous nature. From this, and from the circumstance of its being formed only in the light, Berthollet has inferred that the leaves of plants have the property of decomposing water as well as carbonic acid when exposed to the light of the sun. The oxygen emitted, according to him, is derived partly from the decomposed carbonic acid, and partly from the water, while the carbon and hydrogen enter into the composition of the inflammable parts of the plant. This ingenious theory, though sufficiently probable, is not susceptible of direct proof. From the experiments of Saussure we learn that when plants are made to vegetate in pure water, in atmospheres destitute of carbonic acid gas, the quantity of their fixed matter does not increase; but when their atmospheres contain this acid gas the increase of weight which they receive is considerably greater than can be accounted for by the carbon and oxygen derived from the carbonic acid absorbed. Hence it is clear that a portion of the water must enter into their composition. It is more likely that the elements of this portion arrange themselves in a different way than that they still continue in a state of water. These facts certainly strengthen the hypothesis of Berthollet. Indeed, if we consider the great quantity of hydrogen contained in plants, it is difficult to conceive how they should obtain it, provided the water which they absorb does not contribute to furnish it.—(*Thomson's Vegetable Chemistry.*)

When the leaves are of any other hue than green they are said to be *coloured.* This variegation is often considered to be a symptom either of tenderness or debility; and it is certain, when the leaves of a plant become generally white, that that individual is seldom long-lived. Mr. Knight, however, has demonstrated that variegation is not a certain indication of a deficiency of hardihood.

All organs exhibiting or assuming a green colour are found to be capable of decomposing the carbonic acid of the sap or of the air when exposed to the action of solar light. In this operation the oxygen of the acid is exhaled into the atmosphere, and its carbon fixed in the vegetable tissue. Whence it seems to follow that the green colour of the leaves is owing to the fixation of carbon; for where the decomposition of carbonic acid is not going on the organ remains colourless. The brightness of the green seems to depend upon the degree of light to which the organ is exposed; and yet solar light is not indispensable. De Candolle gave the green colour to some plants of *Lepidium sativum* merely by the light of a few Argand lamps; but they did not give out oxygen when placed in water.

Still the deposition of carbon caused by the action of solar light does not affect the membranous tissue. Still this tissue retains its original colour and transparency, so that it is only the chromule which assumes the green colour. But how does carbon, which is black, yield a colour which is green? Sennebier solved the problem as follows:—Carbon is, in strict propriety of speech, not a black, but a very deep blue; and vegetable tissue is not absolutely a pure white, but rather a pale yellow. Hence, the green is formed by the mixture of a yellow and blue. This explication, *quoique un peu mecanique*, De Candolle regards as likely to be the true one. Yet we cannot help entertaining some doubts with regard to its validity. Surely the membranous tissue of many plants assuming a green colour has nothing in it of a yellow. But wherever we turn to look for an explication there is doubt; and the solution of the problem may be said to be a chemical puzzle. One attributes it to the presence of an oxide of iron; another to the predominance of an alkali; and neither solution is satisfactory. Yet plants placed in the dark do not lose their green colour if the atmosphere in which they grow contains a certain quantity of hydrogen or of azote. Humboldt found the leaves of *Poa annua* and *Plantago lanceolata* still green though growing in the galleries of the mines of Freyberg. It should be recollected, however, that they must have been occasionally exposed to the light of the miners' lamps. Leaves, bracts, calices, ovaries, are the organs that are most generally green: though you may find exceptions to the rule, both in organs which it includes and in organs which it excludes. The bracts of *Bartsia coccinea* are scarlet, and the embryo of the Mistletoe is green.—(*Keith's Lexicon.*)

The functions of the leaves appear to be a combination of those of the lungs and stomach of animals; they not only modify the food brought to them from the roots, so as to fit it for increasing the size of the parent plant, but they also absorb nourishment from the atmosphere. The sap, after elaboration in these organs, differs in every plant, though, as far as experiments have been tried, it appears to be nearly the same in all vegetables when it first arrives to them. The power of a leaf to generate sap is in proportion to its area of surface, exposure to the light, and congenial situation.

Leaves throw off a very considerable quantity of water. Dr. Hales found that a Cabbage emitted daily nearly half its weight of moisture, a Sunflower, three feet high, perspired 1 lb. 14 ozs., and Spearmint exhales 1¼ times its weight in the same period. But of all the plants the diurnal perspiration of which has been ascertained, the Cornelian Cherry (*Cornus mascula*) transpires the most; the exhalation amounting to nearly twice the weight of the plant in twenty-four hours. This aqueous expiration takes place chiefly during the day, is much promoted by heat, and checked by rain, or a reduction of temperature.

On the free performance of this function of plants their health is dependent in a very high degree; and we believe that half the epidemics to which they are subject arise from its derangement. That consequence of the clubbing of the roots of the Brassica tribe called *fingers and toes* arises, we consider, entirely from it. In the drought of summer, when the moisture supplied to a club-rooted Cabbage by its root does not nearly equal the exhalation of its foliage, to supply this deficiency the plant endeavours, by forming a kind of spurious bulbous root, to adapt itself to the contingency; in the same manner that in dry situations, the fibrous roots of *Phleum pratense*, *Alopecurus geniculatus*, &c., acquire a tuberous form, because bulbous or tuberous-rooted plants, it is well known, will exist in a soil so deficient in moisture as to destroy all fibrous-rooted vegetables.

Evergreens transpire less moisture than deciduous plants; which would lead to the expectation that they are more capable of living in dry situations, which, in general, is really the case.

The matter transpired by a healthy plant is nearly pure water, 5,000 grains of it never containing more than one grain of solid matter, and this is constituted of resinous and gummy matter, with carbonate and sulphate of lime. It appears to be nearly the same in all plants. The quantity, however, varies in every species, probably in every individual—and is greatly influenced by the quantity of water applied to the roots. Under precisely similar circumstances Sennebier obtained the following results:—

	Grs.		Grs.
A Peach branch, imbibing	100	exhaled	35
" "	210	"	90
" "	220	"	120
" "	710	"	295

We have found the branch of a Pelargonium, that, whilst growing on the parent stem, exhaled only twenty grains in twenty-four hours, more than trebled that quantity, in the same time when cut from the stem, and placed with the divided end in water. This increased transpiration is attended by a proportionate reduction of temperature; for a collection of Pelargoniums, in the midst of which Fahrenheit's thermometer stood at 55°, fell to 48° within two hours after a plentiful watering to their roots only, though the water was of the same temperature as the greenhouse.

For the purpose of ascertaining the composition of the liquid transpired by plants, M. Sennebier collected 13,030 grains of it from a Vine during the months of May and June. When evaporated 2 grains of residuum were left, composed of nearly ½ grain of carbonate of lime (chalk), 1-12th grain of sulphate of lime (gypsum), ½ grain of matter apparently gum, and ½ grain apparently resinous. He analysed 60,768 grains of a similar liquid collected from the Vine during July and August. The residuum after evaporation weighed 2⅛ grains, composed of ¾ grain of carbonate of lime, ¼ grain of sulphate of lime, ½ grain of gum, and ¼ grain of resin. The liquid transpired by *Aster Novæ-Angliæ* afforded precisely the same ingredients.—(*Encyc. Meth. Phys. Veget.*, 287.)

As the season of growth advances the transpiring power of leaves decreases. Under similar circumstances Sennebier found the transpiration much greater in May than in September.

The transpiration of plants decreases with that of the temperature to which they are exposed, as well as with the period of their growth. This explains why the gardener finds that his plants do not require so much water in cold weather, nor during the time that elapses between the fall of their blossom and the ripening of their seed. During this period they do not transpire more than one-half so much as during the period preceding and attending upon their blooming.

The transpiration takes place from the upper surfaces of the leaves; and, if these surfaces are coated with varnish, the leaves gradually decay and fall, and the growth of the plant ceases until fresh leaves are produced. Hence arises the benefit which plants derive in rooms, greenhouses, and other confined enclosures, from keeping those surfaces cleansed with the sponge and syringe. Some plants are particularly sensitive to injury from any check to their transpiration, among which are the Tea-scented Roses; and it thence arises that they cannot now be cultivated in nursery gardens near London, where they once flourished when that metropolis was less extensive. The advantage derived by plants from having their leaves cleansed was exemplified by the following experiment:—

Two Orange trees, weighing respectively 18 ozs. and 20 ozs., were allowed to vegetate without their leaves being cleansed for a whole twelvemonth; and two others, weighing 19 ozs. and 20½ ozs. each, had their leaves sponged with tepid water once a week; the two first increased in weight less than half an ounce each; whilst of the two latter, one had increased two, and the other nearly three ounces. In all other respects they had been treated similarly.

It must be remembered, however, in using the sponge and the syringe, that the under side of the leaves is an absorbing surface, benefited by being kept clean, and by the application of moisture. The Kidney Bean, Sunflower, Cabbage, and Spinach, absorb moisture equally by their under and upper surfaces; the Cockscomb, purple-leaved Amaranth, Heliotrope, Lilac, and Balm, absorb most freely by their upper surfaces; and the Vine, Pear, Cherry, Apricot, Walnut, Mulberry, and Rose, absorb most by their under surfaces.

The transpiration from the leaves of plants is effected through pores, or stomates, varying in number and size in every species, but being, usually, either largest or most numerous in plants inhabiting moist or shady localities. This is a wise provision; for such plants, consequently, have an abundant supply of moist food to their roots, requiring a competent provision for its elaboration and reduction from superfluous water. Those plants which are natives of sandy, exposed soils, have, on the other hand, either fewer or smaller stomates. *Crinum amabile*, an inhabitant of swamps near Calcutta, has 40,000 of the largest known stomates on every square inch of its leaves; whilst an Aloe from the exposed sands of the Cape of Good Hope has 45,000 of the smallest, and not equal in transpiring power to half the same number of stomates in the leaves of the Crinum. We have not been able to test their relative transpiring powers; but of two similarly constructed plants, of nearly similar size, the rate of perspiring in July, both in a temperature of 65°, but not exposed to the sunshine, was as follows. In six hours *Mesembryanthemum deltoides*, native of a dry soil, exhaled eight grains, while *Caltha palustris*, found only in marshy places, exhaled twenty-five grains. In the absence of certain information, therefore, the gardener may conclude, as a guide for his treatment of a new plant, that, if its stomates are large, it will require abundance of water.

The stomates present themselves under the form of oval pores, sometimes almost round, at others rather elongated. They are usually open in leaves which grow well, and in parts exposed to the sun; they are less open, or sometimes entirely closed, on the surfaces of leaves which are very old, or which have not been exposed to the light for some time. Their border has the appearance of a kind of oval sphincter, capable of being opened and closed. The line which surrounds this sphincter is always continuous with those which form the network of the cuticle. Under this, and in the interval between the border of the sphincter and the pore, granules of a green matter are very frequently found.

Stomates exist in a more or less distinct manner in all the foliaceous surfaces of vascular plants—viz., in leaves properly so called, in stipules, in the green bark, in the calyx, and in pericarps which are not fleshy; they are wanting in all *buds*, aged stems, petioles which are not foliaceous, most petals, fleshy fruits, and all seeds of vascular plants; they are also absent in all the organs of cellular plants.

The stomates are absent in several plants, on account, it seems, of their manner of living. Thus—1st, They are not found either on the leaves or stems of plants which grow under water, such as Zostera, Ceratophyllum, &c.; and in those which have part of their organs under and part above water, as several species of Potamogeton, Myriophyllum, Nymphæa, &c., the stomates exist only in the parts exposed to the air; they are found on the leaves of *Ranunculus aquatilis* when they are raised above the water, but are wanting when they grow under it. 2ndly, The part of the leaves of bulbous plants, which is concealed in the

Onion, and consequently blanched, is either entirely deprived of them, or presents some closed and imperfect ones. All truly parasitical vascular plants which are not of a green colour have no stomates either on their stems, or on the imperfect rudiments of their scale-like leaves, such as Orobanche, Lathræa, Monotropa, Cuscuta, &c.; on the contrary, those which are green, as the Mistletoe (*Viscus*), and Loranthus, are abundantly supplied with them.—(*De Candolle's Vegetable Organography.*)

We have hitherto only considered the perspiration which passes from leaves imperceptibly in the state of vapour; but there are other kinds thus particularised by Mr. Keith:—"It is very generally to be met with in the course of the summer on the leaves of the Maple, Poplar, and Lime tree; but particularly on the surface exposed to the sun, which it sometimes wholly covers. Its physical as well as chemical qualities are very different in different species of plants; so that it is not always merely an exudation of sap, but of sap in a high state of eleboration, or mingled with the peculiar juices or secretions of the plant.

"Sometimes it is a clear and watery fluid conglomerating into large drops, such as are said to have been observed by Mr. Millar, of Chelsea, exuding from the leaves of the *Musa arbor*, or Plantain tree; and such as are sometimes to be seen in hot and calm weather exuding from the leavés of the Poplar, or Willow, and trickling down in such abundance as to resemble a slight shower. This phenomenon was observed by Dr. Smith under a grove of Willows in Italy, and is said to occur sometimes even in England. Sometimes it is glutinous, as on the leaf of the Lime tree; sometimes it is waxy, as on the leaves of Rosemary; sometimes it is saccharine, as on the Orange leaf, according to the account of M. de la Hire, as related by Du Hamel, who, having observed under some Orange trees a saccharine substance somewhat resembling Manna, found upon further investigation that it had fallen from the leaves. Sometimes it is resinous, as on the leaves of the *Cistus creticus*, from which the resin known by the name of Labdanum is obtained, by means of beating it gently with leathern thongs, to which the exudation adheres; as also on the leaves of the *Populus dilatata*, or Lombardy Poplar, the exudation from which Ovid in his metamorphosing flights regards as the tears of Phæton's sisters, whom he transforms, as it is supposed, into this species of Poplar. Their tears were now gum. The leaves of Fraxinella, or *Dictamnus albus*, are also said to be often covered with a sort of resinous substance. And after a hot day, if the air is calm, the plant is even found to be surrounded with a resinous atmosphere, which may be set on fire by the application of the flame of a candle.

"The cause of this excess of perspiration has not yet been altogether satisfactorily ascertained; though it seems to be merely an effort and institution of Nature to throw off all such redundant juices as may have been absorbed, or secretions as may have been formed, beyond what are necessary to the due nourishment or composition of the plant, or beyond what the plant is capable of assimilating at the time. Hence the watery exudation is perhaps more than a redundancy of the fluid thrown off by imperceptible perspiration, and the waxy and resinous exudations nothing more than a redundancy of secreted juices; all which may be still perfectly consistent with a healthy state of the plant."

The circumstance most influential in controlling the transpiration of plants is the hygrometric state of the atmosphere in which they are growing. The drier the air, the greater is the amount of moisture transpired; and this becomes so excessive, if it be also promoted by a high temperature, that plants in hothouses where it has occurred often dry up as if burned. Mr. Daniell has well illustrated this by showing, that if the temperature of a hothouse be raised only five degrees, viz., from 75° to 80°, whilst the air within it retains the same degree of moisture, a plant that, in the lower temperature exhaled fifty-seven grains of moisture, would, in the higher temperature, exhale 120 grains in the same space of time.

Plants, however, like animals, can bear a higher temperature in dry air than they can in air charged with vapour; animals are scalded in the latter, if the temperature is very elevated; and plants die under similar circumstances as if boiled. Messrs. Edwards and Collins found Kidney Beans sustained no injury when the air was dry at a temperature of 167°; but they died in a few minutes if the air were moist. Other plants, under similar circumstances, would perish, probably, at a much lower temperature. Yet others are still more enduring of great heat. On the banks of a thermal river in the island of Luçon, the largest of the Philippines, Sonnerat found plants of *Vitex Agnus-Castus*, together with a species of Aspalathus, or African Broom, growing, and as we may suppose thriving, though the roots were swept by the water at a temperature of 174° (*Voyage à la Nouv. Guinea*); and in the thermal springs of Italy, though heated to the boiling point, certain species of Confervæ are said to grow abundantly. The same is the case with many fishes. In the above island of Luçon, Sonnerat saw fishes frolicking in a hot spring, the temperature of which was found to be 150°; and in the province of Quito, in South America, Humboldt saw fishes thrown up from the bottom of a volcano, together with water and heated vapour that raised the thermometer to 210°. This was quite high enough to have killed and boiled European fishes; but the fishes in question were still alive.

Seeds, as we have before stated, are still more capable of bearing great heats, and we may further illustrate this by the following statement of Professor Henslow :—

"Sir John Herschel sent some seeds of an Acacia from the Cape of Good Hope, to Captain Smith, of Bedford, with directions that they should be scalded, in order to secure their germination. Captain Smith having presented the Professor with a dozen of these, he subjected them to the following experiments :—Two were placed in boiling water, and left to soak for an hour, until the water had become cool; two were kept at the boiling temperature for one minute and a half; two for three minutes; two for six minutes; and one for fifteen minutes. Some of these were sown immediately, under a hand-glass, in the open border; and the rest were kept for three or four days, and then sown in a hotbed. The following are the results obtained :—

Under the hand-glass,—

One, boiled for 1½ minute, failed.
One „ 3 minutes came up in 14 days.
One „ 6 „ „ „ 13 „
One, not steeped at all, did not germinate.

In the hotbed,—

One, boiled for 1½ minute, came up in 8 days.
One „ 3 minutes „ „ 7 „
One „ 6 „ „ „ 7 „
One „ 15 „ „ „ 13 „
Two, in boiling water, left to cool . 9 „
Two not steeped . . . . 21 „

"We cannot draw any decided inference from the single seed which was boiled for fifteen minutes having been more retarded than the rest, as it might have been a bad specimen; but it seems very clear, that the heat to which these seeds were exposed must have acted as a decided stimulus to their germination;

whilst it is a very singular fact that they should not have been completely destroyed by it."

In pursuance of this subject, at the Bristol Meeting of the British Association, Mr. Hope mentioned a practice, common in some parts of Spain, of baking corn to a certain extent, by exposing it to a temperature of 150°, or upwards, for the purpose of destroying an insect by which it was liable to be attacked. Dr. Richardson mentioned that the seeds sold in China for the European market were previously boiled, for the purpose of destroying their vitality, as the jealousy of that people made them anxious to prevent their exportation in a state fitted for germination. Upon sowing these seeds, he had, nevertheless, observed some few of them were still capable of vegetating.—(*Edin. New. Phil. Journ.*, vol. xxi., October, 1856, p. 333.)

Though growing plants can bear an elevated temperature without injury, a very different effect is produced upon them by even a lower heat, after they have been separated from their roots. This has to be borne in mind in the drying of potherbs, which, though it is a process very simple, and very important for the winter's supply that it should be conducted correctly, is usually more neglected and more thoughtlessly practised than any other in the varied range of the gardener's duties. To demonstrate this will only require to have pointed out how it ought to be managed. The flavour of almost every potherb arises from an essential oil which it secretes, and this being in the greatest abundance just previously to the opening of its flowers, that is the time which ought to be selected for gathering. Potherbs ought to be dried quickly; because, if left exposed to winds, much of the essential oil evaporates, and mouldiness occurring, and long continuing, destroys it altogether, for nearly every plant has its peculiar mucor (mould), the food of which is the characteristic oily secretion of the plant on which it vegetates. A dry brisk heat is therefore desirable. The temperature should be 90°; for if it exceeds this, the essential oils are apt to burst the integuments of the containing vessels, and to escape. Forty-eight hours, if the heat be kept up steadily, are sufficient to complete the process of drying. The leaves, in which alone the essential oils of potherbs reside, should then be carefully clipped with scissors, not crushed, from the stalks, and stored in tightly-corked wide-mouthed bottles. Each will thus preserve its peculiar aroma, not only through the winter, but for years, and be infinitely superior to any specimens producible in the forcing department, for these are unavoidably deficient in flavour.

Leaves have the power of absorbing moisture as well as of emitting it, which power of absorption they principally enjoy during the night. With this view M. Bonnet, of Geneva, placed a number of leaves over water, so as that they floated on it, but were not immersed; some with the upper surface, and others with the under surface applied to the water. If the leaf retained its verdure the longest with the upper surface on the water, the absorbing power of the upper surface was to be regarded as the greatest; but if it retained its verdure the longest with the under surface on the water, then the absorbing power of the under surface was to be regarded as the greatest. Some leaves were found to retain their verdure the longest when moistened by the upper surface, and some when moistened by the under surface; and some were altogether indifferent to the mode in which they were applied to the water. But the inference deducible from the whole, and deduced accordingly by Bonnet, was, that the leaves of herbs absorb moisture chiefly by the upper surface, and the leaves of trees chiefly by the under surface. What is the cause of this singular disparity between the absorbing surfaces of the leaf of the herb, and of the tree? The physical cause might be the existence of a greater or of a smaller number of pores found in the leaves of the herb and tree respectively. The chemical cause would be the peculiar degree of affinity existing between the absorbing organs and the fluid absorbed. Duhamel seems to have been content to look to the physical cause merely, regarding the lower surface of the leaf of the tree as being endowed with the greater capacity of absorbing moisture, chiefly for the purpose of catching the ascending exhalations which must necessarily come in contact with it as they rise, but which might possibly have escaped it if absorbable only by the upper surface, owing to the increased rapidity of their ascent at an increased elevation; and regarding the upper surface of the leaf of the herb as being endowed with the greater absorbing power, owing to its low stature, and to the slow ascent of exhalations near the earth.—(*Keith's Botanical Lexicon.*)

During the day leaves also absorb carbonic acid gas, which they decompose, retaining its carbon, and emitting the greatest part of the oxygen that enters into its composition. In the night this operation is in a certain measure reversed, a small quantity of oxygen being absorbed from the atmosphere, and a yet smaller proportion of carbonic acid emitted.

It has occasionally been observed, however, that the bulk of oxygen given off by the leaf has not been precisely equal to that of the carbonic acid absorbed, and hence it is also fairly concluded that a portion of the oxygen of the carbonic acid which enters the leaf is retained, and made available in the production of the various substances which are formed in the vascular system of different plants. On the other hand, it is stated by Sprengel that, if compounds containing much oxygen be presented to the roots of plants, and thus introduced into the circulation, they are also decomposed, and the oxygen they contain in part or in whole given off by the leaves, so that, under certain circumstances, the bulk of the oxygen which escapes is actually greater than that of the carbonic acid which is absorbed by the leaves. Such is the case, for example, when the roots are moistened with water contained carbonic, sulphuric, or nitric acids.

As a general rule, the quantity of carbonic acid given off during the night is far from being equal to that which is absorbed during the day. Still it is obvious that a plant loses carbon precisely in proportion to the amount of this gas given off. Hence, when the days are longest, the plant will lose the least, and where the sun is brightest it will gain the fastest;—since, other things being equal, the decomposition of carbonic acid proceeds most rapidly where the sky is the clearest, and the rays of the sun most powerful. It thus appears why in Northern regions, where spring, summer, and autumn are all comprised in one long day—vegetation should proceed with such rapidity. The decomposition of the carbonic acid goes on without intermission, the leaves have no night of rest; but Nature has kindly provided that, where the season of warmth is so fleeting, there should be no cessation to the necessary growth of food for man and beast.—(*Johnston's Lectures on Agricultural Chemistry.*)

Carbonic acid gas in small proportions is essential to the existence of leaves, yet it only benefits them when present in quantities not exceeding one-twelfth of the bulk of the atmosphere in which they are vegetating; though one twenty-fifth is a still more favourable proportion; and as hotbeds, heated by fermenting matters, rapidly have the air within their frames contaminated to a much greater extent than the proportions above-named, thence partly arises the injury to the plants they contain from a too-long-neglected ventilation. The leaves turn yellow from the excess of acid, which they are unable to digest, and which consequently effects that change of colour which also occurs in autumn, and which will be more fully considered when the decay of plants is detailed.

It is the accumulation of carbonic acid and other gaseous matters, such as sulphurous acid and ammonia, which renders ventilation so essential to the health of plants in forcing-pits and hothouses. They cannot inhale air overloaded with these contaminations without being speedily injured, and the proportions of those gases which rapidly cause disease, or even death, are much less than the gardener usually suspects; for if the sulphurous acid amounts to no more than one cubic foot in ten thousand of the air in a hothouse, it will destroy most of its inhabitants in two days. To avoid such destruction, for the comfort of visitors, and, above all, for the sake of the plant's vigour, air should be admitted as freely as the temperature will permit. The foul warm air can be easily allowed to escape through ventilators in the most elevated parts of the roof, and fresh warm air can be as readily supplied through pipes made to enter near the flooring of the house after passing over hot water, or other source of heat.

We are quite aware that Mr. Knight has stated that he paid little attention to ventilation, and that plants will be vigorous for a time in Wardian cases; but this does not prove that their Creator made a mistake when he placed vegetables in the open air. Plants confined in houses or other close structures may be made to grow in spite of such confinement; but all experience proves that other favourable circumstances, such as heat, light, and moisture, being equal, those plants are most vigorous and healthy which have the most liberal supply of air.

Though an excess of carbonic aid gas is detrimental, yet its partial absence from the atmosphere is equally fatal to a plant's leaves, for without it they wither and fall. It is not a matter of indifference, therefore, whether a greenhouse or hothouse be whitened with a solution of lime, which absorbs that gas from the air, a fortnight or only a day or two before plants are introduced or forcing commenced; for it is the infliction of several trivial injuries to a plant that prevents its successful cultivation; no one who is entitled to practise in the higher departments of his art ever makes such great blunders as at once to destroy the plants under his care. That fresh-limed walls do injure plants is beyond dispute, for the plants in a row of small pots next the back wall in a propagating-house which had been thus whitened only the day before, have been more than once observed to be the only plants that acquired a sickly hue, and shed nearly all their leaves. Fleshy-leaved plants would not be so liable to injury if obliged to be brought into a house fresh limed, for these require much less carbonic acid daily than thin-leaved plants. Five plants of *Cactus speciosissimus* in the injured row just noticed were not apparently affected. Thin-leaved plants consume daily from five to ten times their own bulk of carbonic acid gas, whilst fleshy-leaved plants, such as the Cacti, Aloes, Agaves, and Mesembryanthemums, do not consume more than their own or double their own bulk of that gas.

Other species of decomposition also, besides that of carbonic acid, go on in the leaf, or are there made manifest. Thus when plants grow in a soil containing much common salt (chloride of sodium) or other chlorides, Sprengel and Meyen observed them to evolve chlorine gas from their leaves. This takes place, however, more during the night than during the day. Some plants also give off ammonia, while others (Cruciferæ) emit from their leaves pure nitrogen gas (*Daubeny's Three Lects. on Agri.*, p. 59). This emission of nitrogen from the leaves is, according to Schutz, not an uncommon occurrence, and on a dark day may amount to nearly two-fifths of the entire bulk of the gas given off.

Plants and their leaves, if excluded from light, become of a white or pale yellow colour, in which state they are said to be *blanched* or *etiolated.* This, as already noticed, is occasioned by their being neither able to decompose the water they imbibe, nor to inhale carbonic acid. In the dark plants can only inhale oxygen, and thus, deprived of free hydrogen and carbon, on the due assimilation of which by the leaves all vegetable colours depend, and saturated with oxygen, they of necessity become white. An excess of oxygen has uniformly a tendency to whiten vegetable matters; and, to impart that excess to them is the principle upon which all bleaching is conducted. An over-dose of oxygen causes in them a deficiency of alkaline, or an excess of acid matter, and light enables plants to decompose the acid matter, and to restore that predominancy of alkalinity on which their green colour depends. Sennebier and Davy found most carbonic acid in blanched leaves; and all green leaves contain more alkaline matter than the rest of the plant which bears them. Every cook knows that a little alkali, carbonate of soda, added to the water, improves the green hue of her boiled vegetables. That this is the cause of the phenomenon is testified by direct experiment. Blanched Celery and Endive, and the white inner leaves of the Cos Lettuce, contain about one-third more water than the same parts when green; and if submitted to destructive distillation do not yield more than half so much carbon. Then, again, if a plant of Celery is made to vegetate in the dark, under a receiver containing atmospheric air, with the addition of not more than one-twenty-fifth part of its bulk of a mixture of carburetted hydrogen, and hydrogen such as is afforded by the distillation of coal, that plant, though it becomes paler than when grown in the daylight, still retains a verdant colour.

So effectual is the metamorphosis of plants effected by excluding them from the light, that Professor Robinson brought up from a coal mine, near Glasgow, some whitish-looking plants of which no one could detect the name or character. After exposure to the light the white leaves decayed, and were succeeded by green ones, which speedily revealed that the plants were Tansy. They had found their way into the mine in some sods from a neighbouring garden; but though they had retained life in its dark galleries, they had entirely lost their natural colour, odour, and combustibility. This is only in accordance with the gardener's yearly experience; for his blanched Sea-kale, Endive, and Lettuce are totally dissimilar in flavour and appearance to the plant left in its natural state.

Sir H. Davy excluded a Cos Lettuce from the light. In six days it was rendered very pale, and at the end of another week it was quite white: the growth of the plant was checked, and the analysis of its leaves showed that they contained more carbonic acid and water, but less hydrogen and residual carbon, than an equal weight of green leaves.

A Potato has been observed to grow up in quest of light from the bottom of a well twelve feet deep—and in a dark cellar a shoot of twenty feet in length has been met with, the extremity of which had reached and rested at an open window. In the leaves of blanched vegetables peculiar chemical compounds are formed. Thus in the blanched shoot of the Potato a *poisonous* substance called *solanin* is produced, which disappears again when the shoot is exposed to the light and becomes green (*Otto.*) In Asparagus, in blanched Clover (Piria), and other plants grown in the dark, *asparagin* is formed, and no doubt other peculiar changes take place, which are not yet understood.—(*Johnston's Lectures on Agricultural Chemistry.*)

It deserves notice, that it has been proved by the experiments of Dr. Hope and others, that light from artificial sources may be concentrated so as to enable plants to absorb oxygen and perfect those elaborations on which their green colour depends; and the light of the moon has a similar influence. A similar concentrated light will make the Pimpernel, and other flowers which close until sunrise, open their petals and rouse from their rest; a fact which gives another reason why plants in rooms frequented at night become weak and exhausted sooner than those that remain, as Nature dictates, unexcited at night.

The yellow, red, and light brown tints which render the foliage of our plants so beautiful in autumn arise from the absorption of an excess of oxygen gas. When the reduced temperature of the season deprives a leaf of the power to elaborate the sap, and, indeed, stops the circulation to it of that fluid, the absorbent powers of the organ are reversed, and, instead of carbonic acid, it inhales oxygen. The effect is speedily perceptible. Gallic acid forms, and this, modified by the various saline constituents of different leaves, changes the hue of their green colouring matter, called chlorophyll or chromule, into various tints of yellow, red, and brown. This is the general effect of acids acting upon vegetable greens, and that it is the cause of the autumnal change of colour in leaves is proved by the fact, that if a green leaf be dipped into an acid it assumes the same hue; and if some red or yellow leaves be dipped into an alkaline solution they are rendered green—the alkali evidently neutralising the acid that had wrought the unnatural change of colour.

Changes similar to those resulting from age may occur merely from accident, as from the puncture of insects, the growth of parasitic fungi, or the blighting influence of frost. First they change to yellow; then they change to red.

But some leaves present naturally a different colour on each surface. The upper surface of the leaf of the Cyclamen is green; the under surface is red; yet the red chromule, in this case, exhibits the same chemical properties as the chromule that has been changed to red as the result of age.—(*Macaire.*)

The hints and warnings which these facts suggest to the mind of every reflecting practitioner are numerous. They explain and enforce the necessity of a regular, and by no means as to quantity, indiscriminate, supply of water to plants; the importance of shading after their transplanting, yet the avoidance of unnecessary shading to those established; and of a free circulation of air, &c.; and the necessity of keeping the leaves as clean and as free from injury as possible. The leaves of plants must often be removed; and in some instances this is done with essential benefit; but the horticulturist should constantly keep in mind that, with every leaf that he removes, he deprives the plant of a primary organ of its existence.

Light, it has just been stated, is the cause of the green colour of plants; but it should be observed that its full power is only beneficial when directed upon their upper surface. This is evidenced by the position they always maintain. Trees whether nailed to a north or south wall, or trained as espaliers, always turn the upper surfaces of their leaves outwards to where there is most light. Plants in a hothouse uninfluenced by the direction from whence proceeds the first supply of air, or the greatest degree of heat, turn not only their leaves but their very branches towards the source of brightest light, and, if not turned almost daily, entirely lose their symmetrical form.

If the branches of a tree trained against a wall, or other support, are so moved when their leaves are completely expanded, that the under side of the foliage is the most exposed to the light, they are always found to regain their natural position in a day or two. If the experiment be often repeated on the same individual, the leaves to the last continue to revert, but becom gradually weaker in the effort, partially decay, and their epidermis peels off. Succulent leaves are particularly sensitive of light, but those of pinnated, leguminous plants—as the Pea and Kidney Bean—are still more so.

THE SAP.

As there is a very close similarity in the blood of all animals, so does the same resemblance obtain in the sap of plants. Uniformly it is limpid as water, its chief constituent, and contains an acid, salts, and mucilage or saccharine matter. The proportions, of course, vary.

The basis of this sap is the moisture of the soil and atmosphere absorbed by the roots and other organs; and that that power of absorption is very great we have previously stated. Neither is it an indiscriminate power; for if the roots of a plant are placed in water containing two or more salts in solution, they will abstract different portions of those salts, and will reject some of them entirely. Thus, when 100 grains of each of the following salts were dissolved in 10,000 grains of water, and plants of *Polygonum persicaria*, *Mentha piperita*, and *Bidens cannabina* were made to grow in it, they took up six grains of sulphate of soda (glauber salt), and ten grains of chloride of sodium (common salt), but not a grain of acetate of lime.

The moisture from the soil absorbed by organs having such discrimination and absorbing powers passes up vessels situated in the wood, but especially in the alburnum, impelled by their contractile power—a power so great that it drives the sap from the extremity of a cut Vine-branch with a force capable of sustaining a column of mercury thirty-two inches and a half high. If a proof of their contractile power, evidently resembling the peristaltic motion of the animal bowels, be required, Dr. Thomson justly refers for such proof to the evidence afforded by milkyjuiced plants like the *Euphorbia peplis.* If the stem of this plant be divided in two places, the juice flows out at both ends so completely, that if it be again bisected between the two former cuts no more juice will appear. Now, it is impossible that these phenomena could take place without a contraction of the vessels; for the vessels in that part of the stem which has been detached could not be more than full; and their diameter is so small, that, if that diameter continued unaltered, the capillary attraction would be more than sufficient to retain their contents, and, consequently, not a drop would flow out. Since, then, the whole liquid escapes, it must be driven out forcibly, and, consequently, the vessels must contract.—(*Thomson's Organic Chemistry*, 988.)

The ascent of the sap has been endeavoured to be explained by M. Dutrochet, upon mere mechanical principles. He observes—"If one end of an open glass tube be covered with a piece of moistened bladder, or other fine animal membrane, tied tightly over it, and a strong solution of sugar or salt in *water* be then poured into the open end of the tube, so as to cover the membrane to the depth of several inches—and if the closed end be then introduced to the depth of an inch below the surface of a vessel of pure water, the water will after a short time pass through the bladder inwards, and the column of liquid in the tube will increase in height. This ascent will continue, till, in favourable circumstances, the fluid will reach the height of several feet, and will flow out or run over at the open end of the tube. At the same time the water in the vessel will become sweet, or salt, indicating that while so much liquid has passed through the membrane inwards, a quantity has also passed outwards, carrying sugar, or gum, or salt along with it." To these opposite effects Dutrochet gave the names of—*endosmose* denoting the inward progress, and *exosmose* the outward progress of the fluid. He supposed them to be due to the action of two opposite currents of electricity, and he likens the phenomena observed during the circulation of the sap in plants to the appearances presented during the above experiment.

This hypothesis cannot be satisfactory; for such *endosmose* has no power sufficient to sustain thirty-two inches and a half of mercury, as is done by sap propelled by the Vine, and it entirely fails to explain the discriminatory power possessed by the spongioles, as well as the fact that the sap will be ascending on the heated side of a tree, whilst it will be quite unmoved on the side which is cold.

Thus propelled, the sap is distributed along each branch to every leaf, and to every fruit of the plant, gradually acquiring during its passage a greater specific gravity, not only by exhalation, but by dissolving the peculiar secretions of the plant formed during its previous year's growth, and deposited in the alburnum from the sap during its downward course in the inner bark from the leaves. It is in the leaves that the chief elaboration of the sap takes place, and those peculiar juices are formed characteristic of the plant, and which are found deposited there, or in the bark, or still further altered in the fruit and seed.

The ascending sap of the Vine, Elm, Beech, and some few others has been analysed, but the results are so similar that we need only particularise two. Dr. Prout, M. Robiquet, M. Deyeux, and others, agree in stating that the sap of the Vine (*Vitis vinifera*) has a specific gravity not greater than that of pure water, a fact explained by its containing much carbonic acid gas. Its taste is sweetish. When 2300 grains of it were evaporated to dryness, only one grain of solid matter remained, about half of which was saline, composed of tartrate of lime and bitartrate of potash, and the remainder was a gummy vegetable substance.

Boussinghault has analysed the sap of the Plantain (*Musa Paradisica*), finding in it tannin, gallic acid, acetic acid, common salt, and salts of lime, potash, and alumina.—(*Journ. de Pharmacie*, xxii., 385.)

After being elaborated in the leaves the ascending sap is entirely changed in its qualities and constituents, and the *descending* sap is found to be either milky, gummy, resinous, astringent, sugary, acid or saline.

Milky descending saps.—We will only particularise that of the Lettuce (*Lactuca sativa*). This contains albumen, caoutchouc (Indian-rubber), wax, chloride of calcium, phosphate of lime, potash, gum, nitrate of ammonia, acetic, with another acid, and a bitter principle called *lactucarium*. In this lactucarium the peculiar flavour and properties of the Lettuce reside. It has been employed in medicine as a substitute for opium, possessing its soothing without its inconvenient properties.

Gummy descending saps are familiar to us in the Cherry, Plum, and Peach; but, in truth, all descending saps are gummy, for *cambium*, the substance deposited in all those parts of vegetables where growth is occurring, is chiefly gummy or mucilaginous matter.

The *resinous descending saps* are familiar to us in the Coniferæ; and the *sugary* in the Carrot, Parsnip, and Beet.

The *saline* and *acid* descending juices are still more varied and peculiar. Thus that of Wolf's-bane (*Aconitum lycoctonum*) contains citrates of lime and potash; *Delphinium elatum*, *Ranunculus aconitifolius*, *Thalictrum flavum*, *Clematis recta*, and *C. viticella*, all contain similar combinations of citric acid; Clary (*Salvia sclarea*) contains benzoate of potash; Rue (*Ruta graveolens*) contains malates of potash and lime; Agrimony (*Eupatorium cannabinum*) contains phosphoric and another acid; Spinach (*Spinacea oleracea*) contains oxalates of lime and potash, and malate and phosphate of potash; the common Indian Cress, or Nasturtium (*Tropæolum majus*) contains phosphoric, nitric, and malic acids united to lime and potash; Virginian Poke (*Phytolacca decandra*) contains oxalate of potash; and the Sorrels and Oxalises all contain an excess of oxalic acid.

Although the sap increases in specific gravity, and consequently obtains an accession of solid matter during its progress up the stem, yet the matter thus obtained is not of paramount importance, nor absolutely controlling the subsequent changes to be effected; for in such case the Green Gage would be altered by its Plum stock, and the *Nonpareil* by its Crab stem. So far from this being the case, the old gardener's maxim—"The graft overruleth the stock quite," is consonant with truth, though it is to be taken with some reservation. The graft prevails and retains its qualities, yet the stock has the power of influencing its productiveness as well as the quality of the fruit. Thus, a tree having an expansive foliage and robust growth, indicative of large sap vessels and vigorous circulation, should never be grafted upon a stock oppositely characterised, for the supply of sap will not be sufficient: illustrations are afforded by the *Codlin* never succeeding so well on a Crab, nor a *Bigarreau* on a wild Cherry, as they do on freer-growing stocks. Indeed, we have no doubt that every tree and shrub succeeds best, is most productive, and most free from disease, if it be supplied with sap from roots and through a stem of its own peculiar kind. This is evident to common sense; nor would any scion be grafted upon a stock of another species or variety, if it were not that such stocks are most easily obtainable, or for producing some alteration in the habit of the plant, or to fit it for some particular soil.

For example: our choicest Cherries are grafted or budded upon the wild Cherry only because of its being easily obtained; and every one must have noticed the frequently occurring consequence, an enlargement, appearing like a wen, encircling the tree just above where the graft and the stock joined—the growth of the former having far outstripped that of the latter.

The results from grafting upon stocks differing from the scions in their ratio of growth have thus been illustrated by M. Turpin:

FIG. 1.

Fig. 1. *a* Stem of a Black-heart Cherry, of soft texture and free growth.
b The stock, being of the Bird Cherry, hard-wooded, and slow in growth.
c The scar at the point of junction, the swelling occasioned by the sap being checked there in its descent.

If a tree could be nourished from its own roots—from organs assigned by its Creator as those best suited to supply the most appropriate quantity and quality of sap, there can be no doubt that it would be productive of benefit in a soil and climate natural to it; and this desideratum seems to be secured by the plan suggested by M. Aibret. In the instances of Apples and Pears—and we see no reason forbidding its adoption to any other grafted tree—he recommends the grafts always to be inserted close to the surface of the ground, or they might be even rather below the surface, by scooping out the earth around the stems of the stocks. When planted out, the lowest extremity of the graft should be about four inches below the surface. After two or three years, at the close of June, the soil should be removed, and just above the junction of the graft and stock, with a gouge, one-fourth of the bark removed by four cuts on opposite sides of the stem; the cuts being deep enough to remove the inner bark, and the wounds covered immediately with rich soil, formed of one part putrescent cowdung and two parts maiden loam. If kept constantly moist with water, and occasionally with liquid manure, roots will usually be speedily emitted, especially if the place where a bud once was formed be thus kept moist beneath the soil.

But the stock has some other influence over the sap, besides limiting the quantity of sap supplied to the scion—an influence not only arising from the size of its vessels, but from its susceptibility to heat. It has a further influence over the scion by the sap becoming more rich, indicated by its acquiring a greater specific gravity in some stocks than in others, during its upward progress. The specific gravity of the sap of a *Black Cluster* Vine stock on which a *Black Hamburgh* had been grafted was, when obtained six inches from the ground, 1·003, and at five feet from the ground 1·006; but the same *Black Hamburgh*, growing upon its own roots, had specific gravities at corresponding heights of 1·004 and 1·009. This increase is of great importance to a tree's growth when the quantity of sap passing annually through its vessels is considered. The exact amount of this it is perhaps impossible to discover, but its extent may be appreciated by the quantity of moisture their roots are known to imbibe, and by the facts that a small Vine-branch has poured out 16 ozs. of sap in twenty-four hours; a Birch tree a quantity equal to its own weight during the bleeding season; and a moderate-sized Maple about 200 pints during the same period.

The habit of the stock also is of much more importance than is usually considered. If it grows more rapidly, or has larger sap-vessels than the scion or bud, an enlargement occurs below these; but if they grow more rapidly than the stock, an enlargement takes place just above the point of union. In either case the tree is usually rendered temporarily more prolific; but in the case where the stock grows most slowly the productiveness is often of very short duration, the supply of sap annually becoming less and less sufficient to sustain the enlarged production of blossom and leaves. This very frequently occurs in the freer-growing Cherries when inserted upon the wild species; and still more frequently to the Peach and Apricot upon stocks of the slower-growing Plums. It is highly important, therefore, to employ stocks the growth of which is as nearly similar as may be to that of the parent of the buds or scion.

FIG. 2.

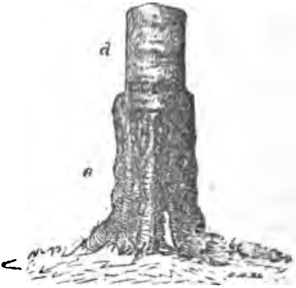


Fig. 2. *d* Stem of a Paper Birch (*Betula papyracea*), smooth-barked. *e* The stock of the White Birch (*Betula alba*), rough-barked, showing that although the barks unite perfectly, yet that they do advance beyond the scar over the place of union.

FIG. 3.

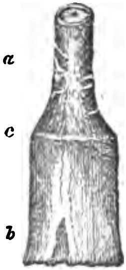


FIG. 4.

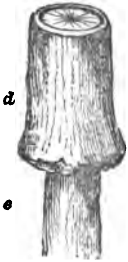


Fig. 3. *a* The *Pavia lutea*, never exceeding the stature of a shrub.

b The stock of the common Horse-Chestnut on which the scion was cleft-grafted. It is observable in this instance that the stem of the Pavia at the point of junction (*c*) is expanded by the stock to which it is attached. Here, again, the barks remain perfectly distinct.

Fig. 4. *d* The White Lime tree (*Tilia alba*).

e The stock of the common Lime or Linden tree (*Tilia Europæa*). Here, each retains, with but a slight enlargement, its own rate of growth.

The earlier vegetation of the stock than of the bud or graft is also important; for if these are earliest in development they are apt to be exhausted and die before the flow of sap has enabled granulation and union between the faces of the wounds at the junction to occur. Mr. Knight's observations upon this point are the results of experience, and are so consonant with the suggestions of science that we will quote them in his own words without comment:—

"The practice of grafting the Pear tree on the Quince stock, and the Peach and Apricot on the Plum, where extensive growth and durability are wanted, is wrong; but it is eligible wherever it is wished to diminish the vigour and growth of the tree, and where its durability is not thought important. The last remark applies chiefly to the *Moorpark* Apricot—the *Abricot-pêche*, or *Abricot de Nancy* of the French.

"When great difficulty occurs in making a tree, whether fructiferous or ornamental, of any species or variety, produce blossoms, or in making its blossoms set when produced, success, probably, will be obtained by budding or grafting upon a stock nearly enough allied to the graft to preserve it alive for a few years, but not permanently. The Pear tree affords a stock of this kind to the Apple, and I have obtained a heavy crop of Apples from a graft inserted in a tall Pear stock only twenty months previously, when every blossom of the same variety of fruit in the orchard was destroyed by frost. The fruit thus obtained was perfect externally, and possessed all its ordinary qualities; but the cores were black, and without a single seed; and every blossom, certainly, would have fallen abortively if it had been growing upon its native stock. The graft perished the winter following.

"My own experience induces me to think very highly of the excellence of the Apricot stock for the Peach or Nectarine; but whenever that or the Plum stock is employed, I am confident the bud cannot be inserted too near the ground if vigorous and durable trees are required.

"The form and habit which a Peach tree of any given variety is disposed to assume are very much influenced by the kind of stock on which it is budded. If upon a Plum or Apricot stock its stem will increase in size considerably as its base approaches the stock, and it will be much disposed to emit many lateral shoots, as always occurs in trees whose stems taper considerably upwards. Consequently, such a tree will be more disposed to spread itself horizontally than to ascend to the top of the wall, even when a single stem is suffered to stand perpendicularly. On the contrary, where a Peach is budded upon a stock of some cultivated variety of its own species, the stock and the budded stem remain very nearly of the same size at the point of junction as well as above and below. No obstacle is presented to the ascent or descent of the sap, which appears to arise more abundantly to the summit of the tree. It appears, also, to flow more freely into the slender branches which have been the bearing wood of preceding years; and these extend, consequently, very widely compared with the bulk of the stock and large branches.

"When a stock of the same species, with the graft or bud, but of a variety far less changed by cultivation, is employed, its effects are very nearly allied to those produced by a stock of another species or genus. The graft generally overgrows its stock; but the form and durability of the tree generally are less affected than by a stock of a different species or genus. Many gardeners entertain an opinion that the stock communicates a portion of its own power to bear cold without injury to the species or variety of fruit which is grafted upon it: but I have ample reason to believe that this opinion is wholly erroneous; and this kind of hardiness in the root alone never can be a quality of any value in a stock; for the branches of every species of tree are much more easily destroyed by frost than its roots.

"Many believe, also, that a Peach tree when grafted upon its native stock very soon perishes; but my experience does not further support this conclusion than that it proves seedling Peach trees, when growing in a very rich soil, to be greatly injured and often killed by the excessive use of the pruning-knife upon their branches when these are confined to too narrow limits. I think the stock in this instance can only act injuriously by supplying more nutriment than can be expended: for the root which Nature gives to each seedling plant must be well, if not best, calculated for its support; and the chief general conclusions which my experience has enabled me to draw safely are that a stock of a species or genus, different from that of the fruit to be grafted upon it, can be used rarely with advantage, unless where the object of the planter is to restrain and debilitate; and that where stocks of the same species with the bud or graft are used it will be found advantageous generally to select such as approximate in their habits and state of change, or improvement, from cultivation those of the variety of fruit which they are intended to support."—(*Trans. Hort. Soc. of London for* 1816.)

The only situation in which we can believe that the stock of another species can be advantageously employed is where the soil happens to be unfriendly to the species from which the bud or scion is taken. This is justified by our observing that in a garden so low-lying as to be very subject to an overflow of water, the only Pear trees which were at all productive were those grafted upon Quince stocks; and the Quince is well known to endure water much better than either the Apple or Pear.

The circumstances and phenomena attendant upon successful grafting are as follows. It is absolutely needful that the liber, or inner bark, and the alburnum, or sap wood, of the scion come in contact respectively with the liber and alburnum of the stock. It matters not whether the surfaces of the inner wood of the scion and the inner wood of the stock come in contact or not, for they never unite; and were it not that its wood enables the scion to retain its position firmly, that wood might be absent without any hindrance to the success of the grafting.

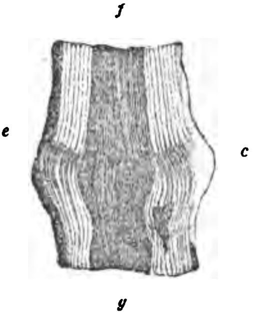
Grafting is nothing more than the healing of a wound in a tree; the lips of the wound, instead of re-uniting to each other, uniting to the lips of a wound made on part of another tree. It is a process that has been successfully practised in creatures of a higher order. The head of a Polypus has been made to unite to the decapitated body of another Polypus; the spur of a cock has been grafted upon the comb of another cock; and flaps of skin have been taken from the human body and made to unite with the skin of the face in establishing an artificial nose.

In all these operations similar phenomena occur—a granular adhesive secretion arises from the wound of the body grafted upon, and through this the circulatory vessels establish a union.

In the case of the graft of a tree, as shown in the annexed sketches, the alburnums and barks of the scions and stocks have united; but the inner woods are entirely separate. The first figure represents a Pear scion on a Pear stock the first year after grafting, split longitudinally down their centres. If the barks and alburnums had not united there would have been a line of separation at *a*, as markedly as is seen between the two woods. This drawing was made during December, 1859, from the section of a grafting effected in the spring of 1858. Even in that brief

period the stock had formed alburnum so as to fill up entirely various small spaces about the lower part of the scion.

In *Fig.* 2, a longitudinal section is shown of an Almond tree (*f*), cleft-grafted on a Plum tree (*g*), showing that the wood remains perfectly unchanged on each side of the line of junction (*e c*). This is a marvellous demonstration of the assimilating and secreting powers of the vessels of the inner bark. This bark of the Plum stock received the descending sap altered as it had been by the leaves of the Almond; above the line of junction is deposited Almond wood, but beneath that line, at a distance too minute to be appreciated, Plum wood is deposited!



We have said that the woods of the scion and graft never unite. If the graft and the stock are both small, of recent growth, their surfaces fit closely, and they have not been allowed to become at all dry, such union may take place, for the wood of the scion is in such case almost all alburnum; but under other circumstances the union of the inner woods does not occur. New wood in each succeeding year is deposited over the lines of separation, and growth goes on until scion and stock are of the same dimensions; but if at any period of their growth they are cut through transversely, the original spaces between the scion and stock will be found remaining.

In order to ascertain whether the new layer of wood is formed from the former layer of wood, or of bark, M. Du Hamel made a graft *par l'ecusson* (*Phys. des Arb.*, liv. iv., chap. 4); which is done by means of detaching a portion of bark from the trunk of a tree, and supplying its place exactly by means of a portion of bark detached from the trunk of another tree that shall contain a bud. In this way he grafted the Peach on a Plum tree, because the appearance of the wood which they respectively form is so very different, that it could easily be ascertained whether the new layer was produced from the stock or from the graft. Accordingly, at the end of four or five months after the time of grafting, the tree was cut down; and as the season of the flowing of the sap was past, a portion of the trunk, including the graft, was now boiled to make it part more easily with its bark; in the stripping off of which there was found to be formed under the graft a thin plate of the wood of the Peach, united to the Plum by its sides, but not by its inner surface, although it had been applied to the stock as closely as possible. Hence Du Hamel concluded that the new layer of wood is formed from the bark, and not from the wood of the preceding year. The same experiment was repeated with the same result upon the Willow and Poplar; when it was also found that if a portion of wood is left on the graft it dies, and the new wood formed by the bark is exterior to it.

The ascent of the sap, like the circulation of the blood, is increased in rapidity by an addition to the temperature in which the plant is vegetating; and when it is flowing from incisions made in a stem at various heights from the ground, a sudden reduction of temperature will cause a cessation of the flow from the upper wounds whilst it continues from those below.

These facts indicate most satisfactorily why the gardener finds his Vines, Peaches, and other plants in the forcing-houses injured by keeping them in a high temperature during the night. It is then, as in the animal economy, that the individual functions are renovated by a temporary repose, and if left to the dictates of healthy nature, the sap, like the blood, flows at night with a much diminished velocity.

If the night is cold, the ascending sap actually sinks back—a fact observed by Hales and Knight, and further established by the experiments of M. Biot. Thus showing that, as in most animals, it is the daily period of diminished circulation and of consequent rest. Hales found that a Sunflower which perspired 30 ozs. during a warm day, perspired only 3 ozs. during a warm, dry night.

In man the number of inspirations are diminished during sleep, in the ratio of six to seven when awake, and the pulsations in the ratio of three to four per minute. The temperature of the body is about 2° lower at midnight than early in the morning.

It is evident that in plants as well as in animals, light acts as a stimulant, and darkness, or the absence of light, acts as a sedative. Thus, it is known that the leaves of many plants assume a very different position in the night from what they have had in the day. These positions are not the same in the case of all leaves that are said to *sleep*. They differ with the species in which the change of position takes place. Simple leaves that sleep are affected in their totality. Compound leaves that sleep are not always affected in their totality, but only in some of their parts.

Of simple leaves some,—*the opposite*, meet by the bending in of their petioles, and sleep face to face, as in *Atriplex;* some,—*the alternate*, by the folding in of their edges, so as to embrace the stem, and cover the flower in their axil, as in the Mallows; and some by the bending down of the leaf-stalk, so as to cover the flowers below, as in *Impatiens.*

Of compound leaves, some are trefoils, and some winged, forming the ground of a primary division. Of trefoils, some bend their leafits so as to bring the base and summit nearly into contact, leaving a cradle-like cavity in the middle, which sometimes protects the flowers, as in *Trifolium incarnatum.* Some bend them by the lower half, and leave the summit divergent, as in the Melilots; and some bend them down so as to face by their inferior surfaces, as in *Oxalis.* Of winged leaves, some erect their leafits, so as to meet above the petiole, face to face, as in *Colutea.* Some bend them down so as to meet below the petiole by their under surfaces, as in *Acacia.* Some fold them up, above and along the common foot-stalk, so as to overlap one another, in a direction looking to the summit of the petiole, as in the genus *Mimosa*, in which there is this singularity, that while the leafits bend up, the main petiole bends down. Lastly, the leafits of *Tephroisa Caribœa* fold up and overlap like those of Mimosa, but in a direction looking to the base of the petiole. — (*De Candolle, Phyto. Veg.*, 857.)

No other evidence need be given that plants are benefited by exposure to a lower temperature at night than that to which they have been subjected by day, than the fact that wherever a plant grows naturally, there it is subjected to such daily alternations of temperature.

The following table exhibits the average day and night temperatures at a few places in each month of the twelve:—

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
London	40·3 31·4	44·6 33·7	48·1 35·3	55·4 39·4	64·1 46·5	68·4 49·8	71·5 53·8	71·2 53 9	65·7 48·7	57·1 43·5	47·2 36·5	42·7 33·9
Canton	57 45	58 45	71 60	76 69	78 73	84 79	88 84	86 83	84 79	76 70	68 61	63 52
Sadiza (Assam)	60·5 47·5	61 52·5	69 56	73·5 66·5	78·5 70	83·5 76·5	83·5 76	84 77	85 76	80 69·5	77 64·5	... ...
Mussooree (Himalaya)	51·5 34·5	63 27	69 37	77 41	78 41	74 61	71 63	69 63	69·5 57	66·5 48	57 48	55 29
Macao............	72 53	71 49	77 55	83 66	85 71	89 74	92 81	90 79	88 76	86 61	80 57	70 57
Madras	81·1 72·7	83·6 72·6	87·6 76·9	91·4 81·0	92·9 82·4	93·0 82·0	92·3 81·5	90·2 80·1	88·5 79·2	84·9 77·4	82·8 74·3	80·6 73·0
Dodabetta (Neilgherry Hills)	58 6 44·4	56·7 45·9	61·7 47·1	61·3 51·2	62·4 49·9	54·9 46·1	54·4 47·9	55·1 46·8	54·9 47·4	55·6 48·1	55·6 47·2	54·0 45·1

Such a table as this of the lowest and highest temperatures to which the plants of every country are subjected, would be one of the best guides for their culture that could be bestowed upon the gardener. Tables of average temperatures, jumbling together those of the day and the night, are worse than useless, for they often mislead. Who can tell from a general average of 60°, whether the day's highest is 80° and the night's lowest 40°; or 70° and 50°; or 65° and 55°? The best light we can throw upon such dark, uncertain tables, is to remind the gardener that the average night temperature of any place is usually from 10° to 20° lower than its average day temperature.

In addition to this we will add M. Boussingault's list of the maximum and minimum temperatures favourable to the particular vegetables in the success of which man is more especially interested.

Coco or Chocolate Bean	82 to 73	Pine Apple	82 to 68
Banana	— to 64	Melon	— to 67
Indigo	— to 71	Vanilla	— to 77
Sugar Cane	— to 71	Grape Vine	79 to 74
Cocoa nut	— to 78	Coffee	— to 66
Palm	— to 78	Wheat	74 to 59
Tobacco	— to 65	Barley	— to 57
Manihot (Tapioca)	— to 72	Potatoes	75(?) to 49
Cotton Tree	— to 67	Flax	74 to 59
Maize	— to 59	Apple	72 to 59
Haricots	— to 59	Oak	67 to 61
Rice	— to 75		

That plants do become exhausted by too unremitting excitement is proved to every gardener who has a Peach-house under his rule; for if the greatest care be not taken to ripen the wood by exposure to the air and light during the summer, no Peach tree will be fruitful if forced during a second successive winter, but will require a much more increased temperature than at first to excite it even to any advance in vegetation.

We have said that the night temperature usually averages from ten to twenty degrees lower than the day temperature. That there are exceptions we are quite aware, but they are extreme exceptions; and where these extremes prevail, the plants subject to them are peculiar and few in number.

For example: We may quote the summers within the arctic circle, when for a few weeks the sun never sets; yet even then a disparity of temperature exists. Thus, one example among many, we find under the date of June 30th, 1832, this entry in Sir J. Ross's "Journal of a Second Voyage to the Arctic Regions." "The sun had a great effect on the snow, and the aspect of the land was hourly changing. At noon the thermometer was at 47°, and at midnight at 32°." Again: July 9th—15th, he says, "The temperature rose once to 50°; but was at the freezing-point at night on most days."

There are, however, climates with temperatures having vast differences between those of their days and nights at the same season. Such a climate is Affghanistan, where, in March, Mr. Atkinson found at mid-day the weather was oppressively hot; yet "after midnight the servants made up a blazing fire, for the north wind blew bitterly cold." Let the gardener remember that that is the native country of the most delicious Grapes and Melons.

Next, for an illustration of widely differing day and night temperatures, let us turn to the climate of tropical Australia. Sir Thomas Mitchell, Surveyor-General of New South Wales, traversed the land for a twelvemonth, and an abstract of his memoranda will be found in the third volume of the "Journal of the London Horticultural Society." Those who cultivate New Holland plants, will do well to refer to the facts there recorded more fully than in the following epitome :—

"In the end of April (our October), in latitude 28° S., within 4½° of the Tropic, at an insignificant elevation, the thermometer stood at 26° at sunrise, and was as low as 43° at nine P.M.; nevertheless, the country produced wild Indigo, Mimosas, Casuarinas, arborescent Myrtleblooms, and Loranths. A degree nearer the Tropic in May (our November), the thermometer at sunrise marked 20°, 19°, 18°, 17°, 16°, 12°, and on two separate days even 11°! On the 22nd May, the river was frozen, and yet herbage was luxuriant, and the country produced Mimosas, Eucalypti, Acacias, the tropical Bottle-tree (*Delabechea*), a Calandrinia, and even a Loranth. On the 23rd of May, the thermometer at sunrise marking 12°, *Acacia conferta* was coming into flower, and Eucalypti, with the usual Australian vegetation, were abundant. On the 30th of May, at the elevation of 1118 feet, the almost tropical Delabechea was found growing, with the temperature at sunrise 22°, and at nine P.M. 31°, so that it must have been exposed to a night's frost gradually increasing through 12°. And this was evidently the rule during the months of May, June, and July (our November, December, and January); in latitude 26° S., among Tristanias, Phebaliums, Zamias, Hoveas, Myoporums, and Acacias, the evening temperature was observed to be 29°, 22°, 37°, 29°, 25°, falling during the night to 26°, 21°, 12°, 14°, 20°; in latitude 25° S., the tents were frozen into boards at the elevation of 1421 feet; the thermometer, July 5, sunk during the night from 38° to 16°, and there grew Cryptandras, Acacias, Bursarias, Boronias, Stenochiles, and the like. *Cymbidium canaliculatum*, the only orchidaceous epiphyte observed, was in flower under a night temperature of 33° and 34°; that by day not exceeding 86°. These facts throw quite a new light upon the nature of Australian vegetation.

" It may be supposed that so low a temperature must have been accompanied by extreme dryness, and such appears to have been usually the case. Nevertheless, it cannot have been always so; for although we have no hygrometrical observations for June and July, and only four for May, yet there is other evidence to show that the dryness cannot always have been remarkable. In May the hygrometer indicated ·764, ·703, ·934, or nearly saturation, and ·596; yet the sunrise temperature was on those occasions 25°, 28°, 30°, and 34°. On the 22nd of May, the grass was white with hoar frost, and then the thermometer was, at sunrise, 20° under canvas, and 12° in the open air; and on the 5th of July, when it rained all day and the tents were 'frozen into boards,' the thermometer sank during the night from 38° to 16°.

" It is probable that this power of resisting cold is connected with the very high temperature to which Australian vegetation is exposed at certain seasons, and this is horticulturally a most important consideration. We find that in latitude 32° S., in January (our July), the thermometer stood eight days successively above 100°, and even reached 115° at noon; that it was even as high as 112° at four P.M.; that in the latter part of February, one degree nearer the line, it was twice 105°, and once 110°; that in March, one degree further northward, it frequently exceeded 100°, and there was not much fall in this excessive temperature up to the end of April. This will be more evident from the following

TABLE OF NOON-DAY TEMPERATURES.

Lat.	Date.	Average Temperature.				Maximum	Minimum
deg.					deg.	deg.	deg.
29 S.	Nov., Dec.	Average of 3 Observ.			102	103	62
32 S.	Jan., Feb.	,,	18	,, .	97¼	115	73
31 S.	Feb., March	,,	17	,, .	90	110	80
30 S.	March . .	,,	20	,, .	95	105	84

"At this time the dryness was also excessive. Even such heats as these do not, however, destroy the power of vegetation, for we find in the midst of them all sorts of trees in blossom, a few bulbs, and even here and there (in damp places, no doubt), such soft herbs as Goodenias, Trichiniums, Helichrysum, Didiscus, Teucrium, Justicia, herbaceous Jasmines, Tobacco, and Amaranths.

"During these heats the night temperature seldom remains high. Sometimes, indeed, the thermometer was observed as much as 88°, and once even 97° at sunrise, the average noon heat of the month being 97½°, but generally the temperature is lower. Thus:—

				Temperature occasionally at Sunrise.
Nov. and Dec. .	averaging	102 °	at noon .	62°, 58°, 61°.
Jan. and Feb. .	,,	97¼°	,, .	61°, 60°, 59°, 47°, &c.
Feb. and March .	,,	90 °	,, .	61°, 59°, 54°, 48°, &c.
March .	,,	95 °	,, .	68°, 55°, 51°, 47°, &c."

Intimately connected with the salutary alternations of day and night temperature, is the proper maturing of the shoots and other permanent growth of plants during the year.

Mr. Barnes, one of the best practical gardeners of the day, has very justly observed that there is more judgment required in thoroughly ripening the wood of forced fruit trees than in ripening their fruit. It is too generally an error to think that when the fruit is off no further trouble is required; that the wood has got to be hardened,—and that no other care is necessary until the times for pruning, forcing, &c., come round. This is a mistake fraught with failure. When the fruit is off, the whole vegetative power of the tree is employed, until the leaves begin to fall, in imbibing and elaborating the sap which is to be the source from whence next year's growth and produce are to arise. The hurry some gardeners are in to expose the forced trees to the full influence of the air, and allowing them to remain without the shelter of glass at night, after the arrival of frosts, are all errors, sources of injury and loss. A far more judicious plan is to promote the lengthened vigorous vegetation of the trees, by sheltering them during inclement weather; by not reducing the temperature of the house suddenly; by giving liquid manure occasionally, and never allowing the trees to be subjected to a freezing temperature. It will be found, generally, that the forced tree that is kept longest vegetating healthily after its fruit is gathered will be the most vigorous next season.

The experiments of Harting and Munter upon Vines grown in the open air, and those of Dr. Lindley upon Vines in a hothouse, coincide in testifying that this tree grows most during the less light and cooler hours of the twenty-four. But the hours of total darkness were the period when the Vine grew slowest. This, observes Dr. Lindley, seems to show the danger of employing a high night temperature, which forces such plants into growing fast at a time when Nature bids them repose.

That the elevation of temperature at night does hurtfully excite plants is proved by the fact, that the branch of a Vine kept at that period of the day in a temperature not higher than 50°, inhales from one-sixteenth to one-tenth less oxygen than a similar branch of the same Vine during the same night in a temperature of 75°. The exhalation of moisture and carbonic acid is proportionably increased by the higher temperature.

The evidence of the Vine's growth being most rapid during the hours of diminished light, but not of entire darkness, is curiously coincident with the observation of Moses, that, though fruit is brought forth by the sun, yet that the plant itself is put forth by the moon (*Deut.* xxxiii. 14).

It must not be supposed, however, by the gardener that all plants make their greatest growths uniformly at the same period of the twenty-four hours, nor even that the same individual grows most every day during the same hours. So far is this from being the fact, and so irregular is every plant in the amount and period of its daily extension, that we think Dr. Lindley was quite right when he thus summed up his report of a series of experiments made in the Chiswick Garden:—"It does not appear satisfactorily that the varying rates of elongation are, under the circumstances of the experiments now detailed, dependent, to any considerable extent, upon fluctuations of temperature, light, or moisture. On the contrary, it seems almost certain that some other powerful agent is in operation, the nature of which we have, at present, no means of ascertaining."—(*Horticultural Society's Trans.*, 2nd Series, iii., 113.)

The following table gives the epitome of the results of those experiments. The amount of growth merely gives the increase in length in inches and decimal parts of inches :—

	In a curvilinear-roofed Stove. Temperature during the day 73°; during the night 65°.				In the open air before a vinery in a sheltered situation.		
	6 A.M. to noon	Noon to 6 P.M.	6 P.M. to 12 P.M.	12 P.M. to 6 A.M.	Morning.	After-noon.	Night.
Willow	11·13	10·42	9·71	9·37	4·81	5·13	3·77
Fig	4·88	5·04	5·23	4·37	3·16	2·12	1·63
Vine	17·24	17·21	16·02	18·13	2·04	2·16	2·34
Passion-Flower	13·41	22·24	18·20	18·00			
The period over which these experiments extended was from the 1st of March to the 14th of August, 1843.					The period over which these experiments extended was the month of July, 1844.		

The sap, after ascending the stem, and being distributed along the various branches, is poured by their vessels into their leaves and there undergoes that elaboration, the phenomena of which have been already described. The sap vessels are ramified from the wood of the branches along the upper side of the leafstalks, are minutely subdivided so as to form a web resembling lace work on their superior surfaces, and unite at the edge of the leaf with equally minute vessels, forming a similar web on their lower surfaces. These fall into larger vessels, which return the sap along the under side of the leafstalks, into vessels traversing the inner bark of the branches, stem, and roots, and the sap is found to be converted, during its elaboration in the leaves, into the peculiar juices of the plant. The limpid insipid sap has been converted into the austere Gallic acid and tannin of the Oak; the acrid perfumed oil of the Lemon; the insipid gum of the Cherry; the starchy matter of the Potato, and the pungent resin of the Pine tribe.

In its descent in trees and shrubs it deposits between the bark and the wood that juice, known as *cambium*, from part of which the year's increase or enlarged growth is obtained, and the remainder is deposited ready to be communicated to the sap during its course the following spring, as it may be required for the development of the next year's foliage, flowers, and fruit. This abundant deposition of cambium is what the gardener terms "ripening the wood." In the Potato, Dahlia, and other tuberous-rooted plants, the deposition is in the tuber; it is in the bulbs of the Onion and Tulip, and in the fibrous roots of the Ranunculus and grasses.

A knowledge of these facts suggested to the gardener that if the return of the sap were checked by a ligature so tight as to compress the vessels of the bark, the fruit above the ligature would be rendered finer and more abundant. Practice has shown that this is the desired result; and it may be taken as a rule, that whatever mechanical means checks the downward flow of the sap, causes the enlargement of buds or the production of new. If it be practised upon the Artichoke, a ligature being twisted round the stem, about three inches below the head, its size will be very much increased. If a similar ligature be passed round the branch of a fruit tree just previously to the bursting of its buds in the spring, the fruit on that branch will set more abundantly and be of finer growth. When the fruit is beginning to ripen, the ligature should be removed, that the reflux of the sap to the inferior parts may be less impeded, and the growth of those parts be, consequently, less checked. The power to do this renders a ligature much superior to another mode of producing the same effect, first introduced in Germany—viz., by removing an entire zone of bark, about an inch wide round the branch to be rendered more fruitful, and taking care that the bark be completely removed down to the very wood. This was designated the *ring of Pomona*, but it certainly was not auspiciously received by that deity, for although it renders the part of the branch superior to the wound more fruitful for two or three seasons, yet it renders the branch unsightly, by the swelling which occurs around the upper lip of the wound, and is often followed by disease and unfruitfulness.

No such injury accrues when ringing is performed on the lateral shoots of the Vine, which laterals are removed at the autumn pruning.

There must be a ring of bark full an inch wide removed; the cuts being made boldly down to the very young wood, or alburnum, and every particle of bark, inner and outer, must be removed between the cuts.

This drawing represents, faithfully, the ringed part of a rod at the close of autumn, and shows how the removal of the band of bark checked the return of the sap, and how, in consequence, the rod above the removed band increased in size beyond that portion of the rod below the band.

The increase of size is not confined to the bark. We have a Vine-branch in our possession, the wood of which above the ring doubles in diameter the wood below the ring.

The effect upon the berries was, in every instance, to advance their early ripening a fortnight, and to about double the size and weight of the berries, when compared with those grown on unringed branches of the same Vine. Nor were the colour and bloom of the berries diminished; indeed, so excellent were they, that we have seen them exhibited deservedly by the side of Grapes grown under glass, and they were sold in November, at Winchester, for 2*s*. 6*d*. a-pound.

Ringing the branches of fruit trees, to render them fruitful, was practised in France, and recommended there in print, about one century and a half since. There are various letters upon the subject in the early volumes of the Horticultural Society's Transactions, and in one of them (*Vol. I.*, p. 107), published in 1808, Mr. Williams, of Pitmaston, gives full directions for ringing the Grape Vine. He tells the result in these words:—"I invariably found that the fruit not only ripened earlier, but that the berries were considerably larger than usual, and more highly flavoured."

The improvement in fruit obtained by ringing is not confined to the Grape Vine, nor merely to an increase of size. Josiah Twamley, Esq., of Warwick, exhibited to the London Horticultural Society, many years since (1818), Apples from trees in his garden, produced on branches ringed and unringed. In the *French Crab* the fruit by ringing was increased to more than double the size, and its colour was much brightened. In the *Minchall Crab* the size was not increased, but the appearance of the Apple was so improved as to make it truly beautiful; its colours, both red and yellow, were very bright. In the *Court-pendu* the improvement was still more conspicuous, the colours being changed from green and dull red, to brilliant yellow and scarlet (*Hort. Soc. Trans.* iii. 367). The benefits conferred upon Pears by ringing are still more striking; but to all stone fruit and Figs it seems to be injurious; and this arises, probably, from the bleeding which occurs from the wound.

When adopted, as above, for accelerating the maturity of the fruit, to increase its size, and to improve its flavour, the process is called *Maturation ringing;* but when adopted to induce the formation of flowers, it is termed *Production ringing.* This shows its effect in the year next after that in which it was performed; but Maturation ringing during the same season. Production ringing may be practised at any time while the trees are without their leaves, but maturation ringing should be deferred until the flowers are fully expanded, or, rather, until they are passing into fruit, or even until the fruit is set.—(*Ibid.* iv., 557.)

That production ringing is influential has often been proved. Mr. W. Baxter, when gardener to the late Countess de Vandes, had a *Waratah* Camellia which he had never been able to flower. He cut a ring round the stem, so close to the root that he could cover the wound with the earth in the pot. The ring closed at the end of the year; abundant flower-buds formed, which expanded into blossom perfectly in the following spring. The branch of an *Aubletia Tibourbon* similarly ringed, was the only one which produced blossoms; and a similar result occurred to a branch of *Pyrus spectabilis.*—(*Ibid.*, iv., 128.) So certain is this ringing to cause the production of blossom-buds, that it is often employed to hasten such a production in young fruit trees.

Mr. Knight thus explained the mode in which ringing operates. Whatever portion of the descending sap is not expended in the growth of the plant sinks into the alburnum and joins the ascending current, to which it communicates powers not possessed by the recently absorbed fluid. When the course of the descending current is intercepted, that necessarily stagnates and accumulates about the decorticated part, whence it passes into the alburnum, is carried upwards and expended in an increased production of blossom and fruit. Consistently with this theory, Mr. Knight found that part of the alburnum situated above the disbarked space exceeded in specific gravity very considerably that lying below the space.—(*Ibid.*, iv., 159.)

If the branch of a tree be cut off; or if an incision be made so as to remove entirely, not only a section of its bark, but also the alburnum of the wood beneath it, one bud or more, if the tree be vigorous, often will be put forth below the incision. Lateral vessels are formed from the alburnum, communicating with the bud; and having a similar return-communication with those of the bark, it speedily enlarges into a perfect branch, with its necessary leafy organs. If instead of leaving the portion of the branch above the incision exposed to the air, it be covered with moist earth, which is easily effected by the aid of a layering-pot, roots will be protruded from the lips of the wound; and as these are furnished, like the bud produced from below, with vessels from the alburnum and bark, it is evident that such plant has the power of producing branches or roots accordingly as the medium, air or earth, renders the production appropriate. This may be proved in two ways; for if a Gooseberry bush be trimmed, and then its head be buried in the earth with the roots exposed to the air, these will put forth leaves whilst the branches will emit roots. On the other hand, if a root be induced by the layering-pot in the mode mentioned, and, subsequently, it is gradually introduced to the air, by removing the soil and filling the pot with moist moss, and then by removing the moss and giving only moisture, it may eventually be left exposed, and will put forth leaves. The experiment will succeed with the Codlin, and, probably, with the Joanneting Apple.

Buds contain the rudiments of a plant, and it very early suggested itself to the gardener that they might be employed advantageously as a means of propagation; and budding has now become the most prevalent mode. In performing the operation, as the nourishment has to be afforded to the bud from the alburnum of the stock with which it is brought in contact, this should not be exposed to the air for one minute longer than is necessary to insert the previously prepared bud, for if the surface of the alburnum becomes dry in the slightest degree, vegetation on that part is permanently destroyed. The alburnum of the stock only supplies sap, which is elaborated in the bud and its developed leaves; and through its bark is returned the peculiar juice from whence the woody matter is formed that unites it to the stock. A confused line marks the point of union; but all the deposit of wood is between that line and the bud, and is always the same in character as the tree from which the bud is taken.

A bud, with almost the solitary exception of that of the Walnut, succeeds best when inserted on a shoot of the same year's growth, and apparently for the reason that the sap and juice it yields are most nearly of the same state of elaboration as they were in the parent of the bud; and because, as in the animal frame, repair of injury, the healing of wounds, is always advanced most favourably by the vital energy of youth.

"There are," says Mr. Knight, "at the base of the annual shoots of the Walnut and other trees, where those join the year-old wood, many minute buds, which are almost concealed in the bark; and which rarely, or never vegetate, but in the event of the destruction of the large prominent buds which occupy the middle and opposite end of the annual wood. By inserting in each stock one of these minute buds, and one of the large and prominent kind, I had the pleasure to find that the minute buds took freely, whilst the large all failed without a single exception. This experiment was repeated in the summer of 1815 upon two yearling stocks which grew in pots, and had been placed during the spring and early part of the summer in a shady situation under a north wall; whence they were moved late in July to a forcing-house, which I devote to experiments, and instantly budded. These being suffered to remain in the house during the following summer, produced from the small buds shoots nearly three feet long, terminating in large and perfect female blossoms, which necessarily proved abortive, as no male blossoms were procurable at the early period in which the female blossoms appeared; but the early formation of such blossoms sufficiently proves that the habits of a bearing branch of the Walnut tree may be transferred to a young tree by budding, as well as grafting by approach.

"The most eligible situation for the insertion of buds of this species of tree (and probably of others of similar habits), is near the summit of the wood of the preceding year, and, of course, very near the base of the annual shoot; and if buds of the small kind above mentioned be skilfully inserted in such parts of branches of rapid growth, they will be found to succeed with nearly as much certainty as those of other fruit trees, provided such buds be in a more mature state than those of the stocks into which they are inserted."—(*Knight's Horticultural Papers.*)

The more mature any part of a plant, the less easy is it excitable; a branch from which the leaves have fallen in autumn, requires a higher temperature to induce vegetation than does a similar branch in the spring. So is it with a bud; and, as was suggested by Mr. Knight, it appears to be occasioned by those parts having passed into a state of repose; a decreased degree of vital energy occurring preparatory to their winter sleep. Let no man scoff at the idea of this vital energy continuing in a bud after a separation from the parent, for even the head of a polypus may be cut off and grafted, without injury, upon the decapitated body of another. The mature bud is, consequently, always inserted with more success in a stock, the buds of which are less mature; for it does not commence vegetating until the supply of sap is abundant, nor until the union between the bark and alburnum has had time to be completed. When Mr. Knight reversed this comparative state of the stock and the bud, by inserting immature buds from a wall Peach upon Peach trees in a forcing-house which had nearly completed their growth for the season, the buds broke soon after their insertion, and necessarily perished for want of sufficient nourishment.

In performing the operation of budding, we have the following directions from Mr. Errington:—

"Expedition is the principal thing, and this of course presupposes some dexterity and expertness. In summer budding, the cutting or shoot from whence the buds or scions are taken is not cut from the parent tree until the moment the operation is about to commence. The best way is, to provide a pan or can with some water in it. The moment the young shoot which is to produce the scions is removed from the parent, let all the leaves be cut off, leaving the petioles, or footstalks, of the leaves to handle the buds by. The ends of the young shoots may then be stuck on end in the water, taking care, of course, to number or name them, if accuracy of this kind be requisite. All being thus in readiness, and the operator having a bundle of long bright, and strong bast hanging by his side, and a finely whetted budding-knife (or a relay of them where much business has to be done), in his hand, operations may commence. We will suppose what may be termed a nurseryman's case—viz., a young Plum, Apricot, or Peach stock—that is to say, in their phraseology, the Brussels stock for the Plum, the commoner stock for the Apricot, and the muscle stock for the Peach. Such stocks are generally about a couple of feet in height, and they are mostly budded about a foot from the ground. The operator generally turns his back to the stock, for such stocks are generally branched a little, and by backing up to them, the axillary branches are forced right and left out of the way of the operator by means of his legs. Well, he then takes a scion out of his waterpot, and generally commences at the lower end of it. With a clean cut he takes out a bud, now called 'a shield,' for it is necessary to cut nearly an inch above the bud, and the same below it: and with this shield a slight portion of the woody part of the stem is taken. Now, with railway speed, the wood must be extracted: this is readily done with the finger and thumb of the right hand, and one caution is here necessary. If a hole appears at the back of the bud, on the shield, it must be rejected as worthless; it is a sign that the shoot is not sufficiently mature, and that the bud was not properly organised, or that it has been drawn out in extracting the piece of wood, or rather alburnous matter. The bud being right, a slit must be made across the stock at the very point where the bud must be inserted. This slit runs across, and with the assistance of another below it, and running perpendicularly into the centre of it, must form a figure like the capital letter T. The haft of the budding-knife must now be applied to the sides of the incision, and by a gentle pressure up and down, the bark will be found to become readily detached from the wood. Taking hold of the leafstalk of the bud, or shield, the operator now slips it in beneath the raised bark of the incision in the stock, and when this is done, a compact

and close tying of bast, from the bottom of the shield to the top, completes the process. All this, though apparently tedious in the detail, is merely the work of a minute, or, at most, a couple of minutes, to an expert and well-practised operator. We, however, can do no more than state the details of the process, and the mode of carrying it out: expertness must be acquired by some practice in this as in most other matters. All we can say in addition is, that unless each bud is quickly inserted after being extracted from the parent shoot, success becomes very doubtful, especially if the atmosphere is dry and the sun shines brightly. We would advise that any side of the stock be selected but that directly south. The sun has a powerful action in the neighbourhood of the bud when in this situation ; and such is, therefore, to be avoided, although we are aware many old practitioners in the nurseries do not pay any heed to such distinctions. The reason is, that their mode of conducting the operation is so expert, and so much expedition is exercised, that the bud scarcely suffers at all in its transit; it therefore succeeds in nine cases out of ten.

"We would advise particular attention to the following points, whatever the kind of tree may be, or whatever the height or position may be at which it is budded.

"1st.—That the tree be in a state of high elaboration—that is to say, great part of the foliage thoroughly developed, and the growing or extending principle rather on the wane. This will, in general, take place between the second week of July and the second week in August, in most parts of Britain.

"2nd.—That a lively course of root action be secured, by having recourse in seasons of drought to copious watering a day previous to budding.

"3rd.—To reject all buds that appear torn out or otherwise injured: this is indicated by the hollow before named.

"4th.—To avoid any extreme of mutilation or pruning back, at the period of budding; we have seen Roses reduced to a mere stump for convenience' sake: such cannot be successful.

"5th.—To avoid too tight ligatures; the bast must be quite close, but not tight. It should be understood that the bud does not form the union by means of pressure alone; the bast acts beneficially also by shading the bark of the shield, or bud, thereby preventing excessive perspiration.

"Those who have a variety of fruits to bud should take them according to the order in which the wood becomes perfect: thus, Cherries may stand first, Apricots second, Plums and Pears third, and Peaches and Nectarines fourth. The only after care, is to water occasionally during the first fortnight, if the weather is very dry, and to remove the bandages in due time. This may, in general, be safely done within a month, and the best criterion of the success of the bud is the dropping off of the footstalk. If the bud is taking well, this will fall away in a week or two; but if the footstalk shrivels up, it is a bad sign. The portion of the stock below the bud should, in all cases, be kept clear from useless spray. In cases where it is necessary to reserve such shoots, it will suffice to pinch off their growing-points."

There are some other curious facts connected with buds, and of which the gardener takes advantage. Foremost among these is the power of some buds to produce stems and roots from their base at the same time. By this mode the Grape Vine and Hollyhock are propagated. Their power to do this depends upon the albumous matter they contain, and, consequently, the strength of the plants thus produced depends upon what the gardener calls the well-ripened state of the wood on which the bud, or eye, grows. "I found," said Mr. Knight, "a very few grains of alburnum to be sufficient to support a bud of the Vine, and to occasion the formation of minute leaves and roots; but the early growth of such plants was extremely slender and feeble, as if they had sprung from small seeds; and the buds of the same plant, wholly detached from the alburnum, were incapable of retaining life. The quantity of alburnum being increased, the growth of the buds increased in the same proportion."—(*Hort Soc. Trans.*, ii., 115.)

The only other curious fact we shall here notice, relates to what is known as the production of *adventitious buds*.

There exists, says Mr. Beaton, great difference of opinion respecting the true origin of that anomalous production—the purple Laburnum, *Cytisus Adami*. Some believe it to be a cross-bred plant between the common Laburnum and the purple Cytisus; while others as firmly assert that it must be the result of artificial treatment, although the facts respecting the process have escaped notice. The question is, therefore, still at issue. Mr. Adam, in whose nursery, near Vitry, in France, it was originated about the year 1825, believed it to have issued from a blind bud of the purple Cytisus inserted in the Laburnum as a stock in the common way, as related in the Annals of the Horticultural Society of Paris in 1830 by M. Poiteau. A deputation from the Society was sent, after Mr. Adam's death, to ascertain if the original plant was really a seedling or a budded plant. But the evidence of this deputation was contrary to that of Mr. Adam's, and in favour of the cross-seedling side of the question.

Dr. Herbert suggested a very ingenious and probable hypothesis to account for the possible origin of this tree, which can easily be reconciled with the statement given by Mr. Adam, already referred to. Dr. Herbert believed that the shield of the purple Cytisus bud might be still alive after the bud itself was destroyed, and that this live portion might unite with the Laburnum stock in the absence of a bud; and that the new wood or cellular matter, which formed over the wound, between the shield and the stock, might produce an incipient bud, in the absence of a leading bud; and if the new bud were from an intermixed matter formed by the two plants, it could hardly fail of partaking of the two natures—that is, of the Laburnum stock and the purple Cytisus bud, which, in reality, it does; and the question is, How are we to proceed in order to obtain similar productions between other allied plants? for we must still adhere to the fact that species can only mix by pollen, or by this kind of union, when they are nearly related to each other. If it is possible to force a bud from two wounds in union with each other, and partaking of the natures of two different species thus brought together, there can be no doubt about our being able to push this process farther than can be done by means of strange pollen in the usual way; and we think it can be done, for we perfectly concur in Dr. Herbert's view of the question. The well-known fact, that two natures in the purple Laburnum aspire to separate themselves from the union, and assume their original character, cannot be accounted for on any other principle.

The means which Dr. Herbert suggested for effecting intermediate forms were to bud in the usual way, and when the union took place to kill the bud, and to prevent the edges from uniting by lacerating the bark till a quantity of cellular matter was formed, from which a bud might be expected to issue, if the growth of the tree were checked in other parts. It is impossible, however, to succeed simply by this process. The question involves the true origin of latent or incipient buds—a question that has never been satisfactorily answered by any one.

Mr. Beaton asserted, many years since, in the "Gardeners' Magazine," that if you cut out the buds from a yearling shoot, leaving only the top bud to carry on the branch, the part of the branch thus disbudded was incapable of producing a latent bud afterwards by any kind of manipulation. This assertion was much disputed by some in private correspondence, when Dr. Herbert opened the question in reference to the origin of the purple Laburnum. A new set of experiments were, therefore, set on foot, to prove if Dr. Herbert's suggestion could or could not be effected; these experiments were begun in 1841, and carried on till the end of 1847. The most conclusive of these experiments we shall briefly relate, as the result is, probably, the only stumblingblock in the way of clearing up the mystery which hangs over the origin of the purple Laburnum.

Truncheons of the common Willow are proverbial for the ease with which they root and produce shoots from all parts of their surface when planted or stuck into the ground. The Willow was, therefore, fixed on as the most likely plant to produce incipient buds. In the spring of 1841 cuttings were made from the stongest Willow shoots that could be procured of the former year's growth. They were two feet long, and all the eyes or buds were carefully cut out, except the three top ones, and they were planted in the usual way in rich kitchen-garden soil. In 1843, when these had made two years' growth, some of them were cut below the growing branches, leaving only a bare stump. Now, we should naturally suppose that a Willow shoot of full three years' growth, and with abundance of roots, in good soil, would not refuse to shoot forth buds and twigs from all parts of the bark. Not so, however; for they died away inch by inch, roots and all, without ever offering to produce a single leaf. In 1844, another lot of the same batch were cut, and they died in the same way. After this, the bark of others was lacerated in all directions, to see if buds would issue from the new-formed wood over these wounds, but all to no purpose; and the last two were cut in the spring of 1847, when they were much stouter than a walking-stick, and they died also. Now, these Willow-shoots, although united to other Willows by inarching or budding, could hardly be capable of producing a union-bud—as we suppose the purple Cytisus and Laburnum to have done—seeing that they could not do so on their own roots; at any rate the inference is rational enough, and can hardly be controverted. How then, it may be asked, can you suppose the shield of a bud of the purple Cytisus could be capable of taking a part with the Laburnum stock to produce the purple Laburnum? We answer—simply, by surmising that the said bud was taken from a two or three-year-old shoot of the purple Cytisus, which is not at all unlikely, seeing how thin the bark of a younger Cytisus shoot is. Another inference in favour of this view of the question is, that in France they have always been in the habit of leaving more of the young wood attached to the buds in their nursery operations than is generally done in England; and all of us know, that if a bud on a two or three-year-old shoot is destroyed, a quantity of incipient buds will immediately issue from the surrounding parts. The close-spurring of the Grape Vine is founded on a knowledge of this fact or principle. Therefore, we can see no reason why two shoots of mature age, to form incipent buds, may not be made to produce a union-bud, if the parts are at first properly arranged; and we think we can see why union-buds are not produced in our nurseries when the more natural bud fails, leaving the shield alive and in union with the stock. Our invariable practice is to take the buds from one-year-old shoots; and we have seen, by the experiment with the Willow, that if buds on one-year-old shoots are destroyed, the shoots are not able to furnish others; besides, it may require more than a season or two to ripen the young wood over wounds sufficiently to produce buds; and leaving a portion of the young wood attached to the bud, may have something to do with the time required.

Whatever promotes an over-luxuriant production of leaf-buds proportionately diminishes the production of flower-buds, and the reason is obvious. A luxuriant foliage is ever attendant upon an over-abundant supply of moist nourishment to the roots, the consequent amount of sap generated is large, requiring a proportionately increased surface of leaf for its elaboration, and for the transpiration of the superfluous moisture; and as the bud becomes a branch or a root accordingly as circumstances require, so does it produce, as may be necessary for the plant's health, either leaves or flowers. This is ascertained by the universal fact that a tree or shrub, if headed down, throws out leaf-producing buds only, but never flower-buds; the former are required for the plant's existence, but the latter are only needful for the propagation of its species. A cloud of other testimonies might be produced, showing the alteration of vegetable form to accommodate the individual to altered circumstances. Place some aquatic plants in a running stream, the Water Cress, for instance, and its submerged leaves will be very small, thus giving the stream less power to force them from their rooted hold; but plant them in still water, and the leaves are uniform in size. Mountain plants have, for a similar reason, the smallest foliage near their summits, thus giving less hold to the boisterous winds which sweep over them. Nor is this contrary to reason, as some persons would have us believe; for the petals, and even the minutest parts of every flower, are only different forms of the same alburnum, parenchyma, and bark, which take another shape in the leaf. And it is only one other instance of that power of adaptation to circumstances so wisely given by God to all organised beings, which makes the wool of the sheep become scanty hair in tropical temperatures, and the brown fur of our hare become white amid the snows of the arctic regions. In the case of plants, it is familiar to every gardener; and he knows, that by differing modes of treatment, he can make, according to his pleasure, his plants produce an exuberance of leaves or of flowers, and a well-known instance is the *Solandra grandiflora.* This native of Jamaica had for many years been cultivated in our hot-houses, had been propagated by cuttings, and each plant put forth annually shoots of surpassing luxuriance; but no flower had ever been produced. Accidentally one plant was left for a season in the dry stove at Kew, and this plant had only a moderately luxuriant foliage, but a flower was produced at the extremity of every shoot. It now blooms every season in our stoves, a drier and less fertilising course of treatment being adopted.

The circumstances of soil and climate and cultivation effect changes in plants sufficiently permanent to render it very difficult to define the difference between a variety and a species. These changes are not produced in one member of a plant, but in all. A root not remarkably fibrous when growing in the earth, becomes in water so multitudinously fibrous as to be called "a Fox-tail Root." In the water nourishment is more diffused than in soil, and the root-surface for its absorption requires to be proportionately enlarged.

The *Phleum pratense*, or Meadow Cat's-tail, and *Alopecurus geniculatus*, or Kneed Fox-tail Grasses, delight in moist-soiled localities, and in these their roots are always fibrous; but when grown in a dry soil they as uniformly become bulbous-rooted. Bulbous-roots are adapted to endure excessive droughts, being reservoirs of moisture.

In the alpine plants, Burnet, Saxifrage, Coriander, and Anise, the lower leaves are entire, whilst the upper leaves are divided, thus offering a less hold for the winds which sweep over them. In some aquatic plants, especially *Ranunculus aquatilis*, the lower immersed leaves are capillary, offering little surface to the stream, whilst the upper leaves are flat and circular, being the form best suited for floating on its surface. What is still more remarkable, as is observed by MM. De Candolle and Sprengel, the blossoms of *Juncus subverticillatus* when it remains as *Juncus fluitans* constantly under water are transformed into long stem-leaves.

Then, again, as remarked by Mr. Keith, some plants which are annuals in a cold climate, such as Sweden, become perennials in a hot climate, like that of the West Indies. This has been exemplified in *Tropæolum* and *Malva arborica.* On the other hand, some plants which are perennials in hot climates, are reduced to annuals when transplanted into a cold region, examples being offered in Mignonette, *Mirabilis* and *Ricinus.*

All these results, and many more which might be quoted, are no more than illustrations of that power so often bestowed upon vegetables and animals to adapt themselves to circumstances. That power is always for the purpose of preserving the health, or safety, or propagation, of the individual on which it is bestowed; but it effects changes of form and development which increase the difficulty of distinguishing species from varieties.

Those who ridicule the idea of the leaf, the flower, and the fruit being only different developments of the same parts, which take different forms as the necessities of the plant render them desirable, surely forget that the leaf naturally takes such varying shapes, as in many instances to have more the appearance of fruit than of that usually assumed by foliage. Of this number are many of our fleshy-leaved plants; and the tubular vessel at the extremity of the leaf of the *Nepenthes distillatoria.* In the calyx of the Strawberry Spinach (*Blitum*), and in that of the Mulberry, the transformation is still more complete; for here it actually changes colour when the flowering is over, becoming the edible part of the fruit, and enclosing the seed like a genuine berry.

The difference of colour usually existing between leaves and petals is a very unsubstantial distinction. Many flowers are altogether green; many leaves are brilliantly coloured, as those of Melampyrum, Amaranthus, Begonia, &c. Then, again, green leaves become yellow, red, and brown, in autumn; and M. Macaire has shown, that the chromule, or colouring matter of leaves and flowers is identical, being only more oxygenised in the latter; and we incline to the opinion that the variegated colour in leaves also arises chiefly from those coloured parts being more highly oxygenised.

There are circumstances—there are certain degrees of nourishment, of heat, and of light, though our knowledge is too limited to assign them with arithmetical precision, which have a tendency to promote the development of some vegetable organs rather than others. Accordingly, as those circumstances prevail, we find the pistils increased in number at the expense of the stamens, as was observed by Mr. Brown in the case of the Wallflower, and in the *Magnolia fuscata;* and by M. Rœper, in the *Campanula rapunculoides;* or the pistils changed into stamens, as was noticed by the same botanist in *Euphorbia palustris* and *Gentiana campestris;* so the petals have been observed converted to calyx in the *Ranunculus abortivus*, and the calyx into petals in *Primula calycanthema;* petals changed to stamens in the Black Currant, and in *Capsella bursa pastoris;* and stamens as well as pistils to petals in double flowers. But all those parts of a flower have been observed changed into leaves. Nor is this matter of surprise, for these are the organs most necessary for the well-being of a plant; and when the production of blossom fails, it is only because more foliage is required for the elaboration of a superabundant sap. Illustrations of these changes of the floral organs into leaves have been observed by M. De Candolle, and others, in a variety of the Gilliflower (*Hesperus Matronalis*), in varieties of the Anemone, Ranunculus, and

Fraxinella (*Dictamnus albus*); in *Ranunculus philonotis; Campanula rapunculoides, Anemone nemorosa, Erysimum officinale,* and *Scabiosa columbaria.*

To promote the production of blossoms, and the maturity of the fruit they engender, is the usual object of stopping, pruning, and training—confessedly three of the practices requiring most judgment in the gardener's art; for if the branches are too much reduced in length or number, or are unfavourably trained, the development of leaves is induced, and the production of blossom as proportionately prevented. The reason for this has already been explained; and in these pages, devoted to the science rather than the practice of gardening, little more can be added than a few hints upon the subject.

Stopping is the practice of removing a part of the leading end of a shoot during the season of the plant's growth, and *pinching* is merely destroying during the same season the leading bud. Both practices are performed by the finger and thumb.

It is not to make a fruit tree more bushy that we stop the robbers, as we call the strongest shoots, but to stop the current of the sap, and so force it into the weaker branches, which are seldom stopped at all. When it is necessary to stop all the shoots on a plant, the weakest ought to be first stopped, in order to get them stronger, and is easily shown on a common Laurel. Take a branch during June with two young shoots—the one very strong, and the other a weak one; stop the weak one, and allow it to push two or three eyes into leaf; then stop the strong one, and before it can break again, the shoots on the weak one are grown, and able to draw on the sap more than those which are merely breaking bud on the stronger shoot. Then, suppose we leave only two shoots to come from the weaker parent, and four or five shoots on the stronger, the balance of strength is restored in a month, and you have six shoots of equal, or nearly equal, strength; but if you stop the strongest first, and allow it to break into three or four fresh ones before you stop the weak shoot, these three or four having the start of whatever the weakest shoot will give out, they will keep a-head to the end of the season, if they do not starve the weaker and later shoots altogether. If we could *stop the growth* of the strong shoot till such time as the weak shoot was nearly as strong as the first, and then let them both go on equal terms, all would go on well: but we cannot stop growth one moment in the growing season—the right season for stopping; for as soon as we "top" a shoot, if only by breaking a bud, the next buds below will yield to the force of the rising fluid or sap immediately, and many of the summer practices are founded on this knowledge; as, for instance, a Rose-bud of last autumn is now a one-shoot plant, and very apt to be blown over by the wind or other force; but stop it at the top, and out it branches in ten days, and will soon make a compact round head. Those who neglect to take advantage of this, may get one shoot from a bud up to three feet in length; but what is the good of that? they must be cut down to four or five eyes next winter; and it will be next year before a head can be had. Almost all nurserymen spoil, or lay down the foundation for the ruin of Peach and Apricot trees, by leaving the original bud to form one gross shoot the first year, instead of stopping it when it is nine or ten inches long, and take five shoots from the next start for wall trees, and four shoots only, and of equal strength, for pots and orchard-house work.

We pinch and stop the shoots of our fruit trees in June, and throughout the summer, whether they are grown against a wall, or as dwarf standards. We take off one-third of a weak shoot, only one-fourth if of average strength, and merely the point if it be strong. The upper bud on each usually breaks again, but this is of no consequence, and we stop these secondary shoots by breaking them off entirely. This stopping promotes the production of blossom-buds, and fruit-bearing spurs, according to the mode of the tree's bearing.

The season for *pruning* must be regulated in some degree by the strength of the tree; for although, as a general rule, the operation should not take place in deciduous trees until the fall of the leaf indicates that vegetation has ceased, yet if the tree be weak, it may be often performed with advantage a little earlier, but still so late in the autumn as to prevent the protrusion of fresh shoots. This reduction of the branches before the tree has finished vegetating prevents the mere increase of length, and directs a greater supply of sap to those remaining, and stores up in them the supply for increased growth next season. If the production of spurs is the object of pruning, a branch should be pruned so as to leave a stump; because, as the sap supplied to the branch will be concentrated upon those buds remaining at its extremity, these will be productive of spurs, though otherwise they would have remained dormant, it being the general habit of plants first to develope and mature parts that are furthest from the roots. It is thus the Filbert is induced to put forth an abundance of young bearing wood, for its fruit is borne on the annual shoots; and similar treatment to a less severe extent is practised upon wall fruit.

In pruning evergreen trees and shrubs cultivated for their foliage, the operation should be performed just when growth has commenced in the spring, for this induces the production of more vigorous and more numerous shoots.

Pruning, however, may be justly divided into three kinds—*Summer* or *Growth-pruning*, which we have just considered under the head of *Stopping; Root-pruning*, which we dwelt upon whilst writing about the roots of plants; and *Winter* or *Rest-pruning*, on which we will make some further notes.

So far as the Science of Gardening is concerned, it has to be practised for the following objects:—

1. The admission of more light.
2. Relieving oppressed trees.
3. Furnishing blanks.
4. Inducing spurs.

1st. *Admission of Light.*—That the removal of a portion of the shoots, or branches of a tree, will enable the remaining portion to receive a greater degree of light, is self-evident. A free and equal admission of light tends to produce an equality in the branches, and, by consequence, equality in the character and size of the fruit; for in trees totally unpruned we may often see a few fine fruit just at the extremity of the branch, whilst the remainder, especially the interior, is crowded with produce deficient both in size and quality. The free and equal admission of light also tends to produce solidification of the wood, and thereby to promote healthiness of habit—one step, assuredly, to size and quality of fruit.

2nd. *Relieving Oppressed Trees.*—If, through overbearing, general debility, age, canker, or temporary loss of power, through removal, or any adventitious circumstances, trees evince weakness, pruning judiciously performed is a certain relief, and very frequently a permanent one.

3rd. *Furnishing Blanks.*—This, indeed, with regard to young trees especially, is one of the most important ends of *rest-pruning.* The chief misfortune is, that in attempting to carry out neat systems of training, much sacrifice of wood, which would otherwise prove of fruitful character, is too apt to be made. This, indeed, is almost inseparable from a systematic course in the earlier stages of the tree; still a judicious course of "summer-stopping" and timely training will save many a twig, which otherwise falls before the hand of the "*rest*" *pruner.* Whatever be the course pursued in regard of summer management, rest-pruning should be resorted to with trees of all ages, when and where deficiencies exist. The pruner, in this case, may merely remember that a tendency exists in most free-growing shoots (on young trees especially) to lengthen, and that it very frequently serves the cultivator's purpose much better to cause one strong shoot to branch into four or five subordinate ones; this the rest-pruner's knife can accomplish under ordinary circumstances.

4th. *Inducing Spurs.*—One of the most important offices of *rest-pruning*, and in carrying out a dwarfing system, needs to be practised annually on many of the long shoots of young and free-growing trees, until the side-buds are made to develope in some degree.

Pursuing this subject, we have from Mr. Beaton these further suggestions of practice combined with science:—

"If you stand before a young tree, about six feet high, and see one or more of the side-branches much stronger than the rest, with their ends more upright—showing plainly that they, too, would be leaders in time, as much so as the centre and true leader—science teaches that if the top, or tops, are merely cut off or stopped, the ascending force is divided, and the leading character is lost, from that hour, to those shoots. But science mav be at fault for all that; and practice alone must guide the pruner as to which of four buds to cut to. If you take the point of a shoot, and bend it to you, there are eyes, or buds, on the upper side of it, also on the under side, and on the right and left sides as well. Now, the question is, to which of these buds is the shoot to be cut to; and to that science cannot direct you, at least not to three of them, science being based on fundamental rules. If you understand it, you will never cut a side-branch, in any tree or bush, to a bud directly on the upper side of it; because it is natural, or fundamental, that the top bud left on the upper side will either take the lead, or, by growing inwards, crowd the distance between it and the stem or trunk of the tree. A pruner may work to get more flowers, more fruit or timber, or he may only want a more regular disposition of the branches; but none of these can be had by crowding them: still there are three more chances in the three buds left out of the four; but as science does not go by chance, it cannot tell which of the three buds is the right one to cut to. If you cut to a bud on the under-side of the shoot, that bud will make a shoot that will grow outwards; and if there is room in that direction, that is the best way for it to grow: but, suppose there is another shoot which occupies, or which will soon occupy, that space, then your causing a new one to grow in that direction will crowd that part; therefore, cutting to an under-side bud, in such a case, is manifestly wrong.

"Let us now take a bud on the left side of the shoot, and cut to it. This also may be right or wrong, as it happens. A leader rising from the left side of a shoot will grow more to the left than the shoot itself would do were it not stopped; and if that left side is already better furnished than the right side, there will be more crowding than need be; and it is just the same on the right side of the branch.

"This teaches us to stop an aspiring leader to lessen its force in that direction; never to stop it to a bud on the upper side of it, and to be guided to the right bud to cut to by the rest of the branches; choosing the bud on that side where they are less crowded, and so, by directing a new growth to the more open part of the head, balancing the whole more equally.

"I put the question, which is the root and foundation of all pruning on this footing, because, in nine cases out of ten, in general pruning, it stands just as here set forth; though never, or but in very rare cases, in pruning a forest or timber tree; for exceptions, take a pillar Rose. If one of them, or one out of every hundred of them, were to be led up with one central stem, like a forest tree, the chances are that it would get bare at the bottom, some time or other; and if it did, there is no other shoot to fall back upon, or rather to cut back, to furnish the feathers to the ground; therefore, the safest plan is to have two, three, or more leaders, for the centre of a pillar Rose, and, in pruning the side-branches from them, we meet with exceptional cases to that of not pruning back to a bud on the upper side of a timber tree. We want the pillar to rise as fast as practicable, after furnishing side-branches enough to form the body; and if we always avoided the cut to an opposite bud, we might have more for the body of the pillar than was really necessary, and not enough of upright growth to carry on the height in proportion. In such cases, if we are sure of sufficient side-branches, it is always best to cut back to a bud on the upper side of all the topmost branches. On the other hand, if we take the case of fruit trees trained against something, or of flowering plants merely, trained the same way, and find that the young wood from the main branches is too strong for our purpose, we prune back to a bud on the under side of the shoot, because a shoot from such under-bud is never so strong as one from the upper side."

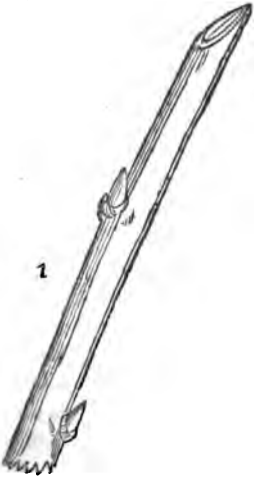
Another maxim is this—pruning will add very much to the size and weight of a great variety of fruit, by confining the energies of the parts next to the fruit, for that very purpose, instead of being expended in making more wood; but all the pruning we can do, except in very rare cases indeed, will not add one inch, or one ounce, to the size or weight of a tree, although more than half the pruners in the world believe to the contrary.

The next step in pruning, after stopping buds and aspiring leaders, is a process which every gardener and forester puts in practice every season. Let us suppose a common case: A young, healthy tree, six or seven feet high, is removed from the nursery, and is planted along the boundary line of a villa garden, where it is intended for a screen more than for its timber; and let us say that the first three feet of it from the ground are without any branches, then a thick head of branches, with all the large ones about the same size, and none of them seeming to vie with the leader, which is freely setting off without a rival—just such a tree as one would select out of a whole nursery row. When this tree begins to make a free growth after planting, the pruner comes round in the winter to see that all is right; he finds no necessity for the first step in pruning-in this tree—namely, to stop a too-forward branch, for there is none of that class.

Then follows the second step in pruning—to see that the branches are not crowded in any part of the head; and the third step, that of cutting away the lowest tier, should never be taken until the second step, that of thinning the head, was accomplished. Therefore, when we know that too much pruning at one time hurts a tree, if the necessary thinning happens to require more than the value of two bottom tiers to be removed, the third *step* should not take place at all that season. A tree taken thus early should be so managed to the last day of its life as that no branch need be cut from the main trunk of more than one inch in diameter. A wound made by such a cut will be healed over by new wood the first season, and leave no blemish in the wood.

In pruning the shoots of a tree it is not a matter of indifference where the cut is made. All wounds die back, more or less, after winter pruning; those of young shoots more so than those of older wood; therefore, when you cut close to a bud—say about the end of October, Nature cannot heal that wound till new wood is formed next June or July; and in this long interval it is almost certain that this close wound will cause the wood to perish immediately under the bud, so that if it starts at all, it will only make a weak shoot, and the next bud below it will become the leader, and thus derange the shape of the tree at once. A Vine shoot, a Cherry, Currant, or Raspberry, or, indeed, any soft shoot with a large pith, cut in that way late in the autumn, would be certain to kill the bud near it.

In summer, prune close to a bud, as in *fig.* 2, in order that there may not be any snag to prevent the wound healing over immediately; but in winter pruning, cut from a quarter of an inch to an inch in advance of the bud, as in *fig.* 1, to prevent the wound from destroying it; and by making the cut on the same side as the bud is on, you give a greater length of living wood beyond the bud, without increasing the length of the snag; and by cutting on the opposite side from the bud, the snag may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be the same length as in the other case, but the living wood beyond the bud will be lessened, according to the angle of the cut.

In all gardens and nurseries, cutting off snags left at the winter pruning forms a chief item in summer pruning.

We have already considered the phenomena attendant upon the union of the scion with the stock in grafting, and we will now examine more in detail the various processes adopted in completing the operation.

Grafting is a more difficult mode of multiplying an individual than budding, because it is requisite so to fit the scion to the stock that some portion of their inner barks must coincide, otherwise the requisite circulation of the sap is prevented. No graft will succeed if not immediately grafted upon a nearly kindred stock—we say immediately, because it is possible that by grafting on the most dissimilar species on which it will take, and then moving it, with some of the stock attached to another stock still more remotely allied, that a graft may be made to succeed, though supplied with sap from roots of a very dissimilar species. Thus some Pear scions can hardly be made to unite with a Quince stock; but if they be grafted upon a young shoot of a Pear that can be so united to the Quince, and this young shoot be afterwards inserted in a Quince stock, they grow as freely as if inserted in a seedling Pear stock.

The reason for this unusual difficulty in the way of uniting kindred species arises from one or more of these causes. First, the sap flowing at discordant periods; secondly, the proper juices being dissimilar; or thirdly, the sap vessels being of inappropriate calibre.

It is quite certain that the ancient Romans were skilful grafters, for Cato (in his *De Re Rusticâ*), gives very full and accurate directions on the art. If it be true, as he asserts, in common with Varro, Palladius, Virgil, Columella, Pliny, and other writers, contemporary as well as more ancient, that they engrafted any kind of tree upon any stock, though of an entirely different genus, as the Apple upon the Plane, and the Vine or the Fig on the Cherry, then, indeed, is there another added to the list of lost arts. But there is just reason for concluding that the ancients never possessed the knowledge thus claimed—not only because it is denied by modern experience and science; but because we know that by stratagem such unions may be made to appear as if effected, and none of the ancient writers on the soil's culture were practical men. Moreover, in considering this question, it must not be forgotten that it was denied that such grafting was possible, even by some of their contemporaries. Columella, in his treatise on trees, has a chapter maintaining by argument the possibility of promiscuous grafting in opposition to some other authors who denied its practicability. Arguments would have been needless if there were examples of success ready for reference.

The objects of grafting are:—1st. To increase choice kinds of plants. 2nd. To increase the vigour of kinds too delicate. 3rd. To reduce the vigour of those which are too gross. 4th. To accelerate the period of fruiting. 5th. To adapt kinds to soils for which they would be unfitted on their own roots. 6th. To renew, or renovate, old kinds.

These six points comprise all that we think it necessary to say on this head for ordinary gardening purposes, and we now proceed to give a series of illustrations of such modes of grafting as are essential in general horticulture. Many others are practised by our continental neighbours, but they offer no advantages.

1. *Whip-grafting*, called also *splice* and *tongue-grafting*, is

the most common mode, and is that almost universally adopted in our nurseries; and, indeed, when the stock and scion are about equal in size, it is, perhaps, the handiest plan of all. The head of the stock is pruned off at the desired height, and then a slip of bark and wood removed at the upper portion of the stock, with a very clean cut, to fit exactly with a corresponding cut which must be made in the scion. A very small amount of wood must be cut away, and the surface made quite smooth; care being taken that no dirt be upon the cuts in this, and, indeed, in all the other modes. The scion must now be prepared; this should have at least three or four buds, one of which should, where possible, be at the lower end, to assist in uniting it to the stock. A sloping cut must now be made in the scion; this cut must correspond with that on the stock, and a slit be made to fit in a cleft made in the stock when heading it. This slit serves to maintain the scion steadily in its place until properly fastened, and is more a matter of convenience that anything else. Care must be taken that the scion fits *bark to bark*, on one side at least.

Where the stock and scion disagree in point of size, of course only one side can touch, and great care should be taken in this part of the operation; and, in the case of a young scion on an old tree, some allowance must be made for the ruggedness of the bark.

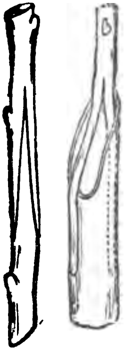
The scion being thus adjusted, the whole is bound close, but not too tightly, with a shred of bast mat, care being taken that the inner barks coincide. The clay is now applied, in order to keep the parts moist, and some practitioners pile soil over the grafted part, when near enough the ground. In all the modes of grafting it may here be observed, that *the chief ground of success lies in nicely fitting together some corresponding portions of the inner bark of the scion and stock.*

2. *Crown*, called also *Cleft*, or *Wedge-grafting.*—This is applied to various plants as well as fruits, as, for instance, the Rose, Cactuses, &c. Vines, also, are frequently grafted by this mode. As in whip-grafting, it accelerates the union if the bottom of the scion has a bud or two. In the case of the Vine it is considered necessary to let the stock grow a little before grafting; care must be taken, however, to keep some growing portions on the stock, above the graft, or severe bleeding would ensue. As the name indicates, a cleft, or division, is made in the stock to receive the scion, which is cut like a wedge; again taking care, in case of inequality of size, to make one side fit *bark to bark.* When the scion and stock are unequal in size, both sides of the scion may be brought to fit by cutting the cleft nearer to one side of the crown than the other. The wound is bound over, as in the other processes, with bast, and covered over with clay, or grafting-wax. The Camellia succeeds well when, grafted this way, even a single bud will make a plant provided the stocks are kept in a damp and shady atmosphere for a few weeks after grafting. The stock here, also, should be slightly in advance—that is, should be forwarder in growing than the graft or scion. The best time is just as the sap is rising.

3. *Cleft-grafting*, as represented in this sketch, is only a kind of crown-grafting, and is practised on stocks one or two inches in diameter, and, therefore, too large for whip-grafting. Cut or saw off the head of the stock in a sloping form; with a knife or chisel cleave the stock at the top, making the cleft about

two inches deep; keep it open by leaving in the chisel; cut the lower end of the scion into the form of a wedge, one inch and a half long, and the side that is to be towards the middle of the stock sloped off to a fine edge; place the bark of the thickest side of the wedge-end of the scion so as to correspond exactly with the bark of the stock; take away the chisel, and then the sides of the stock will pinch and hold fast the scion. Two scions may be inserted, one on each side of the cleft; but in this case the top of the stock must not be cut off sloping. Bast and clay must be put on as in the other modes of grafting.

4. *Saddle-grafting*.—The top of the stock is cut to a wedge shape, and the scion or graft cleft up the middle, and placed astride on the wedge of the stock; hence the name. The binding and claying are performed as in the other modes, care being taken to make at least one of the sides meet, *bark to bark*.

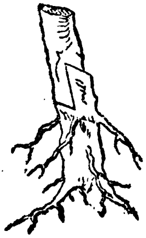


A modification of this mode is practised in some of our cider counties, where they do not hesitate to practise it in the middle of summer, when the young wood has become somewhat mature. The scion is chosen smaller than the stock, and is cleft about three inches at the lower end, so that one side is rather thicker than the other. The rind of the stock is then opened on one side, and the thick side of the scion introduced between the bark and wood; the thinner portion is carried astride the stock, and down the opposite side, a slight cutting having been made to receive it, on the principle of making corresponding parts meet. This, though tedious, is a very safe mode of grafting, inasmuch as it presents a greater expanse of alburnum for effecting the junction.

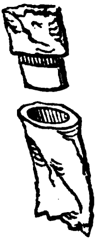
5. *Side-grafting.*—This, in general, is performed on trees on which the top is required to remain, and is well adapted for the insertion of new kinds of Pears, or other fruits on established trees, in order to increase the collection, or to hasten fruit bearing. It is also adapted to fill up naked portions of old shoots. It is, however, not so safe a mode as some of the others. Little description is needed; the cut will sufficiently illustrate it.

6. *Chink or Shoulder-grafting.*—This is not much in use in this country, and, indeed, we see little occasion for its practice. When the stock and scion are equal in size, however, it offers an opportunity of gaining the advantage of an extra amount of alburnous union. The cut will explain it.

7. *Root-grafting.*—An old practice, but with regard to deciduous fruit trees it offers no particular advantage over the ordinary whip-grafting, when performed near to the ground. It is, perhaps, better adapted for very large scions, for in many trees such may be used when two or three inches in diameter. When strongly bound they may be soiled overhead, merely leaving a hole for the bud of the scion to come through, which in this case will rise like a sucker.



8. *Peg-grafting.*—This mode is now never practised in England. Peg-grafting never having been practised by ourselves,



we shall only make this extract relative to it:—"The scion must be of the exact size of the stock; bore a hole into the centre of the stock, one inch and a half deep; cut the bottom of the scion to fit; the edges of the barks must be very smooth, and fit exactly."

For ordinary garden purposes, we think the whip, the cleft, the saddle, and the crown, the most eligible modes by far.

In all these a few axioms must be kept steadily in view: of such are the following:—

1st. The scions of deciduous trees should be taken from the parent tree some weeks before the grafting season, and "heeled" (the lower ends put into the soil) in some cool and shady place; this causes the stock to be a little in advance of the graft, as to the rising of the sap, a condition admitted on all hands to be essential.

2nd. Let all the processes be performed with a very clean and exceedingly sharp knife, taking care that nothing, such as dirt or chips, gets between the scion and the stock.

3rd. Let the bandage be applied equally and firmly; not so tight, however, as to cut or bruise the bark. For this reason, *broad* strands of bast are exceedingly eligible.

4th. In selecting grafts be careful in choosing the wood, avoiding on the one hand, exhausted or bad-barked scions; and, on the other, the immature, watery spray which frequently springs from the old trunks of exhausted or diseased trees.

Grafting Clay.—Take some strong and adhesive loam, approaching to a clayey character, and beat and knead it until of the consistence of soft-soap. Take also some horse droppings. and rub them through a riddle, of half-inch mesh, until thoroughly divided. Get some cow manure, the fresher the better, and mix about equal parts of the three; kneading and mixing them until perfectly and uniformly mixed; some persons add a little road scrapings to the mass. A vessel with very finely riddled ashes must be kept by the side of the grafter, and after the clay is closed round the scion, the hands should be dipped in the ashes; this enables the person who applies the clay to close the whole with a perfect finish. It must be so closed as that no air can possibly enter; and it is well to go over the whole in three or four days afterwards, when, if any have rifted or cracked, they may be closed finally.

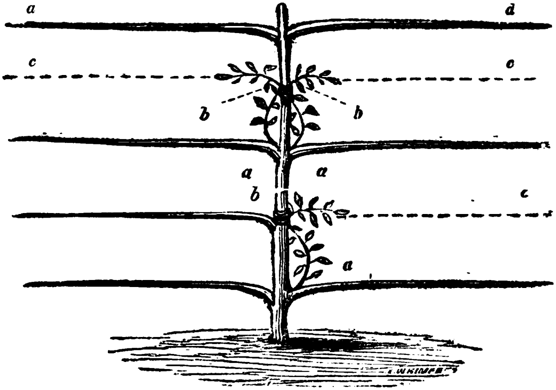
Grafting Wax.—The following recipe has been recommended by a first-rate authority. Take common sealing-wax, any colour but green, one part; mutton fat, one part; white wax, one part; and honey one-eighth part. The white wax and the fat are to be first melted, and then the sealing-wax is to be added gradually, in small pieces, the mixture being kept constantly stirred; and, lastly, the honey must be put in just before taking it off the fire. It should be poured hot into paper or tin moulds, to preserve for use as wanted, and be kept slightly stirred until it begins to harden.

Inarching differs from grafting only in having the scion still attached to its parent stem whilst the process of union with the stock is proceeding. It is the most certain mode of multiplying an individual that roots or grafts with difficulty, but is attended with the inconvenience that both the stock and the parent of the scion must be neighbours.

One of the most ingenious applications of inarching is suggested by Mr. Knight. If a fruit-bearing branch becomes denuded of its leaves above the fruit it has produced, this either falls, or remains stunted and deficient in flavour, owing to being thus deprived of a supply of the elaborated sap or proper juice. In such case a branch having leaves of the same or of a neighbouring tree, may be inarched to the denuded portion of the branch, and the fruit will then proceed to maturity. Mr. Knight's experiment was tried upon a Peach tree, the fruit of which he was anxious to taste, but which produced that season only two Peaches, and from the branch bearing which all the leaves had fallen.

Another excellent adaptation of inarching is where the same tree supplies both the scion and the stock. Mr. Thompson thus describes this adaptation by M. Fourké to Pear trees at Corbeil, in France. The trees had been planted when large and irregularly grown, having, in some places, a redundancy, in others a deficiency, of branches. With the view of supplying branches where wanting, inarching the *growing extremities* of adjoining shoots to the parts of the stem whence the horizontals should proceed, was adopted.

Supposing the branches of a tree are trained horizontally a foot



apart, with the exception of some where the buds intended to produce branches did not break, as is often the case; then a shoot (*a*) is trained up, and, when growing in summer, a small slice is taken off near its extremity, and a corresponding extent of surface immediately below the inner bark of the stem is exposed; the two are joined together, and the point of the shoot (*a*) is inclined in the direction to form the branch (*c*).

The most remarkable feature in the trees at Corbeil, was the uniformity of vigour in the respective branches. It appeared as if the supplied branches, *c c c*, had been allowed to grow in connection both with the stem at *b b*, and the branch from which they originated at *a a a*, till their length and thickness corresponded sufficiently with that of the branches above and below them. This is a great advantage which the mode possesses over budding or side-grafting. At the distance of a foot apart for the horizontal branches, it takes as many years to cover the wall as the latter is feet in height; for although the leading shoot may grow three or four feet in length in a season, yet by shortening it to two feet, although the branches *d d* would be produced, the buds at *b b*, to furnish the intermediate stage, most probably would not. In fact, the attempt to form two tiers of horizontals in one season is generally followed by more or less disappointment. The intermediate stage might, however, be readily supplied by the method above detailed; and a wall twelve feet high might be covered as well in six years as it otherwise would be in twelve.—(*Hort. Soc. Journal*, ii.)

The usual mode of inarching continues the same as it was when thus described by Abercrombie:—

"To propagate any tree or shrub by this method, if of the hardy kind, and growing in the open ground, a proper quantity of young plants for stocks must be set round it, and when grown of a proper height, the work of inarching performed; or if the branches of the tree you design to graft from are too high for the stock, stocks must be planted in pots, and a slight stage erected around the tree of due height to reach the branches, and the pots containing the stock placed upon the stage.

"As to the method of performing the work, it is sometimes performed with the head of the stock cut off, and sometimes with the head left on till the graft is united with the stock, though by previously beheading it the work is much easier performed, and the supply of sap will be directed to the nourishment of the graft.

"*Side Inarching with a Tongue.*—Having the stocks properly placed, make the most convenient branches approach the stock and mark in the body of the branches the parts where they will most easily join to the stock, and in those parts of each branch, pare away the bark and part of the wood two or three inches in length, and in the same manner pare the stock in the proper place for the junction of the graft; then make a slit upward in the branch so as to form a sort of tongue, and make a slit downward in the stock to admit it; let the parts be then joined, slipping the tongue of the graft into the slit of the stock, making the whole join in an exact manner, and tie them closely together with bass, and afterwards cover the whole with a due quantity of clay, or wax. After this let a stout stake be fixed for the support of each graft,

a. The stock, with an under tongue prepared.
b. The scion with upper tongue to insert into *a*.
c. The stock and scion united.

and so fastened as to prevent its being disjoined from the stock by the wind."

Side Inarching without a Tongue is the most simple and most usual mode of inarching. A slice of bark and alburnum of similar dimensions in both stock and scion are removed at the point where they are intended to unite, as in *fig.* 1. These

Fig. 1.

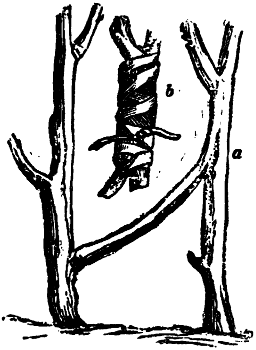


Fig. 2.

parts are placed face to face, so that the barks and alburnums of the two wounds are brought in contact, as at *a*, in *fig.* 2. They are then bound firmly together with strips of bast mat, as represented by *b*. The whole is then enveloped with moss, to be kept moist, or by an egg-shaped mass of grafting clay.

The operation being performed in spring, let the grafts remain in that position about four months, when they will be united, and they may then be separated from the mother-tree; in doing this be careful to perform it with a steady hand, so as not to loosen or break out the graft, sloping it off downwards close to the stock; and if the head of the stock were not cut down at the time of grafting, it must now be done close to the graft, and all the old clay and bandage cleared away and replaced with new, to remain a few weeks longer.

Observe, however, that if the grafts are not firmly united with the stock, let them remain another year till autumn, before you separate the grafts from the parent tree.

Saddle Inarching is effected by heading down the stock, cutting its top in the form of a wedge, and then it is cut with an upward notch, and fitted on to it, as shown in *fig.* 3. The parts are bound and clayed as in the other modes of inarching. A ring of bark is removed down to the wood from the scion-branch. This removal checks the return of the sap, accumulates the cambium about the wound, and consequently promotes the union between the stock and the scion. It is a judicious practice, because the fact that many trees and shrubs which are propagated with difficulty by grafting, can be readily propagated by inarching, points out that in them the deficient supply of cambium is the cause of the scion and stock failing to unite.

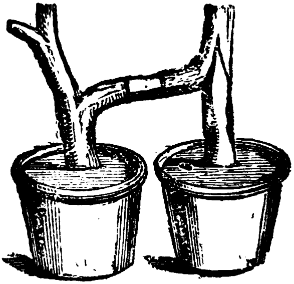


Fig. 3.

When the stock is much larger than the scion to be united to it, the following modifications are practised. The top of the stock is cut off slanting on one side only; then a long tongue is cut in the scion of only one-third of its thickness, and as much of the bark and wood is cut from the back and front of the stock as will correspond with the length and width of the scion's tongue. A ring of bark is also taken off as just described, and the whole when adjusted previously to binding with bast and claying appears as in *fig.* 4.

Fig. 4.

Fig. 5.

Inarching with partly-nourished Scions.—This is merely side inarching with the lower end of the scion plunged in a pot of moist earth, or filled with water, as in *fig.* 5. The water requires renewing occasionally, and a slice from the base of the scion being cut off at the same time, to be then replaced in the fresh water. This mode is sometimes adopted for Camellias. The top of the stock in this mode should not be cut off until the scion and the stock have united.—(*Loudon.*)

Cuttings for multiplying any individual may in general be taken either from the stem, branch, or root, and are, in fact, grafts, which, by being placed in the earth—a medium favourable to the production of roots, expend their juices in the formation of radicles instead of aiding the stock to effect that development of vessels necessary for their union to it had they been grafted. A due degree of moisture and warmth in the soil is all that is absolutely required from it by cuttings, for these will often produce roots if placed in water only. That warmth and moisture promote the production of roots is proved by these being so frequently emitted by the stems of Vines in a stove.

The time for taking off cuttings from the parent plant for propagation is when the sap is in full activity, the vital energy in all its parts is then most potent for the development of the new organs their altered circumstances require. Well-matured buds are found to emit roots most successfully, and apparently for the same reason that they are least liable to failure when employed for budding—viz., that being less easily excitable, they do not begin to develope until the cutting has the power to afford a due supply of sap. Therefore, in taking a cutting it is advisable to remove a portion of the wood having on it a bud, or joint, as it is popularly called, of the previous year's production.

Many plants can be multiplied by cuttings with the greatest facility, but others only with the greatest difficulty, and after every care has been taken to secure to the cutting every circumstance favourable to the development of roots.

Those plants which vegetate rapidly, and delight in either a moist or rich soil, are those which are propagated most readily by this mode, and such plants are the Willow, Gooseberry, and Pelargonium—a budded section of these can hardly be thrust into the ground without its rooting.

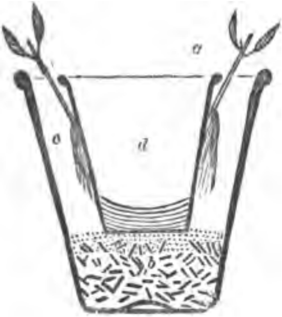
Cuttings of those plants which grow tardily, or, in other words, form new parts slowly, are those which are most liable to fail. These are strikingly instanced in the Heaths, the Orange, and Ceratonia.

A rooted cutting is not a new plant, it is only an extension of the parent, gifted with precisely the same habits, and delighting most in exactly the same degrees of heat, light, and moisture, and in the same food.

A cutting produces roots either from a bud or eye, or from a callus, resembling a protuberant lip, which forms from the alburnum between the wood and the bark round the face of the cut which divided the slip from the parent stem.

If the atmospheric temperature is so high that moisture is emitted from the leaves faster than it is supplied, they droop or flag, and the growth of the plant is suspended. If a cutting be placed in water, it imbibes at first more rapidly than a rooted plant of the same size, though this power rapidly decreases; but if planted in the earth, it at no time imbibes so fast as the rooted plant, provided the soil is similarly moist; and this evidently because it has not such an extensive imbibing surface as is possessed by the rooted plant: consequently the soil in which a cutting is placed should be much more moist than is beneficial to a rooted plant of the same species; and evaporation from the leaves should be checked by covering the cutting with a bell-glass, or either a Wardian or Waltonian Case would be still better.

In cases where cuttings root with difficulty, and it is desirable to keep up the supply of moisture to them very regularly, a reservoir of water is formed by placing a small pot in the centre of a large one, the water being left to ooze slowly through the porous sides of the pot, as shown in the accompanying *fig.*, in which *a* is a No. 60-pot, with the bottom closed up with clay, put into one of larger size; *b*, the drainage in the larger pot; *c*, the sand or soil in which the cuttings are inserted; and *d*, the water in the inner pot, which is prevented from escaping through its bottom by the clay stopping. Mr. Forsyth, the inventor of this mode of striking cuttings, proposes it to be used with hardy plants, such as Pinks and Wallflowers, under hand-glasses or frames, in the open air, as well as for all manner of house plants. The advantages, he says, are the regularity of the supply of moisture, without any chance of saturation; the power of examining the state of the cuttings at any time without injuring them, by lifting out the inner pot; the superior drainage, so essential in propagating, by having such a thin layer of soil; the roots being placed so near the sides of both pots; and the facility with which the plants, when rooted, can be parted for potting off, by taking out the inner pot, and with a knife cutting out every plant with its ball, without the awkward but often necessary process of turning the pot upside down to get out the cuttings.



The temperature to which the leaves are exposed should be approaching the lowest the plant will endure. The warmer the soil within the range of temperature most suitable to the plant, the more active are the roots, and the more energetically are carried on all the processes of the vessels buried beneath the surface of the soil: 50° for the atmosphere, and between 65° and 75° for the bottom heat, are the most effectual temperatures for the generality of plants.

The cutting should be as short as possible consistently with the objects in view.

Three or four leaves, or even two, if the cutting be very short, are abundant. They elaborate the sap quite as fast as required, and are not liable to exhaust the cutting by super-exhalation of moisture.

Cuttings taken from the upper branches of a plant flower and bear fruit the earliest, but those taken from near the soil are said to root most freely.

Cuttings which reluctantly emit roots, may be aided by ringing. The ring should be cut round the branch a few weeks before the cutting has to be removed; the bark should be completely removed down to the wood; and the section dividing the cutting from the parent be made between the ring and the parent stem, so soon as a callus appears round the upper edge of the ring.

Cuttings may often be made readily from the root of a plant, cuttings from the stem of which produce roots with difficulty. The root is the underground part of the stem, and in such instances emits leaves with more facility than the stem above ground can be induced to emit roots.

The roots should be those of healthy plants, rather young than old, and, in general, from half an inch to one or two inches in thickness. They may be cut into lengths of from three to six or nine inches, and planted in free soil, with the tops just above the surface. Care must be taken that the upper end of the cutting, or that which was next the stem before it was separated from the plant, be kept uppermost, for if that is not done, the cutting will not grow. This is the case even with cuttings of the Horse-radish and Sea-kale; but if cuttings of the roots of these and similar plants are laid down horizontally, and but slightly covered with soil, they will protude buds from what was the upper end before removal, and send out roots from the lower end. All Roses may be propagated by cuttings, and all fruit trees which are seedlings, or have been raised by cuttings or layers. The Robinia, Acacia, Gleditschia, Coronilla, Gymnocladus, and many other leguminosæ; Ailantus, Catalpa, the Balsam, Ontario and Lombardy Poplars, the English Elm, the Mulberry, the Maclura, various other ligneous plants, and all plants whatever that throw up suckers, may be increased by cuttings of the roots; as may a great number of herbaceous perennials. The best time for taking the cuttings off is when the plants are in a dormant state, and all that is required is a clean cut at both ends.—(*Loudon.*)

The importance of keeping the proper end of every cutting uppermost is further shown by the experiments of Mr. Knight. He planted in the autumn of 1802 twelve cuttings of the Sallow (*Salix caprea*), inverting one-half of them. The whole readily emitted roots, and grew with luxuriance; but their modes of growth were extremely different. In the cuttings which stood in their natural position, vegetation proceeded with most vigour at the points most elevated; but, in the inverted cuttings, it grew more and more languid as it became distant from the ground, and nearly ceased towards the conclusion of the summer, at the height of four feet. The new wood also, which was generated by these inverted cuttings, accumulated above the bases of the annual shoots.

These facts appear to prove, that the vessels of plants are not equally calculated to carry their contents in opposite directions; and afford some grounds to suspect that the vessels of the bark, like those which constitute the venous system of animals (to which they are in many respects analogous), may be provided with valves, whose extreme minuteness has concealed them from observation.—(*Knight's Papers*, 107.)

Mr. Loudon has classed the cuttings of plants usually in cultivation as follows:—

"*Cuttings of Hardy Deciduous Trees and Shrubs*—such as the Gooseberry, Currant, Willow, Poplar, &c., are easily rooted in the open garden, and the same may be said of the Vine and the Fig. As it is desirable that the Gooseberry and Currant should not throw up suckers, and should have a clean stem, all the buds are cut clean out, except three, or at most four, at the upper end of the cutting. The cuttings are planted erect, about six inches deep, and made quite firm by the dibber at their lower extremity. Cuttings of Honeysuckles, Syringas, Ampelopsis, Artemisia, Atragene, Atriplex, Baccharis, Berchemia, Bignonia, Calycanthus, Ceanothus, Chenopodium, Clematis, China Roses (*fig.* 6),

Fig. 6.—A cutting of *Rosa semperflorens*, prepared and planted.

and the like, are rather more difficult to root, and succeed best in a shady border and a sandy soil.

"*Cuttings of Hardy Evergreens*—such as the common Laurel, Portugal Laurel, Laurustinus, Arbor Vitæ, evergreen Privet, and a few others, may be rooted in common soil in the open garden; being put in in autumn, and remaining there a year. Cuttings of Bupleurum, Buxus, Juniperus, Rhamnus, Holly, Sweet Bay, Aucuba, &c., require a shady border and a sandy soil. They are put in in autumn, of ripened wood; but young wood of these and all the kinds mentioned in this and the preceding paragraph will root freely, if taken off in the beginning of summer, when the lower end of the cutting is beginning to ripen, and planted in sand, and covered with a hand-glass.

"*Cuttings of all Coniferæ and Taxaceæ* may be taken off when the lower end of the cutting is beginning to ripen, and planted in sand, with a layer of leaf mould beneath, in pots well drained, in the month of August or September, and kept in a cold frame, from which the frost is completely excluded, till the growing season in spring, when they may be put into a gentle heat. It is not in general necessary to cover these cuttings with bell-glasses. Taxodium is an exception, as it roots best in winter.

"*Cuttings of Hardy and Half-hardy Herbaceous Plants*—such as Pinks, Carnations, Sweet Williams, Wallflowers, Stocks, Dahlias, Petunias, Verbenas, Rockets, and, in general, all herbaceous plants that have stems bearing leaves, root readily in sand under a hand-glass, placed in a shady border, or in a gentle heat, if greater expedition is required. All the cuttings must be cut through close under a joint, or in the case of Pinks, Carnations, or Sweet Williams, the operation of piping may be performed.

"*Piping* can only be performed with plants having tubular stems, and it is only with a few of these that gardeners are accustomed to practise it. The operation is performed when the plant has flowered, or soon afterwards, when it has nearly completed its growth for the season. The shoot chosen is held firm by the left hand, to prevent the root of the plant from being injured, while with the right the upper portion of the shoot is pulled asunder, one joint above the part held by the left hand. A portion of the shoot is thus separated at the socket formed by the axils of the leaves, and the appearance is as in *fig.* 7.

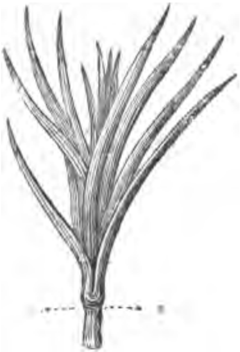


Fig. 7.—A piping of a Pink, prepared and planted.

Some propagators shorten the leaves before planting, but others leave them as in the figure. The soil in which the pipings are to be planted being rendered very fine, mixed with sand and then well watered, the pipings are stuck in without the use of a dibber or pricker, and the operation is completed by a second watering, which settles and renders firm the soil at the lower end of the piping.

"*Cuttings of Soft-wooded Greenhouse Plants*—such as Pelargoniums (*fig.* 8), Fuchsias (*fig.* 9), Brugmansias, Maurandyas,

Fig. 8.—A cutting of the Rose-scented Pelargonium, prepared and planted.

Fig. 9.—A cutting of a Fuchsia, prepared and planted.

and all other soft-wooded plants, being cut off where the wood is beginning to ripen, and planted in sand or sandy loam, or sand and peat, root readily, with or without a bell or hand-glass, in a shady situation, and in a greenhouse temperature. Cuttings of these and all other soft-wooded plants may be divided into one or more lengths; it being only essential that there should be two joints, one for burying in the soil to emit roots, and the other kept above the soil to produce a shoot. The cuttings of soft-wooded plants which root best, are laterals of average strength.

"*Cuttings of Hard-wooded Greenhouse Plants* — such as Camellias, Myrtle, evergreen Acacias, and most Cape and Australian shrubs with comparatively broad leaves, are more difficult to root than soft-wooded greenhouse plants. The cuttings are made from the points of the shoots, after the spring growth has been completed, and before the young wood is thoroughly ripened.

Fig. 10.—A cutting of the young wood of *Acacia alata*, prepared and planted.

Fig. 11.—A cutting of the young wood of a Camellia, prepared and planted.

If put in in February or March, such cuttings will be fit to transplant in July or August. Sometimes they are put in in autumn, or the beginning of winter, in which case they will not root till the following spring, and must be kept cool till that season. In either case, all the leaves must be kept on, except one, or at most two, on the lower end of the cutting, which need not be planted more than an inch in depth, and should, in general, be covered with a bell-glass.

"*Cuttings of Heath-like Plants*—such as Erica, Epacris, Diosma, Brunia, &c., are among the most difficult to root. They should be taken from the points of the side-shoots early in spring, when the plants have nearly ceased growing; not be more than from an inch to two inches in length, and cut clean across at a joint, and the leaves clipped or cut off for about half an inch upwards from the lower end of the cutting. Thus prepared, they should be planted in pure white sand, with a little peat soil as a substratum, and the whole well drained. The pot should then be covered with a bell-glass, and placed in a frame, or in the front of a greenhouse, and shaded during sunshine.

Fig. 12.—A cutting of an Epacris, prepared and planted.

"*Cuttings of Succulent Plants*—such as Cactuses, Cereuses, Euphorbias, Mesembryanthemums, Crassulas, Stapelias, and the like, require to lie a few days before being planted, in order to dry the wounds; after which they may be inserted in pots containing a mixture of peat, sand, and brick rubbish, well drained; after which the pots may be set on the front shelf of a warm greenhouse, and occasionally watered, but shading will be unnecessary."

The cuttings from common deciduous trees—such as the Filbert, Gooseberry, Currant, &c., are, as in *fig.* 13, of the previous year's shoots, and cut just above and just below a bud.


Fig. 13.


Fig. 14.

A Cutting with a Heel (*fig.* 14) is that in which the shoot is taken off with a slice of the branch from which the root sprang.

A Strangulated Cutting is often employed by French gardeners when a common cutting from the same tree produces roots with difficulty. A wire ligature is twisted tightly round the shoot immediately below a bud. (*Fig.* 15). This causes a swelling above the ligature by checking the descent of the sap; and when, after the lapse of one or two years, the swelling has become large, the cut is made immediately below it, and the cutting treated as usual.


Fig. 15.


Fig. 16.

One-bud Cutting (*fig.* 16) is often employed for raising Grape Vines, Mulberries, Hollyhocks, &c., and is called "Raising from an eye." In the Vine and Mulberry, a shoot of the previous year is cut into lengths of about two inches with a bud in the centre; but in the Hollyhock it is usual to split these one-bud lengths, and to extract the pith. The following are the directions given by Mr. Roberts (*Cottage Gardener*, i. 173). He says, in June or early in July (as the season best suits) cut a branch off the plant or plants selected into as many pieces as there are eyes, or shoots, allowing a space of two inches on each side of the eye. Cut them into such lengths, and slit them down the middle, removing all the pith from the inside; put them immediately into some soil or earth in a shady place (say the north side of your garden) about an inch deep, keeping the eye above the earth; water and cover with a hand-glass, and if hot weather, water well over the glass, but do not disturb it. In six weeks there will be nice young plants, which should be planted out early in November in such places as required. They will blossom freely in the June following.

Some plants may be successfully propagated by means of the leaves; and among those whose numbers are thus most commonly increased are the Cacti, Gesneræ, Gloxiniæ, and other fleshy-leaved plants. A few years since, the suggestion was revived that the majority of plants may be thus propagated—a suggestion first made by Agricola at the commencement of the last century. He states that M. Mandirola had raised a Lemon tree in this mode; and then concludes, rather too rashly, "that all exotic leaves may at any time be converted into trees." Since that was written, in 1721, it is certain that plants have been raised from leaves that previously had been considered totally incapable of such extension. Thus M. Neumann succeeded with the *Theophrasta latifolia;* and, going a step further, he even bisected a leaf, and raised a leaf from each half. Mr. Knight has also recorded (in the "Horticultural Transactions" of 1822) that leaves of the Peppermint (*Mentha piperita*), without any portion of the stem upon which they had grown, lived for more than twelve months, increased in size, nearly assumed the character of evergreen trees, and emitted a mass of roots.

In 1839 M. Neumann, of the Paris Garden, seeing the *Theophrasta latifolia* (*Clavija ornata*, D. Don) growing so well from cuttings of leaves, conceived the idea of cutting several of them in two, and treating them in the same manner as entire leaves.

Accordingly, he cut a leaf in two, and planted both parts in the same pot, treating them exactly alike. In about three months the lower half of the leaf (*fig.* 17) had made roots, but the upper half had none; though, some time afterwards, when it became necessary to separate the cuttings, M. Neumann found that the upper part of the leaf had also made roots (*fig.* 18), but that these roots were much shorter than those of the lower half. The rooting of the two halves of a leaf of the Theophrasta, so hard and dry as every one knows these leaves to be, appearing to him an interesting circumstance, he continued to pay attention to them for six months. He wished to ascertain if they would produce buds as in other cases; for he was in hopes they would, as he remarked that the roots increased in the pot. At last in the seventh month, for the first time, he saw at the extremity of his

Fig. 17.—The lower half of the leaf of Theophrasta rooted and sending up a shoot.

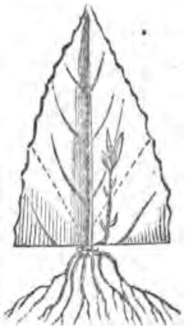


Fig. 18.—The upper half of Theophrasta rooted and sending up a shoot.

two half-leaves, buds appearing, as well formed as those proceeding from the base of the petiole of an entire leaf. In June, 1840, these two cuttings had become beautiful and healthy plants, which it was impossible to distinguish from others produced from entire leaves.

We see from this experiment that it requires double the time to produce a bud from the upper part of the leaf that it requires for the lower half to produce one; and that in propagation by leaves, it is not always necessary to take the heel, or lower end of the petiole, with the leaf, which sometimes injures and deforms the shoots. M. Neumann's experiment proves further, that wherever cambium can be formed, there are at the same time a number of utricules, or germs of the buds formed, from which a new plant will be developed when the parent is placed in favourable circumstances. From this circumstance, in short, we may conclude that all the veins may serve for the reproduction of plants. The dots in *fig.* 18 show the parts of the upper half-leaf which were cut off to allow of its being put into a small pot; and this proves that it is only the middle rib (or prolongation of the petiole), which is required for reproduction. Half-leaves of various plants have been rooted in charcoal in Germany.

The plants usually raised by leaves in British gardens are comparatively few, and chiefly Gesneras; Gloxinias; bulb-bearing leaves, such as Bryophyllum; some succulents, such as Sempervivum, and few others. Leaves of the Orange, the Hoya, the Aucuba, the Camellia, *Ficus elasticus*, the Clianthus, the common Laurel, and a few more, are occasionally rooted, but more as matter for curiosity than for the purpose of increase.

Propagation by the leaves of bulbs has been successfully effected by the Hon. and Rev. W. Herbert, who first tried it, in 1809, by setting a cutting of a leaf of a Cape Ornithogalum. "The leaf was cut off just below the surface of the earth in an early stage of its growth, before the flower-stalk had begun to rise; and it was set in the earth, near the edge of the pot in which the mother plant was growing, and so left to its fate. The leaf continued quite fresh, and on examination (while the bulb was flowering) a number of young bulbs and radical fibres were found adhering to it. They appeared to have been formed by the return of the sap which had nourished the leaf. Thereupon two or three more leaves were taken off and placed in like situations; but they turned yellow, and died without producing any bulbs. It appeared to me then, and it was confirmed by subsequent experience, that in order to obtain a satisfactory result the leaf must be taken off while the plant is advancing in its growth. I found it easy thus to multiply some bulbs that did not willingly produce offsets. I afterwards tried, without cutting the leaf off, to make an oblique incision in it under ground, and in some cases just above ground—attempting, in fact, to raise bulbs by layering the leaf. This attempt was also successful, and some young bulbs were formed on the edge of the cut above ground as well as below. I tried cuttings of the stem of some species of Lilium, and obtained bulbs at the axil of the leaf, as well as from the scales of the bulb; and that practice has been since much resorted to by gardeners, though I believe it originated with me. I raised a great number of bulbs of the little plant which has been successively called Massonia, Scilla, and *Hyacinthus corymbosus*, by setting a pot full of its leaves, and placing a bell-glass over them for a short time. A bulb was obtained with equal facility from a leaf of a rare species of Eucomis; and experiments with the leaves of Lachenalias were equally successful. I apprehend that all liliaceous bulbs may be thus propagated; but the more fleshy the leaf, the more easily the object will be attained."—(*Gard. Chron.* for 1841, page 381.)

Leaves and parts of leaves of the following plants were rooted in charcoal by M. Lucas, of Munich, in 1839 :—Half-leaves of Piereskia, and leaves of *Euphorbia fastuosa*, in a short time filled their pots so full of roots that they were obliged to be repotted.

In from eight to fourteen days leaves of *Cecropia palmata*, *Oxalis mandioccana*, *O. purpurea*, *Euphorbia fastuosa*, *Cyclamen Indicum*, *Lophospermum scandens*, *Martynia craniolaria*, *Begonia monoptera*, *B. bulbifera*, *Ipomæa superba*, *Mesembryanthemum tigrinum*, *Gesnera latifolia*, *G. atro-sanguinea*, *Sinningia guttata*, *Piper piereskiæfolium*, all sorts of Gloxinia, even calices and mere flower-stems, pieces of leaves of *Convolvulus Batatas*, *Peireskia grandifolia*, *Polianthes Mexicana*, and warts of the large-warted Mammillaria.

In three weeks the tops of the leaves of *Agave Americana fol. var.*, leaves of *Jacaranda Brasiliensis*, bundles of leaves of *Pinus excelsa*, leaves of *Mimosa Houstoni*, and *Cyperus vaginatus*.

In five weeks, whole and half-cut leaf-stalks of *Encephalatos Caffer* and *Zamia integrifolia* produced a number of roots from the surface of the cuts.

Many leaves have not yet made roots, but for a considerable time have formed callosities—such as *Laurus nitida*, *Bignonia Telfairiæ*, *Carolinea princeps*, Ardisiæ, Gardeniæ, *Adansonia digitata*, Dracæna, &c. As experiments that did not succeed, we may mention portions of the leaves of Amaryllis and Crinum, of Ferns, of tropical Orchideæ, of Dasylirion, Tillandsia, Pandanus, *Phormium tenax*, of tropical tuberous-rooted Aroideæ, old leaves of the Agave, and some others which, partly through rotting by wet, or other mischances, were prevented from growing.

Leaves with the buds in the axils root freely in the case of many species. The buds and leaves are cut out with a small portion of the bark and alburnum to each, and planted in sandy loam, so deep as just to cover the bud; the soil being pressed firmly against it, and the back of the leaf resting on the surface of the soil. Covered with a bell-glass and placed on heat, in a short time the buds break through the surface of the soil, and elongate into shoots. The late Mr. Knight tried this mode with double Camellias, Magnolias, Metrosideros, Acacias, Neriums, Rhododendrons, and many others, some of which rooted and made shoots the same season, and others not till the following spring.—(*Loudon.*)

That leaves may be made almost universally to emit roots there appears little reason to doubt; for the same great physiologist had long before proved that the roots of trees are generated from vessels passing from the leaves through the bark; and that they never, in any instance, spring from the alburnum. But the question arises, Will they produce buds? and, at present, the answer derived from practice is in the negative. Orange leaves, Rose leaves, leaves of *Statice arborea*, have been made to root abundantly; but, like blind Cabbage-plants, they obstinately refused to produce buds. Dr. Lindley thinks that a more abundant supply of richer food and exposure to a greater intensity of light would have removed this deficiency; and we see every reason for concurring with him; for buds seem to spring from the central vessels of plants, and these vessels are never absent from a leaf. If an abundant supply of food were given to a well-rooted leaf, and it were cut down close to the callus from whence the roots are emitted, we think buds would be produced, for the very roots themselves have the same power.

As a general rule, thick, fleshy, succulent leaves, that form a fleshy underground stem or root, or bulb or tuber, are the best for this purpose. Without these conditions there is little difficulty in forming roots, but there is next to an impossibility in getting these roots to form buds so as to secure a plant. Thus we have rooted Vine, Cucumber, and Melon leaves, &c., in abundance; but when the leaf decayed, the roots also began gradually to decay, without forming a bud as the embryo of a future shoot.

There is no great difficulty in getting leaves of the succulent Scarlet Geraniums to fill small pots with roots, but Mr. Fish was not successful in getting plants from them. Mr. Beaton has told us how to raise such Scarlet Geraniums from leaves; but Mr. Fish suspects there was a little bit of the stem along with the base of the leaf; and therefore, if that were the case, the increase in plants was owing to propagating by leaves and buds united, rather than by leaves alone. Mr. Fish found much the same thing in Dahlias. The leaves will root freely enough, and that without forming any tuber; and even when a tuber is formed, it is seldom that fertile buds will be formed on it. When the leaf was cut off, however, with a small piece of the stem at its base, and thus enclosing in its axil an embryo bud, small tubers would be formed, and a shoot would be produced. Next to the Bryophyllum, the Gloxinia, the Gesnera, and Begonia may be most successfully raised and propagated by their leaves; and those with the thickest, most succulent leaves may be most depended on. Those, also, that have a sort of corm-tuber, or underground fleshy stem, will be the surest to succeed. There are three modes of propagation.

The first is the best and easiest mode for securing strong, healthy plants from leaves, when you wish to have merely one plant from a leaf. In this case select leaves of small size rather than large—say about half their full size; slip them off close, or near, to the stem with a sharp knife, and allow the cut to get dry by exposure, while the top of the leaf is kept moist and shaded to prevent it flagging at all. Then prepare four or five-inch pots, by filling them half full of drainage; then put in a little sandy loam and peat; and over all fully one inch of silver sand, pressed down pretty closely. Insert these leaves by fixing their stems close to the sides of the pot, and the leaves leaning towards the centre, and settle them by watering. If the leaves are topheavy put a small stick in the centre of the pot to keep them up. It is to guard against this that we advise rather small but firmish leaves in preference to older ones. Water so as to fix all in their place firmly, and then put the pot, or pots, where they will receive a close, moist, shaded heat. After March or April, the leaf-cuttings will do in the shaded, close part of a hothouse at work, such as placing them behind a large pot, and damping the leaves occasionally during the day without saturating the soil. A hot-bed, however, would be the best place for them; and if a moist, close, shaded-from-bright-sun heat is given them, no bell-glasses or hand-lights will be wanted, and strong tubers may be expected before the end of the summer, which, after being rested a little, will grow strongly next season whenever they are excited by heat and moisture.

The second plan is a medium between the first and the third, and by which it is desirable to get some half dozen or more plants from a leaf. In this case the pots are prepared in a similar manner; only the surface of the pot must bear some proportion to the size of the leaf when laid flat down over the sand. The practice may be so managed that one leaf may cover the surface of the pot; or several leaves may be laid down on the sand on the surface of a larger one. In this case the leafstalk is cut within an eighth or a quarter of an inch of the base of the leaf. You then turn the lower side of the leaf uppermost, and with your knife make a number of incisions where the large veins meet and cross each other—say from five to ten cuts on a good-sized leaf. The cuts are just notches, as it were, on the chief and subsidiary midribs. The short stump of the leafstalk is then inserted obliquely close to the side of the pot, whilst the under side of the leaf lies close on the sand. To keep the notched parts especially close to the sand, the leaf is kept down by putting some very small wooden pegs through the leaf and into the sand. We prefer them smaller than ladies' hair-pins. We frequently also let a dust of sand lie over the cut parts on the upper side of the leaf. Moisture is given to settle all. The tuber from the stalk end of the leaf will generally be the largest; but mostly fine, healthy little tubers will be formed at every notched part, and even at times on places not notched. These pots must have rather more attention given as to a close, shaded, moist atmosphere; but taking care that extra moisture is not given, or the leaf will be apt to decay. If the leaves get extra dry they are apt to shrivel up before the small tubers are formed. A hotbed or hothouse will do for this plan as well as the first; but placing the pots together under a handlight will enable you to give them a moist atmosphere by day; and giving air at night by tilting the glass will guard against the evils of damping.

The third plan will enable you to make many plants out of a leaf; and though presenting no difficulties in the first stages, requires more attention afterwards to command success. For instance: take a fair-sized leaf of a Gloxinia; run a sharp knife up the centre of its midrib, thus dividing it in two; then begin at the midrib, and cut the half leaf from what was the centre to the side into little narrow pieces—say from an eighth to a quarter an inch in width, and an inch or so in length; do the same with the other half; and these strips will just be so many cuttings. In a large leaf, such as some of the fine-marked-foliaged Begonias, you may make several centres from the larger subdivisions of the leaf. Even this is not absolutely required, as Mr. Fish cut a leaf at random into pieces, and these pieces grew. Still, just as in cuttings in general, we cut to a joint, because, among other reasons, we believe that the vital principle is more active there than in the spaces between the joints, so we have an idea that the vital powers are more likely to be active at the chief and subsidiary ribs of the leaf than in the open spaces; and therefore we prefer that part to be at the base of the portion we insert in the sand of the cutting-pot. More care is required to succeed by this plan; and a hotbed, sweet bottom heat, and bell-glasses for each pot are more necessary. If the little tiny bits are kept too dry, or if the sun strikes them powerfully, they will shrivel and bid you good-bye; and if kept too moist, and the air too confined, they will rot and fade away. Great care, therefore, will be required to give them a stimulating heat, a closeish atmosphere, and shade from bright sun during the day; and to prevent damping, edge up the side of the bell-glass a little at night.—(*Cottage Gardener*, xxiv., 243.)

The soil is an important consideration. The cuttings of Orange trees and others which strike with difficulty if inserted in the middle of the earth of a pot, do so readily if placed in contact with its side. The same effect is produced by the end of the cutting touching an underdrainage of gravel or broken pots. Why is this? and our observations justify us in concluding that it is because in these situations—the side and the open drainage of the pot—the atmospheric air gains a salutary access. A light porous soil, or even sand, which admits air the most readily, is the best for cuttings; and so is a shallow pan rather than a flower-pot, and apparently for the same reason. We have no doubt that numerous perforations in the bottom of the cutting-pan would be found advantageous for cuttings which root shyly.

THE FLOWER.

THE organs of fructification are absolutely necessary, and are always producible by garden plants properly cultivated. They may be deficient in leaves, stems, or roots, because other organs may supply their places; but plants are never incapable of bearing flowers and seeds, for without these they can never fully attain the object of their creation—the increase of their species.

Every flower is composed of one or more of the following parts—viz., the calyx, which is usually green and enveloping the flower whilst in the bud; the corolla or petals, leaves so beautifully coloured, and so delicate in most flowers; the stamens, or male portion of the flower secreting the pollen, or impregnating powder; the pistils, or female portion, impregnatable by the pollen, and rendering fertile the seeds; and lastly, the pericarp or seed-vessel.

Their organisation closely resembles that of the branch by which they are borne, and they are only its parts taking other forms. "Tracing," says the late Mr. Knight, "the progress of the organisation in the full grown fruits of the Apple and Pear, I found, as Linnæus has described, that the medulla, or pith, appeared to end in the pistils. The central vessels diverged round the core, and approaching each other again in the eye of the fruit, seemed to end in ten points at the base of the stamens, to which, I believe, they give existence. The spiral tubes, which are, in all other parts, appendages to these vessels, I could not trace beyond the commencement of the core; but as the vessels themselves extend through the whole fruit, it is probable that the spiral tubes may have escaped my observation."

Although the medulla is traced to the base of the pistils, the central vessels to the part enveloping the seed, and to the stamens, and the spiral vessels throughout the fruit, yet over every part is extended the parenchyma and epidermis, and the sap circulates through the entire of the flower and fruit,—ascending, being elaborated, and descending,—as regularly as through other parts of the plant. Coloured infusions may be traced through the vessels in the stem to the fruit, and if a ligature be passed round a Peach or an Apple, the enlargement is greatest above—that is, between the ligature and the footstalk; and Mr. Knight succeeded, by intergrafting, in proving that the leafstalk, the tendril of the Vine, the fruitstalk, and the succulent point of the annual shoot, may be substituted for each other,—a bunch of Grapes grew and ripened when grafted upon the leafstalk; and a succulent young shoot of the Vine, under the same circumstances, acquired a growth of many feet.

The stamens can be removed without preventing the formation of fertile seed; but their loss must be supplied by the introduction to the pistils of pollen from some kindred flower.

The calyx is not useless so soon as it ceases to envelope and protect the flower, for the flowerstalk continues increasing in size until the seed is perfected, but ceases to do so in those plants whose calyces remain long green if these be removed. On the other hand, in the Poppy, and other flowers from which the calyx falls early, the flowerstalk does not subsequently enlarge.

The corolla, or petals, with all their varied tints and perfumes, have more important offices to perform than thus to delight the senses of mankind. Those bright colours and their perfumed honey serve to attract insects, which are the chief, and often essential, assistants of impregnation; and those petals, as observed by Linnæus, serve as wings, giving a motion, assisting to effect the same important process. But they have a still more essential office; for although they are absent from some plants, yet, in many plants, if removed from those possessing them before impregnation is completed, the fertilisation never takes place. They, therefore, perform in such cases an essential part in the vegetable economy; and that they do so is testified by all the phenomena they exhibit. They turn to the sun, open only when it has a certain degree of power, and close at the setting of that luminary; their secretions are usually more odorous, more saccharine, and totally differing from those of the other organs of plants; and in the absence of light those secretions are not formed.

The corolla is absent in some plants, the Willow for example. But where it exists it is not always short-lived; for although in some, as the Cistus, the petals which open with the rising sun strew the border as it departs; so some, far from being ephemeral, continue until the fruit is perfected. The duration of the petals, however, is intimately connected with the impregnation of the seed, for in most flowers they fade soon after this is completed; and double flowers, in which it occurs not at all, are always longer enduring than single flowers of the same species. Then, again, in some flowers they become green, and perform the functions of leaves after impregnation has been effected. A familiar example occurs in the Christmas Rose (*Helleborus niger*), the petals of which are white, but which become green so soon as the seeds have somewhat increased in size, and the stamens and other organs connected with fertility have fallen off.

It is quite true that some fruit will not ripen if the part of the branch beyond is denuded of leaves; but this only shews that those fruits cannot advance when deprived of leaves as well as of calyx and corolla,—the only organs for elaborating the sap; and there are some flowers, as the *Daphne mezereon*, autumn Crocus, and Sloe, that have their flowers perfected and passed away before the leaves have even appeared.

That the petals in most plants perform an important part in elaborating the sap supplied to the fruit, is further proved by the flower being unable to bloom or to be fertile in an atmosphere deprived of its oxygen; and by their absorbing more of that gas, and evolving more carbonic acid than even a larger surface of leaves of the same plant.

So essential is oxygen to the fertility of a flower, that, as we shall hereafter have occasion to state, the stamens of one plant absorb two hundred times their bulk of the gas at the time of impregnation; and Saussure found that double, or unfertile flowers, do not absorb so much oxygen as those which are productive. The following table shows the number of volumes of this gas inspired by one volume of the flowers and leaves:—

	By the flowers.	By the leaves.
Mathiola incana (Queen's Stock), 6 P.M.	11·0	4·0
Ditto double-flowered	7·7	
Polyanthes tuberosa (Tuberose), 9 A.M.	9·0	3·0
Ditto double-flowered	7·4	
Tropæolum majus (Common Nasturtium), 9 A.M.	8·5	8·3
Ditto double-flowered	7·25	
Brugmansia suaveolens, 10 A.M.	9·0	5·0
Passiflora serratifolia, 8 A.M.	18·5	5·25
Daucus carota (Carrot), 6 P.M.	8·8	7·3
Hibiscus speciosus, 7 A.M.	8·7	5·1
Hypericum calicinum, 8 A.M.	7·5	7·5
Cucurbita melo-pepo (Pompion), male flowers, 7 A.M.	12·0	6·7
Ditto female ditto, 7 A.M.	3·5	
Lilium candidum (White Lily), 11 A.M.	5·0	2·5
Typha latifolia (Cat's-tail), 9 A.M	9·8	4·25
Castanea vesca (Chestnut), 4 P.M.	9·1	8·1

As the flowers inhale more oxygen than the leaves, so do they exhale more carbonic acid than these organs; and, unlike leaves, they pour it forth not only during the night, but in the sunlight—at least, Dr. Priestley, Dr. Ingenhouz, and M. Saussure found this was done by the Rose, Marigold, and Honeysuckle.

It is upon the oxygen combined with their parenchyma that the colour of a petal depends; for sulphurous acid (the fume arising from a burning match), which has a most powerful affinity for oxygen, destroys the hue of all coloured flowers, though it leaves that of white flowers unchanged. Mr. Smithson's experiments, and those of M. Schubler, seem to indicate that the colouring matter of flowers and fruits is fundamentally blue—rendered red by acids or the addition of oxygen, or yellow by the presence of an alkali or the subtraction of oxygen. Mr. Smithson says, that the colouring matter of the Violet is the same in the ruddy tips of the Daisy, Geranium, blue Hyacinth, Hollyhock, Lavender, and various Plums, in the leaves of the Red Cabbage, and in the rind of the salmon Radish. The acid which causes the red tint seems to be usually the carbonic.

M. De Candolle refers to a *memoire* of MM. Schubler and Funk on the colours of flowers, which they divide into two grand series corresponding to the two grand types of vegetable colour—yellow passing into red and white, but never into blue; and blue passing into red and white, but never into yellow. The former they call oxidated colours, the latter de-oxidated colours—green being the point of equilibrium between the two series. In the process of oxidation you have yellow-green, yellow, orange-yellow, orange, orange-red, red. In the process of de-oxidation you have green-blue, blue, violet-blue, violet, violet-red, red. To avoid the hypothesis of oxidation and de-oxidation, De Candolle denominates the two series the *xanthique* and *cyanique*, indicative merely of the blue and yellow types. In the xanthic series we find Cactus, Mesembryanthemum, Aloe, Cytisus, Oxalis, Rosa, Verbascum, &c. In the cyanic series we find Campanula, Phlox, Epilobium, Vinca, Scilla, Hyacinthus, &c.

White is excluded from either series, because it is thought to be doubtful whether it exists naturally in a pure state among vegetables. We do not see the ground of all this distrust, says Mr. Keith; why is not white to be called white? Surely the corolla of *Lilium candidum* is a very good example of the colour in question. The following changes of colour in quick succession are worthy of notice. The flower of *Hibiscus mutabilis* bursts open its integuments in the morning. Its corolla is then white; at mid-day it is flesh-coloured; at sunset it is red.

Black is also excluded with more apparent propriety, and yet it is to be found in the petals of some few flowers. *Pelargonium tricolor* and *Vicia Faba* will furnish examples.

The infusion of vegetable reds in alcohol takes a deeper tinge by the addition of an acid, but gives no uniform result by the addition of an alkali. The infusion of vegetable yellows is discoloured by the addition of an acid, but rendered more intense by the addition of an alkali. The infusion of vegetable blues is rendered red by the addition of acids, and green by the addition of alkalies—furnishing the well-known chemical test.

From what has been said, it follows, according to De Candolle, that the modifications of the *chromule*, occasioned by the degree of its oxidation, are the cause of the diversity of colours in the appendages of plants at least—that is, in the leaves, or modification of leaves, whether spathe, bract, calyx, or corolla. The degree of oxidation proper to leaves produces green; a higher degree leads to yellow and red; a lower degree to blue.

No seed ever attains the power of germinating unless the pollen from the stamens in the same, or some nearly-allied flower, has reached and impregnated its pistils. This was known to the most ancient of the Greeks; for Herodotus relates that the cultivators of the Date (*Phœnix dactilifera*) brought the flowers and, impregnation being effected, the hairs lose their rigidity, sink to the side of the tube, and the prisoner easily escapes.

The efficient agency of insects suggested that in hothouses, from whence they are almost totally excluded, other artificial means might be adopted with success to render fertile flowers that had hitherto failed in producing seed. One of the earliest instances on record of the experiment being tried with a prosperous result was on the *Abroma augusta*, which had bloomed unfertilely for several years in a hothouse at Berlin. The gardener by the aid of a hair pencil applied a little pollen to the stigma, and for the first time perfect seed was produced from which plants were raised. This practice is now very generally adopted to all plants cultivated under glass from which a produce of either fruit or seed is desired; for fruit rarely attains its full size if the seeds within are unfertilised. Thus the gardener always finds the advantage of using the camel-hair pencil to apply pollen to the stigmas of his forced Melons, Cherries, and Peaches.

That seed can be rendered fertile by the agency of other flowers than their own parent flower has long been known; for it had come within the observation of the Israelites some 3400 years now past, as may be gathered from Deut. xxii. 9; Jer. ii. 21; and Lev. xix. 19; but it was not rendered useful knowledge until the late President of the Horticultural Society, Mr. Knight, commenced his experiments in 1787. Mr. Bradley, seventy years before, had demonstrated that hybrid plants may be grown partaking of the qualities of both their parents; but to Mr. Knight first occurred the happy thought that the good characteristics of one parent might thus be employed to correct deficiencies which would otherwise occur in the offspring of another parent of the same species. Since his time this system of cross-breeding has been practised by gardeners upon almost every genus of plant that comes under their care, and by its agency the size, colour, and form of flowers have been improved and varied; the magnitude and flavour of fruits have been increased; and tender plants have been made to bring forth a hardy progeny.

Bradley had only carried out the suggestions of others; for both Lawson and Evelyn, half a century previously, had related that new Apples *ad infinitum* might be raised from kernels; and Bacon, whose penetrating eye pierced the most dark recesses of Nature, had observed that "The compounding and mixture of plants is not found out, which, nevertheless, if it be possible, is more at command than that of living creatures; wherefore, it were one of the most noble experiments touching plants to find this out; for so you may have a great variety of new plants and flowers yet unknown. Grafting doth it not: that mendeth the fruit, or doubleth the flower; but it hath not the power to make a new kind."

Our own observations, and those of others, justify the following statements as affording some guide to the raiser of varieties:—

1. The seed-vessel is not altered in appearance by impregnation from another plant; therefore, no hasty conclusion of failure is justified by that want of change. Mr. Beaton found the position in the growth of the seed-vessel altered in one instance, but this does not refute Mr. Knight's dogma that the appearance of the seed-vessel is not affected. The pods of *Imatophyllum miniatum* stand erect as the umbels of flowers, and the pods of *I. cyrtanthiflorum* hang down as the flowers do. By crossing the two, Mr. Beaton says, the pods of the former become as pendent as those of the latter.

2. The colour of the future seed, not of that first hybridised, seems to be most influenced by the male plant, if its seeds and flowers are darker than those of the female. Mr. Knight found that when the pollen of a coloured-blossomed Pea was introduced into a white one, the whole of the future seeds were coloured.

But when the pollen of a white blossom was introduced to the stigma of a coloured blossom, the whole of the future seeds were not white. Captain Thurtell, from his experiments on the Pelargonium, also informed us that he always found the colour and spot of the petals to be more influenced by the male than by the female parent. Indeed, all experience proves that the progeny usually, though not invariably, most resembles in colour the male parent.

3. Large stature and robustness are transmitted to the offspring by either parent. It does not absolutely matter, for obtaining this characteristic, whether it be the male or female which is large; but Mr. Knight generally found the most robust female parent produced the finest offspring.

4. Captain Thurtell, from lengthened observation and experiment, ascertained that *the form* of the petals in the Pelargonium follows most closely that of the female parent. Mr. Beaton says, "In Geraniums and Calceolarias the leaf and the colour of the flower go more after the pollen parent than not; but the rule is not absolute in any genus that has yet been proved. The seedlings take the habit of the mother if the father and mother are of the same constitutional strength; not otherwise in any instance within my knowledge. In all our common flowers the strength and the colour of the father, and the habit of the mother, are seen ten times to every instance of a perfectly intermediate degree, and both will get less and less to be relied on as the crossing of kinds is multiplied."

5. Mr. Knight says that the largest seed from the finest fruit that has ripened earliest and most perfectly should always be selected. In stone fruit, if two kernels are in one stone these give birth to inferior plants.

6. The time which elapses before seedlings attain a bearing age is very various. The Pear requires from twelve to eighteen

years; the Apple, five to thirteen; Plum and Cherry, four to five; Vine, three to four; Raspberry, two; and the Strawberry, one.

7. The most successful mode of obtaining good and very distinct varieties is to employ the pollen from a male in a flower grown on another plant than that bearing the female parent. To avoid previous and undesired impregnation, the anthers in the female parent, if they are produced in the same flower with the pistils, must be removed before the flower opens by cutting open the sides of the corolla by a sharp-pointed pair of scissors, and the flower enclosed in a gauze bag to exclude insects until the desired pollen is ripe. Another effectual mode of avoiding undesired impregnation is bringing the female parent into flower a little earlier than its congeners, and removing the anthers as above described; the stigma will remain a long time vigorous if unimpregnated.

8. Although the fertility of all the seed in one seed-vessel may be secured by applying pollen only to one style, even where there are several, yet the quantity of pollen is by no means a matter of indifference. Koëlreuter found that from fifty to sixty globules of pollen were required to complete the impregnation of one flower of *Hibiscus Syriacus;* but in *Mirabilis Jalapa* and *M. longiflora*, two or three globules were enough (*Willdenow*, 323); and in the case of Pelargoniums, Captain Thurtell says two or three globules are certainly sufficient.

9. M. Haquin, a distinguished horticulturist at Liège, has impregnated flowers of the Azalea with pollen kept six weeks; and Camellias with pollen kept sixty-five days. He gathers the stamens just previously to the anthers opening, wraps them in writing-paper, places them in a warm room for a day, collects the pollen they emit, and preserves it in sheet-lead in a cool, dry place. M. Godefroy suggests that two concave glasses, like those

employed for vaccine virus, would be better. The globules of the pollen must not be crushed. M. Haquin thinks the pollen of one year will be effective if preserved until the year following. Mr. Jackson, of Cross Lanes Nursery, near Bedale, says he has found the pollen of the *Rhododendron Smithii tigrinum* retain its fertilising power even for twelve months.

10. It is easy to discern whether impregnation has been effected, as in such case the stigmas soon wither. The stigmas which have not received the pollen remain for a long time green and vigorous. By the aid of the Stanhope lens Captain Thurtell thought he could discover the seed of the Pelargonium being closed over in the space of four hours after impregnation.

11. When double flowers are desired, if a double flower should chance to have a fertile anther or two, these should be employed for fertilisation, as their offspring are almost sure to be very double.

12. Many analyses of the pollen of various plants have been made by chemists without throwing any light upon hybridising. M. Grotthus found the components of twenty-six grains of the pollen of the Tulip were:—

Vegetable albumen	20·25
Malates of lime and magnesia	3·50
Malic acid	1·00
Malate of ammonia	1·25
Colouring matter	
Nitrate of potash	
	26·00

—(*Schweigger's Journ.* xi. 281.)

13. Superfœtation has been doubted, but as it occurs in the dog, we see no reason for disbelieving its possibility in plants. Captain Thurtell thinks it may be done by the bee introducing mingled pollens at the same instant. Then why not, if a similar mixture is inserted by the camel's-hair pencil of the cultivator?

We think it quite possible that different seeds in the same pericarp may be fertilised by pollen from more than one different male species; but nothing but the strongest evidence will convince us that the same seed can be effectually fertilised by more than one pollen. M. Foulard asks us to believe that his *Rosa perpetuosissima* had four male parents—the Bengal, the Tea, the Hundred-leaved, and the Noisette! Mr. Beaton does not believe in the possibility of superfœtation, but granting all the facts he mentions, and supposing his theory of impregnation to be true, we do not think they demonstrate beyond dispute the validity of his opinion. He says, "The doctrine of superfœtation has been pushed to its limits by Dr. Herbert and myself from 1836 to 1846, and neither of us believed one word of it. We could not produce the faintest trace of it. Hundreds of self-seedlings, without crossing, come as if they were of several parentages on the pollen side; and I am satisfied that scores of reputed crosses and crossings are of such origin, and merely an account of the trials that were made instead of the result obtained. No flower is more easy to prove by if more than one pollen can influence a cross than any of the common Geraniums. Their stigma is parted into five parts, and each part rolls back from the rest, or from the centre, and there are five seeds for every flower, corresponding to the five divisions of the stigma, or mother, as we say. Now, by applying five kinds of pollen, one kind to each division of the stigma, it is easy to conceive the possibility of each seed being influenced by that pollen only which dusted its corresponding division; and if the scientific explanation of the process by which the pollen reaches the ovum, or skeleton seed, were correct, superfœtation would be inevitable, and five kinds of progeny must be obtained from that flower so operated upon. The Hibiscus is the next easy flower to prove that superfœtation and the explained progress of the pollen to the ovary are both on a baseless foundation. I believe, from my own experience, superfœtation among vegetables is simply impossible; and that implies, also the impossibility of the pollen passing in grains in tubes of extreme tenuity to the embryo seed, which is the way it is explained by scientific men.

"The way I conceive the pollen must act in order to give the results with which many are quite familiar is this—for there is no other way of accounting for such results as we obtain. The pollen dust is in grains, like gunpowder; but the grains are inconceivably small. These grains swell on the application of moisture, and burst, at a certain stage of swelling, and the substance melts and is absorbed in the moisture as sugar is in tea or coffee. In every part of a plant, tree, or flower, from the tips of the extreme roots to the farthest-off leaf and petal, there is a constant moving of fluid, and the fluid is constantly changed in its nature; and there is a natural turn, or condition of the fluid, for every natural requirement of the system of which the plant is composed; and one condition is the fulfilment of the original mandate to increase and multiply by seeds. The viscid fluid on the stigma is the last condition required, and in that condition it is incapable of evaporation by the ordinary heat of the sun. Like other fluids, it cannot come there by chance, only by the usual process of circulation. The pollen sticks in that viscid fluid as flies stick in treacle; it cannot pass through it, or part from it; but it swells and bursts, and its contents are absorbed on the summit of the stigma. The passages in the style, from the stigma to the ovary, allow of the circulation and the return of this viscid fluid, now mixed with the contents of the pollen grains. Were the process different, superfœtation might be possible. But now see the barrier which hindered the influence of the five kinds of pollen on the five divisions of the stigma of a Geranium. The five kinds gave their contents equally to the fluid, but the fluid is not visible in this kind, and the one of the five which had the nearest affinity, as a chemist would say, to the mother, took the lead, and neutralised the effects of the other four."—(*Cottage Gardener*, xxiv.)

14. Plants nearly related—that is, closely similar in the structure of their various parts, are those only which will *immediately* impregnate each other; but it is impossible at present to say what families of plants may or may not be brought into fertile union through intermediate crosses. A very short time ago the Azalea and Rhododendron were thought incapable of such union, but this opinion is now exploded; for *Rhododendron Ponticum* has been fertilised with the pollen of *Azalea sinensis*, and the progeny between that evergreen and this deciduous shrub is the previously unknown phenomenon a yellow Rhododendron. Though such union may be effected, we entirely agree with Mr. Knight in anticipating that the progeny will be mules, incapable of producing offspring. It is quite true that many plants, said by botanists to be distinct species, have between them produced fertile seeds, but we incline decidedly to the opinion that this fact demonstrates that they are not distinct species, but only deviations from a common origin. For example: the Peach and Almond are considered distinct species by botanists, yet the fruit of both and of the Nectarine have been borne spontaneously by the same tree. "I cannot," says Mr. Knight, "by any means admit that plants ought to be considered of originally distinct species merely because they happen to be found to have assumed somewhat different forms or colours in an uncultivated state. The genus *Prunus* contains the *P. Armeniaca*, *P. cerasus*, *P. domestica*, *P. insititia*, *P. spinosa*, *P. Sibirica*, and many others. Of these I feel perfectly confident that no art will ever obtain offspring (not being mules) between the *Prunus Armeniaca* *P. cerasus*, and *P. domestica*; but I do not entertain much

doubt of being able to obtain an endless variety of perfect offspring between the *Prunus domestica*, *P. insititia*, and *P. spinosa;* and still less doubt of obtaining an abundant variety of offspring from the *Prunus Armeniaca* and *P. Sibirica*. The former (the common Apricot*) is found, according to M. Regnier, in a wild state in the oäses of Africa. It is there a rich and sweet fruit of a yellow colour. The fruit of *Prunus Sibirica*, seeds of which came to me last year from Dr. Fischer, of Gorenki, is, on the contrary, I understand, black, very acid, and of small size: but, nevertheless, if these apparently distinct species will breed together, and I confidently expect they will, without giving existence to mule plants, I shall not hesitate to pronounce these plants of one and the same species, as I have done relatively to the Scarlet, the Pine, and the Chili Strawberries. Botanists may, nevertheless, if they please, continue to call these transmutable plants species; but if they do so, I think they should find some other term for such species as are not transmutable, and which will either not breed together at all, or which, breeding together, give existence to mule plants.

"If hybrid plants had been formed as abundantly as Linnæus and some of his followers had imagined, and such had proved capable of affording offspring, all traces of genus and species must surely long ago have been lost and obliterated; for a seed-vessel, even of a monogynous blossom, often affords plants which are obviously the offspring of different male parents; and I

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* The early period at which the Apricot unfolds its flowers, leads me to believe it to be a native of a cold climate; and I suspect the French word Abricot, the English Apricock, and the African Berrikokka, to have been alike derived from the Latin word præcocia, which the Romans (there is every reason to believe), pronounced Praikokia, and which was the term applied to early varieties of Peaches, which, probably, included the Apricot. The Greeks also wrote the Latin word as I suppose the Romans to have pronounced it.—*Harduoin's Ed. of Pliny, lib.* 15, *sec.* xi.

believe I could adduce many facts which would satisfactorily prove that a single plant is often the offspring of more than one, and, in some instances, of many male parents. Under such circumstances, every species of plant which, either in a natural state or cultivated by man, has been once made to sport in varieties, must almost of necessity continue to assume variations of form. Some of these have often been found to resemble other species of the same genus, or other varieties of the same species, and of permanent habits, which were assumed to be species; but I have never yet seen a hybrid plant capable of affording offspring which had been proved by anything like satisfactory evidence to have sprung from two originally distinct species; and I must, therefore, continue to believe that no species capable of propagating offspring, either of plant or animal, now exists which did not come as such immediately from the hand of the Creator."

To the opinion of Mr. Knight as to the non-interbreeding of what are considered distinct genera and species we do not subscribe; and we are sustained in thus differing from his opinion not only by Linnæus, but by one of the most practised of modern hybridists, the late Dr. Herbert. After stating many facts, he thus concludes:—"Can we, in the face of these phenomena, assert that no vegetable since the period before the sun and moon gave it light, no bird or fish since the Almighty called them forth from the salt mud, no creature of the earth since it was evoked from the dust, can have departed from its precise original structure and appearance? Let us be more humble in our assumptions of scientific knowledge, less bigoted and self-sufficient in our examination of revealed truth, and let us give glory to the infinite and unfathomable power and wisdom of God. I call it self-sufficient to hold that ancient and obscure words can have no possible meaning but that which we have been in the habit of attributing to them inconsiderately. It may be unacceptable to the botanist, who has been accustomed to labour in his closet over dry specimens, and thinks he can lay down precise rules for the separation of genera, and looks with complacency upon the scheme he has worked out, to find that the humblest gardener may be able to refute him, and to force him to reconsider the arrangement he has made; but the fact is so. The cultivator has the test of truth within his scope: and, far from being an evil, I look upon it as a great advantage, because it will lead the industrious and intelligent gardener to take a higher view of the objects under his care, and to feel his own connection with science; and it will force the scientific to rely less on their own dictation, and to feel that they must be governed by natural facts, and not by their own preference."

Although we entertain a strong opinion that many botanically widely-divided genera and species can interbreed and have interbred, producing new forms which in their turn have been classified as new genera and new species, yet there is no doubt, as observed by Mr. Fish, that cross-breeding is most easily effected between distinct varieties of the same species. Such crosses are also the most valuable, because many of them, if kept distinct, will reproduce themselves true from seed—such, for instance, as our garden varieties of the Cabbage. They will also cross with other varieties, which also will be reproductive. But this reproduction can be carried only to a certain point, that point being determined by no known rules, but depending upon something constitutional in the nature of that tribe of plants. Thus we have found that Calceolarias long crossed would not produce seed, though apparently possessing perfect stamens and pistils; neither would they do so when fecundated by another variety as high bred as themselves, though seeds would be produced when fecundated with the pollen from some of the coarser, more original, types of the species; but, of course, in that case, the progeny were defective in form and beauty. Even when the seed of the variety continues fertile, and they are not averse from joining issue with kindred varieties, still a deterioration of quality will in time ensue, similar to what takes when the breeding in-and-in system among animals is adopted. When, therefore, a superior flower—root, vegetable, fruit, or grain—is obtained, care should be taken not only to keep the variety true, but experiments should be made to cross it with some other dissimilar, and yet desirable variety, in the hope of obtaining a fresh production which may take the place of both its parents when they are beginning to wear out.

Many experiments would tend to confirm the idea that manner and style of growth will be chiefly regulated by the characteristics that belong to the plant that possesses the pistil, while the flower and other parts of fructification will be influenced by the plant from whence the pollen of the stamens was taken. Thus, when the beautiful *Fuchsia fulgens* was introduced by the house of Lee, great hopes were entertained of what could be done by hybridising it with such old varieties as *globosa*. But as most of the attempts were made by selecting *fulgens* as the mother plant, the progeny were distinguished by large leaves and small flowers; whilst what was desirable was the large flowers of *fulgens*, and the small, compact foliage of *globosa*. Again, for example: our earliest Peas—such as the *Albert* and the *Frame*—are hardy and stubby in their growth; but then no one will use them after the more tender, later, but large and sweet Peas of the various *Marrowfats* appear. To cross the *Marrow* with the early Pea would have the tendency to give a variety possessing the small flavourless fruit of the latter with the tender and late habits of the former. By making the early Pea the mother plant, and the large high-flavoured *Marrow* the father, there is a likelihood of obtaining early Peas, hardy in their nature, large in size, and good in flavour.

We will conclude this branch of our subject with a few practical directions, furnished by Mr. Beaton, for conducting cross-breeding in the Gladioli and Geranium genera. "There is only one style in the centre of a Gladiolus, and that divides into three parts, or stigmas, at the top, and is the part to dust the pollen on. When the parts are ready for the pollen, these stigmas open into two halves, or are dilated, as botanists say, and the edges of these little openings are the real stigmas. The anthers which bear the pollen are always in threes in this flower; each flower invariably having only three stamens, which hold up the anthers. When the pollen is ripe, the anthers burst from the top to the bottom, and there is a furrow down the centre of each opening, so that the anthers are each in two parts. The easiest way of applying this pollen to the stigma is to cut off the flower whose pollen you are to use, then with a penknife cut off first the petals down as far as they are split, then you will only have the tube of the flower to which the bottoms of the stamens are attached; then, with the point of the knife, single out one of the stamens with a ripe anther, keeping hold of it between the knife and your thumb, and in that position apply the anther backwards and forwards on the stigma, when you will see the dusty pollen adhering each time to the stigmas, and then the work is done. It is always a good plan, however, to apply the pollen twice—say in the morning and afternoon; or, after the interval of a day or two, with some flowers whose stigmas remain fresh for several days. Where a cross is difficult to be obtained, it is a good plan to use pollen from two or three flowers, and from as many plants, if they are at hand; but the pollen plants must always be of the same kind."

In cross-breeding Geraniums, if you look at one of their flowers just opening, you will see the pistil all in one; a few hours after that it begins to divide at the point into five divisions;

and finally, each division rolls back so as nearly to embrace the style: in that state it is fit to receive the pollen for one, two, or three days, according to the state of the weather. When the pollen parent is scarce, take only one stamen, and dust all over the five turned parts their whole length, and the work is finished. When we have plenty of flowers we pull one off for the pollen, cut away the petals, and apply all the anthers at once. Thus about eight or ten flowers can be crossed in one minute.

Cross-breeding, aided by cultivation, gives birth to those splendid objects of the gardener's care, generally designated *double flowers*, which are such beauteous ornaments of our borders and parterres. To the uninitiated it seems incredible that the double Moss Rose should be a legitimate descendant from the Briar; neither do the flowers of the Fair Maid of France appear less impossible derivatives from those of the *Ranunculus platanifolius;* nor Bachelor's Buttons from the common Buttercup, yet so they are. Double flowers, as they are popularly called, are more correctly discriminated as the full flower, the multiplicate flower, and the proliferous flower.

The full flower is a flower with its petals augmented in number by the total transformation into them of its stamens and its pistils. One-petalled flowers rarely undergo this metamorphosis; but it is very common in those having many petals, as in the Carnation, Ranunculus, Rose, and Poppy. But this is not the only mode in which a flower becomes full; for, in the Columbine (*Aquilegia*), it is effected in three different ways—viz., by the multiplication of the petals to the exclusion of the nectaries; by the multiplication of the nectaries to the exclusion of the petals; and by the multiplication of the nectaries whilst the usual petals remain. Radiated flowers—such as the Sunflower, Dahlia, Anthemis, and others—become full by the multiplication of the florets of their rays to the exclusion of the florets of their disks.

On the contrary, various species of the Daisy, Matricaria, &c., become full by the multiplication of the florets of the disks.

The multiplicate flower has its petals increased by the conversion of a portion of its stamens, or of its calyx, into those forms. It occurs most frequently in polypetalous flowers. Linnæus gives the only instances we know of the conversion of the calyx into petals, and these are to be observed in the Pink (*Dianthus caryophyllus*), and a few of the Alpine Grasses.

A proliferous flower has another flower, or a shoot produced from it. This is most strikingly exemplified by that variety of Daisy popularly known as the Hen-and-chickens. It occurs also more rarely in the Ranunculus, Pink, Marigold, and Hawkweed. A leafy shoot often appears in the bosom of the double-blossomed Cherry, Anemone, and Rose.

The influences regulating the production and development of leaves and flowers are these :—If an excess of water to the roots, or too little light to the superior parts of plants be applied, they produce an increased surface of leaf, and few or no flowers; for it is a wise power given to them by their Creator that those parts shall increase in size, which circumstances render most necessary. An excess of moisture requires an increased transpiratory surface, as in the case of *Solandra grandiflora* before mentioned.

This knowledge that flower-buds and leaf-buds are mutually convertible is no novel discovery, much less a visionary theory, for, as long ago as the beginning of 1817, the late Mr. Knight thus expressed the results of his experience, when writing to the London Horticultural Society relative to the pruning of Peach trees :—"The buds of fruit trees which produce blossoms, and those which afford leaves only, in the spring, do not at all differ from each other, in their first organisation as buds. Each contains the rudiments of leaves only, which are subsequently transformed into the component parts of the blossom, and, in some species, as the fruit also." And he then proceeds to state his experience that leaf-buds of the Apple and Pear have been thus transformed, and of his having succeeded in obtaining every gradation of monstrous transformation, adding, that "every bunch of Grapes commences its formation as a tendril, it being always within the power of every cultivator to occasion it to remain a tendril," either by removing a considerable portion of the leaves, or reducing the temperature and light to which the Vine is exposed.

Turning to the results obtained by practice in endeavouring to obtain double flowers, we learn from Mr. Fish that, making allowance for exceptions, the following may be adduced as leading general propositions:—First. To obtain double flowers from seed, dependance must not be placed upon the influence of a stray stamen that was not converted into a petal or flower-leaf, but means must be taken to make the seeds possessed of a property which otherwise they would not possess, by superinducing a highly elaborated, full, plethoric habit in the seeds. This can only be done by stimulating the plant with high cultivation at a certain period, after the flower-buds appear, and then by removing the greater portion of the seeds. If the stimulus is applied at an earlier period, the plant will increase greatly in luxuriance; by giving it thus later, a greater degree of strength is conveyed to the flowers. By thinning these flowers, or the seed-vessels, as soon as formed, so as to have only a very few seeds to ripen, these, in consequence, acquire a full plethoric habit; and we know that in the vegetable and animal world alike this state is opposed to productive fruitfulness, while in the deplethoric state it is encouraged. From a full double flower, therefore, we expect and obtain no seeds. From such plants as Balsams, which, though said to be double, yet produce seeds, the rendering them more double must be obtained by the high cultivating and seed-thinning process. In their case, as well as some others, compactness of growth and clearness of colour seem to be gained by preserving the seeds for several years; the fresher a seed, the sooner will it vegetate, and the stronger and more luxuriant the plant. In double composite flowers, such as the Dahlia, which consist of a number of florets upon a common receptacle, though the most of these florets may have their parts of fructification changed into petals, others may be unchanged, though they remain unnoticed until the petals fall off; and from these, when seeds are produced, more double flowers may be expected than from seeds saved from more single varieties, because possessing a greater constitutional tendency in that direction. This will more especially be the result when, as in other cases, high cultivation is resorted to whenever the seed appears. Thus something like superfœtation is induced in the seed, which leads it afterwards, when sown, to develope itself more in leaves and petals (which botanists tell us are the same thing), instead of flowers producing seed; and this altogether independent of the culture it receives for that season. When any of our friends, therefore, look somewhat disconsolate on their beds of Stocks nearly all single, they may rest next to assured that the culture they imparted had little or nothing to do with it. The seeds they sowed would have been single under any circumstances. The matter is different in the perennial plants—such as the Daisy and the Primrose. Without resorting to seeds at all, the plant from being divided, having its soil frequently changed and stimulated by rich compost, will often gradually change from the single into the double-flowering condition upon exactly the same principles; luxuriance and fruitfulness being ever opposed to each other.

Secondly. On much the same principle, care should be taken to preserve double flowers, when propagating them by cuttings, runners, and divisions of the root, by giving them the same careful cultivation, otherwise they are apt to return to the primitive single state. To secure this object effectually, two considerations should be attended to. If a rich stimulating system of cultivation is at first resorted to, there will be the likelihood of having a luxuriant development of stem and leaves, at the expense of depriving the flowers of their requisite proportions. In all free-growing luxuriant plants it will be wise policy not to over-stimulate the plant until the bloom appears; and the increased nourishment judiciously given will then enlarge the size of the flower, while the rest of the plant would continue to maintain a comparative dwarf and stubby character. In choosing seed when it is produced, let it be selected from such plants. Then, again, if the size of the flower is to be maintained, and prevented degenerating into its primitive condition, rich composts should not only be used, but fresh soil, if possible, given to them every year.—(*Cottage Gardener*, iv.)

Another practical man, Mr. Wooler, Geneva House, Darlington, remarks that, "In Germany, seed-growing and thus doubling flowers have been greatly effected by rich culture in pots, and selection of plants with indicating a predisposition to produce excess of petals around the corolla, but particularly when the stamens are converted into petals. From my own experience, I have learnt that a bed, made up on the north side of a three-feet-high new Quickset hedge, which was not too dense or tall to prevent both air and light to permeate, yet, at the same time, afforded shade from the parching sun, produced most flowers from seedlings (which had been raised in light, rich earth, in pans, and then pricked out), partly semi-double, and which, when removed to poorer soil, lost this disposition of their stamens to become petals. I would, therefore recommend such a border made of stiffish loam, with plenty of old Melon or hotbed manure dug into it; although this class of plants will, with due shade and moisture, not only flower best, but these flowers will, under such circumstances, be much larger than if exposed to too much sun and the wind. Were I to make a renewed attempt, I would have every plant in a pot, so that it might be completely under control; and when the seed was perfecting, it might, if needs be,—as, for instance, if the weather should prove wet and cloudy, so as to unduly promote the growth of leaves,—be removed to a drier and more sunny situation.

"Of course, only flowers with six, seven, eight, or more petals, or the stamens transformed into petals, or with any other indication of a predisposition to produce double flowers, should be allowed to remain upon the plant.

"I have heard it said that the double Primrose, if planted in poor soil, will return to the single state. I have tried, but never could accomplish this; my object was to endeavour to get these double flowers with duly-formed seed-vessels and pistilum to enable me to impregnate it, and get seed from it. The double varieties are so fully double, that seed-vessel, stamen, and pistilum, are all converted into petals; and thus, failing in these organs, the flowers are so much more enduring than the single ones, in which, as soon as the ovarium is impregnated, the petals are gradually deprived of their nutriment.

"Flowers, not 'pin-headed,' are difficult to cross, as it is a tedious operation to cut out with scissors the stamens before the pollen has been scattered. I tried many experiments, some years ago, and found that the whole of the corolla, with the stamens, might be amputated without diminishing the power to perfect seed. But, for the sake of doubling this cannot be recommended; for, as the stamens grow from the tube of the corolla, no doubt the petals must have some effect to confer. Besides, as the object is to induce the greatest predisposition to multiply both growth and number of petals, these should be given all encouragement, and several of the pips removed, so that the few remaining may have no stint of the requisites for their development."—(*Ibid.*, xxii.)

For the production of double flowers, a full exposure to light is as essential as an abundant supply of nourishment; for a deficiency of light decreases the decomposing power of the leaves. In proportion to the deficiency of light does the plant under glass become, in the gardener's phraseology, drawn—that is its surface of leaves becomes unnaturally extended in the vain effort to have a sufficient elaboration of the sap effected by means of a large surface exposed to a diminished light, for which a less surface would have been sufficient if the light were more intense. The plant with this enlarged surface of leaves becomes unfruitful, and produces a deficiency of flowers, the sap being expended in the production of leaves.

Mr. Williams made some experiments intended to illustrate this point, and he found that varieties of the Vine, when grown under white or crown glass, under green glass, and in the open air, had the diameters of their leaves, in inches, altered as in the following table :—

Name.	White.	Green.	Open Air.
White Muscat	8	12	7
Malmsey Muscadine	6½	12	6
Syrian	8	14½	...
White Sweetwater	6	9	6
Black Hamburgh	8	13½	...
White Frontignac	6	11	6
White Muscadine	6	11	6

From the foregoing facts, we conclude that a due supply of moisture, but rather less than the plant most delights in when the production of seed is the desired object, a superabundant supply of decomposing organic matter to its roots, and an exposure to the greatest possible degree of sunlight, are the means to be employed most successfully to promote that excessive development of the petals which characterises double flowers.

By these means a greater amount of sap is supplied to the flower than the natural extent of petal can elaborate; and, following the laws of Nature already specified, those parts required for the extra elaboration are developed at the expense of those not demanded for the purpose. In double flowers, too, as was observed by the late Sir J. E. Smith, the corolla is much more durable than in single ones of the same species, as Anemones and Poppies; because, as he conceived, in such double flowers the natural functions not being performed, the vital principle of their corolla is not so soon exhausted. Advantage may be taken of this to prolong the duration of flowers by cutting away the pistils, or stamens, whichever are least conspicuous, with a sharp pair of pointed scissors.

We will conclude our observations on flowers, by observing that their fragrance is rarely considered as an object of the gardener's care. This is a mistake. To improve the perfume of a flower, to add fragrance by cross-breeding to a kind usually destitute of such a source of gratification, and to render the atmosphere of a conservatory, greenhouse, or stove, more grateful by a due combination of odorous flowers, are objects quite worthy of a gardener's attention, and they are objects he can readily attain.

That cultivation and cross-breeding can intensify the odour of plants, and even impart it to seedlings, one of the parents of which was scentless, all gardening experience testifies. Yet there is a wide field still to be won. Why, for instance, should not a Rose be obtained having petals gifted with the substance and brilliant colour of *Général Jacqueminot*, and the high fragrance of the old *Moss Rose?*

In tenanting our greenhouses and conservatories, also, there is a notable opportunity for the gardener to prove that there is high art in the combination of odours as well as of colours. In preparing delicate perfumes it is seldom that a single oil, or the parts of one plant only, are employed for the purpose. The art of the perfumer is shown by the skill with which he combines together the odoriferous principles of various flowers, or mingles together many volatile essences, so as to produce a more grateful scent than any single plant can be made to yield. In this way the *huille de mille fleurs* (oil of a thousand flowers) professes to be made; and the secret recipe for the popular *Eau de Cologne*, called the perfection of perfumery, depends for its excellency on the same principle.—(*Report of the Juries of the Great Exhibition of* 1851.)

Odours represent very much the notes of a musical instrument. Some of them blend easily and naturally with each other, producing a harmonious impression, as it were, on the sense of smell. Heliotrope, Vanilla, Orange blossom, and the Almond blend together in this way, and produce different degrees of a nearly similar effect. The same is the case with Citron, Lemon, Vervain, and Orange-peel, only these produce a stronger impression, or belong, so to speak, to a higher octave of smells. And again, Patchouly, Sandal-wood, and Vitivert form a third class. It requires, of course, a nice or well-trained sense of smell to perceive this harmony of odours, and to detect the presence of a discordant note. But it is by the skilful admixture, in kind and quantity, of odours producing a similar impression, that the most delicate and unchangeable fragrances are manufactured. When perfumes which strike the same key of the olfactory nerve are mixed together for handkerchief use, no idea of a different scent is awakened as the odour dies away; but when they are not mixed upon this principle, perfumes are often spoken of as becoming sickly or faint, after they have been a short time in use. A change of odour of this kind is never perceived in genuine Eau de Cologne. Oils of Lemons, Juniper, and Rosemary are among those which are mixed and blended together in this perfume. None of them, however, can be separately distinguished by the ordinary sense of smell; but if a few drops of hartshorn be added to an ounce measure of the water, the Lemon smell usually becomes very distinct.

The gardener must also keep in mind that some flowers give forth their odours chiefly during daylight, and especially during its most sunny hours. Examples of these flowers are afforded by many of the Labiatæ, the Orange, and the Cistus families. Others, especially such as have dark, lurid colours, such as *Hesperis tristis* and *Gladiolus tristis*, are fragrant only during the hours of night.—(*Johnston.*)

The gardener has also the power to intensify the fragrance of flowers by the soils and manures which he employs. This is almost an untrodden path in his art, but it is well worth exploring, for it would lead to a wide-spread source of additional gratification. That the gardener has such a path to explore is proved by the fact that the delicacy and fragrance of a plant's odour is found to vary considerably with the locality in which that plant has been grown. Thus on the shores of the Mediterranean, near Grasse and Nice, the Orange tree and the Mignonette bloom to perfection in the low, warm, and sheltered spots; while, in the same region, the Violet grows sweeter as we ascend from the lowest land and approach to the foot of the Alps. So Lavender and Peppermint grown at Mitcham, in Surrey, yield oils which far excel those of France or other foreign countries, and which bring eight times the price in the market. This effect of soil and climate on the odour of plants resembles that which they exercise in so remarkable a manner on the narcotic constituents of Tobacco, Opium, and Hemp.

It does not immediately come within our province to consider what is the agent rendering any part of a plant odoriferous, but we may observe that it usually arises from a highly volatile oil, and is often called its *aroma.*

The relation between the colours and fragrance of flowers has not escaped the attention of some botanical physiologists, and the following are the results arrived at by Dr. Landgrebe and MM. Schubler and Köhler :—

As the white-flowering species are most numerous, so are they the most generally odoriferous. Among the coloured flowers, the red have the greatest tendency, and the blue the least, to the formation of odoriferous substances. On the average, there is only one odoriferous species in ten.

If we further separate the species having an agreeable, from those having a disagreeable, smell, we obtain the following results :—

Colour.	No. of Species.	Having an agreeable odour.	Having a disagreeable odour.	Mean in 100 species.	
				Having an agreeable odour.	Having a disagreeable odour.
White	1193·5	755	12·	14·66	1·00
Red	923·	76·1	9·3	8·24	1·01
Yellow	951·3	61·1	14·5	6·42	1·52
Blue	595·5	23·3	7·5	3·91	1·26
Violet	307·5	17·5	6·0	5·68	1·95
Green	153	10·3	2·5	6·73	1·62
Orange	50	1·0	2·0	2·00	4·00
Brown	18·5	0·	1·2	......	6·48
Coloured flowering altogether	2997·8	189·3	43·0	6·31	1·43

From this table it is apparent that white-flowering plants are much more frequently agreeably perfumed than coloured-flowering; for in 100 white-flowering plants, there are, on an average, 14·6 having an agreeable smell, and only one having a disagreeable; whereas in the same number of coloured-flowering plants there are 6·3 having an agreeable odour, and 1·4 having a disagreeable.

There are, therefore, among the white-flowering plants a greater number of species having an agreeable smell than among the coloured-flowering, in the proportion of 63·146; on the contrary, among the coloured-flowering there are a greater number of plants having a disagreeable smell than among the white-flowering, in the proportion of 10·14.

The individual colours exhibit further the following differences, when the flowering odoriferous species in each colour are reduced to 100 agreeable-smelling species: there are, according to the above relations, in the flowers of 100 agreeable-smelling species—

Having a White colour ...	6·8	Having a Violet colour ...	34·2
„ Red „ ...	12·2	„ Green „ ...	24·2
„ Yellow „ ...	23·5	Of coloured flowers altogether	22·7
„ Blue „ ...	32·2		

The orange and brown-flowering plants seem to possess a larger number of disagreeable than of agreeable-smelling species. Among 4200 species examined, there are two brown plants which are odoriferous—viz., *Delphinium triste* L., and the brownish-red flowering *Scrophularia aquatica* L.; and three odoriferous orange and yellowish-red flowers, the *Nicotiana glutinosa* L., *Alestris uvaria*, L., and *Verbascum versiflorum* Schrad. The last alone has an agreeable smell; the others have a disagreeable odour. It is well known, and not on that account the less remarkable, that the great genus Stapelia, which so frequently exhibits flowers of a yellowish-red or yellowish-brown colour, includes so many species having a disagreeable odour, often like that of carrion; further, that two species, distinguished by their peculiarly offensive odour—viz., the *Arum divaricatum* W., and the *Asarum Europæum*, should possess a dark brown, passing into violet, corolla.

We perceive, then, from these details, that white flowers are, for the most part, and especially, sweet-smelling; but the family of the Cruciatæ is in this respect an exception, for many of the species have non-odoriferous flowers, whereas they possess as a compensation a transient sharpness; as in the genera Cochlearia, Lepidium, Cardamine, Thlaspi, Sisymbrium, Senebiera, &c. Among the monocotyledons, we observe the same thing in the genus Allium.—(*Edin. Phil. Journ., January*, 1837.)

* * *

THE FRUIT AND SEED.

When the blossom begins to fade, "the joy of the plant" is departing, but other beauties and parts more important to the animal world are advancing to succeed the decaying inflorescence. The fruit and the seed are then entering on the season of maturity; will soon offer to the palate some of our most delicious luxuries, nor will beauty of colour be altogether wanting. "The ripened tints of autumn are equally pleasing with the bloom of spring, and the colours of the Peach and Apricot, the Plum and Cherry, are in nothing inferior to the blossom which preceded them."

The petals, stamens, pistils, and frequently the calyx, having performed their destined functions, fall and leave the ovary, or embryo seed-vessel, remaining attached to the parent plant. The embryo increases in growth and becomes the fruit, which title is not restricted merely to such as are edible, but includes every matured ovary with its contents, and which matured ovary, in botanical language, is known as the *pericarp*. This takes various distinct forms, and as all are subjects of interest to the gardener, each may have advantageously a separate notice.

1. The capsule is dry, woody, or membranous, containing one or more cells—as in the Poppy, Clematis, Ash, and Pæony.

2. The siliqua, or pod, is long, dry, and has two valves separated by a linear receptacle, along the edges of which are ranged the seeds alternately. Instances are in the Stock, Wallflower, and Cabbage.

3. The legume has two dry, long valves united by a seam at their edges, having no dividing receptacle as in the pod, but with

the seed attached to one edge—as in the Pea, Bean, Laburnum, and other leguminous plants.

4. The drupe, or stone, with fruit usually soft and fleshy, not separating into valves, but enclosing a woody nut to which it is attached—as in the Peach, Plum, Olive, and Cherry; but sometimes the fruit is more dry—as in the Almond and Cocoa Nut.

5. The pome, or apple, is usually fleshy like some drupes, but enclosing a capsule with several seeds, instead of a nut—as in the common Apple and Pear.

6. The berry is pulpy, and has its seed embedded in its substance as in the Asparagus, Currant, Gooseberry, Strawberry, Raspberry, Potato, Orange, Melon, Cucumber, and Medlar.

7. The strobile, or cone, is scaly, tough, and woody, formed of the catkin or calyx which has become indurated. It is the seed-vessel of the Pine tribe, the Plane tree, and Comptonia.

Though thus varying in form, they have all one common office —the protection and maturing of the seed they contain. To effect this they require a due supply of sap as well as of the peculiar juice of the parent plant; for they make no further advance if the entire wood be cut through below them, so that they are only attached to the parent by a strip of bark; neither will they advance, though fully supplied with sap, if the peculiar juices are cut off from them by removing the leaves that are above them on the branch. The loss of such leaves, as previously stated, may be supplied by inarching to the denuded branch one still retaining its foliage. We have also shown that the application of a ligature to a Peach or Apple, shows by the enlargement on one side of the ligature that the sap really circulates through them.

Yet each fruit has a peculiar elaboration of its own to perform; for though the fluids afforded by the branches and leaves be nearly similar, yet each fruit differs from another in fragrance and flavour: six different varieties of the Peach and of the Apple, budded upon the same branch, still retain their particular times of ripening, and their distinctive colours and flavours. Now the processes going on at different periods of a fruit's growth are very opposite in their character. During their green and growing state they are usually converting gummy matter into an acid; but during the ripening they as commonly are converting an acid into sugar.

To convert gum or mucilage into tartaric acid, as in the early growth of the Grape, oxygen in excess should be absorbed; for their relative components stand thus:—

	Gum.	Tartaric acid.
Carbon	42·23	24·05
Oxygen	50·84	69·32
Hydrogen	6·93	6·63
	100·00	100·00

They might, therefore, be expected to absorb more oxygen than the leaves; and this is actually the case, for though a Vine branch will continue to vegetate in a glass globe hermetically sealed, yet the Grapes upon it will not increase in size unless oxygen gas be from time to time admitted. The same phenomenon occurs during the ripening of the Grapes; oxygen has to be absorbed during the conversion of the tartaric acid into sugar, but a larger volume of carbonic acid has to be evolved, and this is coincident with the result of well-established experiments, uniformly testifying that carbonic acid is given out abundantly by ripening fruit. "Six equivalents of tartaric acid," says Liebig, "by absorbing six equivalents of oxygen from the air, form Grape sugar, separating at the time twelve equivalents of carbonic acid."

This, however, is not the only decomposition taking place whereby sugar is formed in ripe fruit; but there is sufficient reason to believe that its mucilage and starchy constituents are converted into saccharine matter by the combined agency of warmth and the acids. It is thus that Apples are rendered so much sweeter by baking, and M. De Candolle states that the pulp of Apple dissolved in water with a vegetable acid is converted into sugar; that gummy matter obtained from starch and mixed with tartaric acid, aided by warmth, effects a similar transmutation; and M. Kirchoff proved long since that starch, digested at a gentle heat with diluted sulphuric acid, becomes sweet.

Dr. Kane observes that, "If we examine the composition of a young Apple, we find it nearly tasteless, and to consist of a loose ligneous tissue, in which is embedded a quantity of ordinary starch; as its growth proceeds, the starch appears to diminish in relative amount, the fruit become sour, from the presence of tartaric acid; after some time the acidity bcomes of a much less disagreeable kind, and the tartaric acid is found to be replaced by malic acid; whilst the tissue is found to be infiltrated with pectin or pectic acid; finally, in the next and concluding stage of maturity, the malic acid disappears, its place being taken by more fully developed pectine and sugar. Oth er reactions appear to be due to the decomposition of the acid constituents of the fruit.

"Fremy has shown that the origin of the pectin of the fruit is to be found in a body having a great analogy to lignine or cellulose, and which he terms *pectose;* when this is boiled it changes into pectine, and this change naturally takes place in the fruit under the influence of a natural ferment, *pectase,* which is analogous to diastase. This by its further action converts the pectine into pectic acid, or into other derived acids which resemble it in properties, and only differ in constitution by the abstraction or addition of the element of water. The *pectic fermentation* being like the lactic, unaccompanied by the evolution or absorption of any gas. Fremy found the formula of pectine to be $C_{64} H_{48} O_{64}$, and that of metapectine $C_{64} H_{46} O_{62}$, in his new researches. The pectine of the ripe fruit, therefore, has no relation either to the starch or to the acid the unripe fruit contained.

"The sugar of the ripe fruit is derived, according to all appearance, from the starch which the green fruit contains; either by the pectase ferment, or by the contact of the organic acid, the saccharine fermentation is induced, and Grape sugar, which is the sugar of fruits, is generated. It is not known whether the tartaric acid is first secreted as such by the plant, or whether it arises from the decomposition of any previously existing body, but it is easy to see how the malic acid is formed from it. Thus, malic acid, $C_8 H_4 O_8$, may be produced by the direct abstraction of oxygen from the tartaric acid, $C_8 H_4 O_{10}$, or, at those periods when the reverse action takes place and carbonic acid is given off, six atoms of tartaric acid, $C_{48} H_{24} O_{60}$, may produce five atoms of malic acid, $C_{40} H_{20} O_{40}$, with eight atoms of carbonic acid $C_8 O_{16}$, and four of water, $H_4 O_4$."—(*Elements of Chemistry.*)

We know from the experiments of Berard that, when unripe fruits are plucked, they do not ripen if excluded from the access of oxygen gas; but that in the air they ripen, absorbing oxygen at the same time, and giving off carbonic acid.

During the ripening of the fruit, the woody or cellular fibre it contains gradually diminishes, and is converted into sugar. This is familiarly noticed in some species of hard or winter Pears. In sour fruit, the cellular fibre seldom exceeds 2½ per cent. of their whole weight; in ripe fruits, however, it is still less, and as the constitution of this substance is so analogous to that of Grape sugar, there is no difficulty in understanding that it may be readily converted into the latter, through the agency, probably, of the protein compounds which are present in the fruits.

The relative proportions of sugar, gum, cellular fibre, acid, &c., in the Peach at three stages of its growth were found to be as follows:—

	Unripe.	Riper.	Fully ripe.	
Sugar	trace	6·64	16·48	per cent.
Gum	4·10	4·47	5·12	„
Cellular	3·61	2·53	1·86	„
Malic acid	2·70	2·03	1·80	„
Vegetable albumen	0·76	0·34	0·17	„
Water	89·39	84·49	74·87	„

So that though in this fruit some of the acid and woody fibre had disappeared *during the ripening*, yet the greatest portion of the sugar contained in the ripe fruit had evidently been derived directly from the ordinary food of the plant.—(*Johnston's Agric. Chemistry.*)

During the ripening process, both of fruit and seed, all plants give out more carbonic acid and less oxygen than during the earlier stages of their growth, and thus is given a reason why room plants should be removed when once past their meridian vigour.

Now, to effect these changes, to ripen perfectly—that is, to generate its best proportions of sugar and aroma, every plant requires a certain amount of sap, light, heat, air, and moisture; and how these are best secured to them, so far as training and the atmosphere around them are concerned, may be here appropriately considered. These circumstances, so far as the roots, flowers, and leaves were also concerned, have been examined in previous chapters.

The more rapidly, and, consequently, the greater the amount of sap poured into the branches, the greater surface of leaf is required for its elaboration; and, as the plant has power given it of increasing most freely, and even at the expense of others, those organs which are most necessary, the leaves of such abundantly supplied branches are increased both in number and size, whilst the blossom is proportionately diminished in number, or is obliterated entirely. A plant propels its sap with greatest force perpendicularly; so much so, that the sap rising in a Vine branch growing in a right line from the root with a force capable of sustaining a column of mercury twenty-eight inches high, will, if the branch be bent down to a right angle, support barely twenty-three inches; and if bent a few degrees below the horizontal, the column sustained will not be more than twenty-one inches. This is the reason why, at such angles, gardeners find the trained branches of their wall trees rendered more productive of blossoms, and furnished with a smaller surface of leaves. A similar effect is produced by training a branch in a waving form, for two-thirds of its length are placed horizontally. Other modes of interrupting the rapid flow of the sap by checking its return have been previously noticed; among which modes are ligatures and wounds round the bark.

Light and heat are so combined, and so equally essential for the ripening of fruit, that they may be considered conjointly. They are both diminished in ungenial summers; and in such, fruit ripens indifferently, or not at all, being, if it does ripen, deficient in colour as well as flavour. In our latitudes, however, warmth is more deficient than light for the maturing of exotic plants; therefore, by securing to them a higher temperature, we have the Peach, the Melon, the Mango, and the Pine Apple as richly-flavoured and even superior in excellence to that which they attain in their native climes.

It must be remembered, in considering this branch of our subject, that all cooling is occasioned either by the heat being conducted from a body by a colder, which is in contact with it, or by radiating from the body cooled, though circumstances accelerate or retard the radiation; and whatever checks the radiation of heat from a body keeps it warmer. For example,—a thermometer placed upon a grass plat, exposed to a clear sky, fell to 35°; but another thermometer, within a few yards of the preceding, but with the radiation of the rays of heat from the grass checked by no other covering than a cambric pocket-handkerchief, declined no lower than 42°. No difference of result occurs, whether the radiating surface be parallel or perpendicular to the horizon; for when the mercury in a thermometer, hung against an openly exposed wall, fell to 38°, another thermometer against the same wall, but beneath a web of gauze stretched tightly at a few inches distance, indicated a temperature of 43°.

These results explain the beneficial operation of apparently such slight shelter to our wall fruit when in blossom. A sheet of canvass, or of netting, prevents the direct radiation of heat from the wall—the cooling goes on more slowly, and is not reduced to that of the exterior air at night before the return of day begins to re-elevate the external temperature.

The colder the body surrounding another body, the more rapid the radiation from the latter; for it is a law of heat that it has a constant tendency to be diffused equally, and the greater the diversity of temperature between two bodies in contact with each other, the greater is the rapidity with which the progress towards equilibrium goes on. This is one reason why a temperature of 32° with a brisk wind attending it, will injure plants to a far greater extent than a temperature many degrees lower with a still atmosphere; but it is aided by the operation of another law of heat—viz., that aëriform bodies convey it from a cooling body, as a wall or a tree, by an actual change in the situation of their own particles. That portion of the air which is nearest to the body cooling is expanded, and becoming specifically lighter, ascends, and is replaced by a colder portion. This, in its turn becomes heated and dilated, and gives place to another colder portion; and thus the process goes on until the body cooling is reduced to the same temperature as the air. In a still atmosphere this goes on slowly, the air in contact with the wall and tree rises very gradually as it imbibes warmth from them; but if there be a brisk wind, a constant current of air at the lowest temperature then occurring is brought in constant contact with them, and the cooling is rapid in accordance with the law of equilibrium just noticed. A shelter of netting, or even the sprays of evergreens are of the greatest service in preventing the sweeping contact of cold air at such times.

It is not altogether immaterial of what substance netting is formed. Worsted is to be preferred, not only because it is the most durable, but because it is the best preventive of a wall's cooling. We have found the thermometer under a hemp net sink during the night from two to four degrees lower than that under a net of worsted, the meshes being small and of equal size in both nets. This can only be because worsted is a known worse conductor of heat than hemp, and, not absorbing moisture so easily, is not so liable to the cold always produced by its drying.

Snow is a protection to plants for the three foregoing reasons—it prevents heat radiating from them—protects them from the chilling blasts—and is one of the worst conductors of heat. We have never known the surface of the earth below a covering of snow colder than 32°, even when the temperature of the air above has been 28°. A similar protection, though less effectual, is afforded by straw.

Strange as it may appear, yet it is nevertheless true, that a shelter is more beneficial in preserving the temperature of trees, when from three to six inches from them, than when in immediate contact with their surfaces. When a woollen net was suspended four inches from the wall, on which a Peach tree was trained, the thermometer fell very slowly, and the lowest degree it reached was 38°; when the same screen was twelve inches off, it fell to 34°; and when drawn tightly over the tree, it barely kept above 32°, the temperature of the exterior air. When at twelve inches from the wall, it permitted the too free circulation of the air; and when in immediate contact with the polished bark of the Peach, perhaps another law of cooling came into operation. That law is that polished surfaces radiate heat slowest. Thus, if two glass bottles, equal in size and thickness of glass, and of the same shape, be filled with warm water, and one of the bottles be covered with an envelope of fine muslin, this bottle will give out heat to the surrounding air with much greater rapidity than the other bottle: so that in a given time the bottle with the envelope will be found colder than the one which has no covering.

In the uniformity of temperature being sustained by the equivalent radiation and absorption of the bodies at the surface of the earth, we find the solution of many interesting natural phenomena. The production of dew and frost is to be thus accounted for. In the absence of the sun, the surface of the earth losing, by radiation, a great quantity of heat, should have its temperature considerably lowered, were it not, that the canopy of clouds which generally lie above it radiate in return, and thus maintain the temperature almost the same. If then the clouds be absent, all the heat radiated by the earth is lost in the planetary space, and the temperature of its surface brought many degrees below that of the atmosphere. The stratum of air which lies in contact with the surface of the ground is then cooled, by contact, and a portion of the watery vapour, which it had possessed in its elastic form, is deposited as liquid water. If the temperature of the air be itself low, and the night very clear, the cooling may proceed so far that the drops of dew at the moment of their deposition shall be frozen, and thus form frost. The truth of this explanation is demonstrated by the fact, that it is only on the surfaces of good radiators, and during clear starlit nights, that the dew or frost is found. If a plate of polished metal be laid on the centre of a rough board, and exposed to the air of a frosty night, the rough surface will be found in the morning covered with copious frost; but on the bright metal no trace will be deposited. It is thus, that by lightly covering a thin layer of water with straw to increase the radiating power, a sheet of ice may be obtained in a single night between the tropics, where the actual temperature of the air may have continued far above the freezing-point. That the cooling effect is produced by the loss of heat in its radiant form, and not by the contact or diffusion of the particles of the air, may be proved by the interposition of a screen of any substance which intercepts the passage of radiant heat, when the deposition of the dew or frost instantly ceases, and the surface cools no more.—(*Kane's Elements of Chemistry.*)

"And mark here a beautiful adaptation," says Professor Johnston. "Different substances are endowed with the property of radiating their heat, and of thus becoming cool with different degrees of rapidity; and those substances which in the air become cool first also attract first, and most abundantly, the particles of falling dew. Thus in the cool of a summer's evening the grass plat is wet, while the gravel walk is dry; and the thirsty pasture and every green leaf are drinking in the descending moisture, while the naked land and the barren highway are still unconscious of its fall.

"How beautiful is the contrivance by which water is thus evaporated or distilled as it were into the atmosphere—largely perhaps from some particular spots—then diffused equably through the wide and restless air, and afterwards precipitated again in refreshing showers or in long mysterious dews! But how much more beautiful the contrivance, I might almost say the instinctive tendency, by which the dew selects the objects on which it delights to fall; descending first on every living plant, copiously ministering to the wants of each, and expending its superfluity only on the unproductive waste."—(*Agricultural Chemistry.*)

Shelters such as we have mentioned, or the slighter agents, sprays of evergreens, placed before the branches of wall-trees, or other plants, as already noticed, operate beneficially in another way—checking the rapid passage of the air over them—such passage is detrimental in proportion to its rapidity, for the more rapid it is, the greater is the amount of evaporation, and, consequently, of cold produced. Mr. Daniell says, "That a surface which exhales 100 parts of moisture when the air is calm, exhales 125 parts when exposed to a moderate breeze, and 150 parts when the wind is high. During all high winds, but especially when blowing from points varying between the east and the south—for they are the driest in this country—the gardener will always find shelters beneficial to his plants whether in blossom or with fruit in its first stages of growth, for these winds cause an evaporation much exceeding in amount the supply of moisture afforded by the roots." In March such shelters are much required, for the winds are then violent and dry even to a proverb; but it is during the days of its successor, April, that sets in the only periodical wind known in this island. It comes intermittingly, and with variable force, from points ranging from E. to N.E., and is one of the most blighting winds we have. It continues until about the end of the second week in May, though often until its close; and it is a good plan to have the trees during the whole period, by day as well as by night, protected. This periodical wind is occasioned, probably, by Sweden and Norway remaining covered with snow, whilst England is some 20° or more warmer; an upper current of warm air is consequently flowing hence to those countries, whilst a cold undercurrent is rushing hither to supply its place. This wind, and its consequent cold weather, is so regular in its appearance, that in Hampshire and some other parts of England the peasantry speak of it as "the Blackthorn winter"—that bush being in blossom during a part of its continuance.

Colour has very considerable influence over a body's power of absorbing heat. If a thermometer on a hot summer's day be exposed to the sun, it will indicate a temperature of about 100°; but if the bulb be blackened with Indian ink, or the smoke of a candle, it will rise from 10° to 20° higher. The reason for this is that the polished surface of the glass reflects some of the sun's rays, but the blackened surface absorbs them all. Blue absorbs all but the blue rays; red all but the red; green and yellow all but those of their own name; and white reflects all the rays. The lightest coloured rays are the most heating; therefore, light-coloured walls, but especially white, are the worst for fruit trees The thermometer against a wall rendered black by coal tar rises 5° higher in the sunshine than the same instrument suspended against a red brick structure of the same thickness; nor will it cool lower at night, though its radiating power is increased by the increased darkness of its colour, if a proper screen be then employed. The elevation of the temperature of a dark-coloured fruit compared with that of a lighter coloured of the same kind is often remarkable, as in the instance of the Muscle Plum and Green Gage growing on standard trees. But there are other causes than colour for fruit often remaining of a cool temperature in the hottest weather, and among these causes is their covering. Every one must have noticed the delicious coolness of the Peach's flesh compared with that of the Nectarine grown on the same wall and in the same bright sunshine; and the reason of this is that the dense woolly cuticle of the first, like all other downy coverings, is one of the worst conductors of heat. Similar coverings are found on Mexican and Cretan plants which have to endure exposure to a torrid temperature.

Despite all the contrivances for rendering more effectual the natural sources of temperature offered by our climate, these can never obtain during the twelve months, by night as well as by day, a heat sufficient for the successful cultivation of most tropical plants. Hence arises the necessity for employing hothouses and other shelters of that description. In these, fuel has to be employed to elevate the temperature, and some transparent medium as a covering, to prevent the radiation of the heat thus obtained, as well as to shut out the colder atmosphere without excluding the light. But few words will suffice relative to the fuel employed, this being so generally coal; yet there are some facts ascertained by the chemist which afford guides to the gardener in the selection of his fuel, as well as tests to enable him to judge whether he employs it economically.

The heating quality of some of the different coals known in Great Britain are in the following proportions :—

Scotch Cannel	199
Lancashire Wigan	196
Yorkshire Cannel	188
Newcastle (best Wallsend)	169
Gloucestershire (Forest of Dean)	108
Welsh (common)	25

Hence, if the Scotch Cannel coal cost 19*s*., when the Gloucestershire could be had for 10*s*. per chaldron, the latter would be no cheaper; for the heating power of the first is as 199 to 108 of the latter. In other words, one hundred and eight chaldrons of Scotch would afford as much heat as one hundred and ninety-nine chaldrons of Staffordshire.

The following are the quantities of the fuels named, required to heat eight gallons of water from 52° to 212° :—

	lbs.		lbs.
Caking coals . . .	1·2	Wood of Service . .	3·00
Splint, or hard coal Cannel coal .	3·13	„ Cherry . .	3·20
Cherry, or soft coal . .	1·5	„ Fir . .	3·52
Wood of Lime . .	3·10	„ Poplar . .	3·10
„ Beech . .	3·16	„ Hornbeam .	3·37
„ Elm . .	3·52	Peat (average, not compressed) . . .	7·6
„ Oak (chips) .	4·20	Charcoal of wood . .	1·52
„ Ash . .	3·50	„ peat . .	3·28
„ Maple . .	3·00		

The specific heat of water being 1, and that of atmospheric air 0·00035, or 1-2850th, if the quantity of fuel which will heat a cubic foot of water 1° be multiplied by 0·00035, the product will be the quantity of fuel required to heat a cubic foot of air 1°, and twenty times that quantity will heat it 20°, thirty times will heat it 30°, and so on. Now 0·0075 lbs. of best coals will heat a cubic foot of water 1°; therefore, 0·000002625 lbs. of coal will heat a cubic foot of air 1°.

It is essential to good and profitable fuel that it should be free from moisture; for unless it be dry, much of the heat which it generates is consumed in converting that moisture into vapour; hence the superior value of old, dense, dry wood, to that which is porous and damp. A pound of dry wood will heat thirty-five pounds of water from 32° to 212°; but a pound of the same wood in a moist or fresh state will not similarly heat more than twenty-five pounds. The value, therefore, of different woods for fuel is nearly inversely as their moisture; and this may be readily ascertained by finding how much a pound weight of the shavings of each loses by drying, during two hours, at a temperature of 212°.

The above are the average of results obtainable in a common, well-constructed furnace. By a complicated form of boiler, perhaps, a small saving of fuel in obtaining the same results may be effected; but it will be found, generally, that the original cost of apparatus, and the current additional expenses for repairs, will more than exceed the economy of fuel.

Flues for imparting heat to hothouses are, for the most part, superseded by either tanks or hot-water pipes; but where retained, the top should be formed of iron plates, these admitting the heat most readily into the house, and, consequently, requiring a less consumption of fuel. If it be desirable to have a covering for the flues that will retain the heat longer, as when the fires are made up at night, this may be readily accomplished by putting a row of the thick square paving tiles on the top of the whole length of the flue an hour or two before the houses are finally closed.

Hot water in a tank is superior to the same source of heat in pipes, because it is not liable to freeze; and it is preferable to steam, because its heating power continues until the whole mass of water is cooled down to the temperature of the house; whereas steam ceases to be generated as a source of heat the moment the temperature falls below 212°.

If steam be employed, Mr. Tredgold has given the following rules for calculating the surface of pipe, the size of the boiler the quantity of fuel, and the quantity of ventilation required for a house 30 feet long, 12 feet wide, with the glass 4 feet high in front; vertical height of the glass roof 8 feet; length of the rafters 14 feet; height of the back wall 15 feet. The surface of glass in this house will be 720 feet superficial—viz., 540 feet in the front and roof, and 180 feet in the ends. Now, half the vertical height, 7 ft. 6 in., multiplied by the length in feet, and added to 1½ time the area of glass in feet, is equal to the cubic feet of air to be warmed in each minute, when there are no double doors—that is, $\overline{7{\cdot}5 \times 30} + \overline{1\frac{1}{2} \times 720} = 1305$ cubic feet. But in a house with wooden bars and rafters, about one-tenth of this space will be occupied with woodwork, which is so slow a conductor of heat, that it will not suffer a sensible quantity to escape. Therefore, 130 feet may be deducted, leaving the quantity to be warmed per minute = 1175 cubic feet.

To ascertain the surface of pipe required to warm any given quantity of air, multiply the cubic feet of air to be heated per minute by the difference between the temperature the house is to be kept at, and that of the external air in degrees of Fahrenheit's thermometer, and divide the product by 2·1, the difference between 200, which is the temperature of the steam pipes, and the temperature of the house; the quotient will be the surface of cast iron pipe required.

Now, in the house, the dimensions of which are above given, if the lowest temperature in the night be fixed at 50°, and 10° are allowed for winds, and the external air is supposed to be at zero, or 0 of Fahrenheit, then 1175 multiplied by 60°, and the product divided by 2·1, the difference between 200 and 60, will give us the quotient 236 = to the surface of pipe required. Now the house being 30 feet long, five pipes of that length, and five inches in diameter, will be about the proper quantity.

If hot water be employed instead of steam, the following proportions and information, obtained from Mr. Rendle, may be adopted confidently as guides. In a span-roof propagating-house, 40 feet long, 13 feet broad, 7 feet high in the centre, and 4 feet high at the two fronts, having a superficial surface of glass amounting to 538 square feet, Mr. Rendle has a tank of 83 feet long, running round three sides of the house, 4 feet wide, and about 8 inches deep; and, consequently, capable of containing nearly 300 cubic feet of hot water, though only half that quantity is used. This is closely approaching to the size pointed out according to Mr. Tredgold's formula. The mean temperature of a hot-water tank will never be much above 160°; so that, for the sized house mentioned by that skilful engineer, the divisor must be 2·1 times the difference between 160° and 60°, which gives as the quotient 335 cubic feet.

The tank in Mr. Rendle's propagating-house is built of bricks lined with Roman cement; and if the temperature of the tank at the time of lighting the fire be 90°, the temperature of the atmosphere of the house 67°, and the temperature out of doors 50°, the quantity of small coal, or breeze, required to raise the temperature of the water to 125° is 28 lbs. In twelve hours the water cools, after the fire has been extinguished, from 125° to 93°.

When steam is employed, the space for steam in the boiler is easily found by multiplying the length of the pipe in feet, by the quantity of steam in a foot in length of the pipe.

Interior diameter of pipe in inches.	Decimal parts of a cubic foot of steam in each foot of pipe.
1	·00545
1½	·01225
2	·02185
2½	·034
3	·049
4	·0873
5	·1363
6	·1964
7	·267
8	·349
9	·442
10	·545

In the above-noticed house, the length of pipe, 5 inches in diameter, is 150 feet, and these multiplied by 1·363 = 20·5 cubic feet of steam; and as the pipe will condense the steam of about one and one-third cubic foot of water per hour; therefore, the boiler should be capable of evaporating 1½ cubic foot of water per hour, to allow for unavoidable loss. In the extreme case of the thermometer being at zero, the consumption of coals to keep up this evaporation will be 12¾ lbs. per hour.—(*Tredgold on Warming and Ventilation.*)

These calculations are all founded upon the supposition that the condensed water is returned to the boiler whilst hot; but if this cannot be effected, then one-twelfth more fuel will be required. The boiler for the supply, either of steam or hot water, should be covered with the best available non-conductor of heat, and this is either charcoal or sand. A case of brickwork, with pulverised charcoal between this and the boiler, is to be preferred to any other. A boiler having a surface of 70 feet exposed to the air in a temperature of 32° requires an extra bushel of coals to be consumed per day, to compensate for the heat radiated and conducted from that surface; and the smaller the boiler the greater is the proportionate waste.

The smaller the boiler and the fireplace, compatible with efficiency, the greater is the economy. We can tell the gardener, also, most decidedly, that the total size of the boiler has nothing to do with that efficiency; the only point to be secured is, *that a sufficient surface of the boiler be exposed to the fire.* The following table shows the amount of boiler surface which must be exposed to the fire to heat given lengths of pipe, respectively 4 inches, 3 inches, and 2 inches in diameter:—

Surface of boiler exposed to the fire.	4-inch pipe.	3-inch pipe.	2-inch pipe.
	ft.	ft.	ft.
3½ square feet will heat. . . .	200 or	266 or	400
5½ „ „	300 „	400 „	600
7 „ „ . . .	400 „	533 „	800
8½ „ „	500 „	666 „	1000
12 „ „ . . .	700 „	933 „	1400
7 „ „ . . .	1000 „	1333 „	2000

To prevent the scale, or limy crust in a boiler, which is often so troublesome, dissolve in the water at the rate of one ounce of sal ammoniac (muriate of ammonia) to every sixty gallons. Do this twice in the year; as, in October and April.

The surface of the pipes should be painted black, because surfaces of this colour give out more heat in a given time than any other.

Solar light is essential to the ripening of all fruit; it will not ripen in the dark, and the greater the light's intensity and the longer its daily endurance, the sweeter and the higher is the fruit's flavour. No fruits are so luscious as those grown within the tropics, and the fruits of the temperate zone are excellent in proportion to the brightness of its seasons.

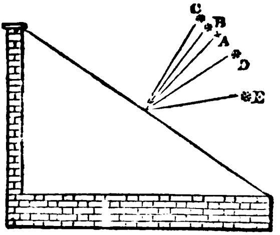
That light is essential in causing the colour of the leaves and other parts of plants has been noticed already; and it aids the ripening process of fruits. In a similar manner, to convert their acid and mucilaginous constituents into sugar, much carbon and hydrogen have to be got rid of, and this is effected, if light be admitted, by the evolution of carbonic acid and watery vapour. How much light promotes the ripening of fruit is well known to all who deal in it. They keep their dessert Pears, which ripen after gathering, in drawers and other dark storing-places. Flavour, however, is promoted by light and warmth; and fruit from the store-room has its flavour intensified by exposure to them for a week before being placed among the dessert.

How light operates in promoting this and other decompositions which are effected by the vegetable organs is at present a mystery, but so it is; and the gardener promotes its access as much as lies within his power by removing overshadowing leaves, by employing the best glass in his forcing-houses, and by having their interior whitened, for white surfaces reflect all the rays of light back upon the objects those surfaces enclose.

The angle formed by the glass roof of the hothouse is of very considerable importance, because rays of light are reflected in proportion to the obliquity with which they fall upon any given surface; those which fall upon it perpendicularly from the source of light pass through with very slight diminution, but those falling upon it in a slanting or oblique direction pass into the house reduced in number in proportion to the obliquity of that direction. To ascertain how a glass roof may be constructed so as to receive the greatest number of rays of light from the sun perpendicularly or near to perpendicularity at any given time of the year, it is necessary to know the latitude of the place where the hothouse is erected, and the sun's declination at the period when most light is required. The latter information may be obtained from most almanacs, and if it be subtracted from the latitude, the remainder will be the angle desired.

If London be the place, and May the 6th the time about when the most light is desired, the latitude being 51° 31′ and the sun's declension then 16° 36′ north, therefore the roof ought to slope at an angle of 34° 55′.

In latitude 52° Mr. Knight found, from lengthened experiment, that the best angle is about 34°, considering the services of a hothouse through the year; and to illustrate this, he gave the annexed diagram.



About the middle of May the elevation of the sun at noon corresponds nearly with the asterisk A; in the beginning of June and early in July it will be vertical at B, and at midsummer at C, only six degrees from being vertical. The asterisk D points out its position at the equinoxes, and E its position at midwinter.—(*Hort. Society's Transactions.*)

If the best glass be employed it is an excellent plan to have it put double in each sash, an interval of half an inch being left between the two panes, and a small hole at the corner of the inner one to prevent the glass being broken by the expansion or contraction of the air between. This confined air is one of the worst possible conductors of heat, keeping the house from being rapidly cooled during the coldest weather; and thus is effected a very great economy of fuel, whilst little or no extra interruption is caused to the entrance of light.

Moisture.—Every fruit-bearing tree requires a larger supply of moisture during the growth of its fruit, and in proportion to its abundance, than at any other season; and for the obvious reason that, as the fruit is a reservoir of accumulated and elaborated sap, that sap requires for its formation an extra supply of moisture, inasmuch as that its chief ingredient is water.

Though abundance is required it must not be excessive; for if this does occur, the sap poured into the fruit is so abundant that it cannot elaborate it sufficiently fast, and, instead of exhaling the superfluous moisture, its cells enlarge, and the fruit greatly increases in size, but at the expense of its flavour. In very wet seasons the supply of moisture is so great that the cells of the parenchymous or fleshy part of the fruit swell faster than its epidermis can expand, and this consequently bursts. This is continually occurring to the Plum and Cherry. When this happens to the Green Gage, and its extremely saccharine juice is exposed to the air, vinous fermentation speedily takes place, and an appreciable quantity of spirit of wine (alcohol) is formed—a discovery to which we were led by observing, what every gardener must have observed, that wasps, after feeding plentifully upon the juice that has been thus exposed, usually fall to the ground stupified and inebriated.

Fruit has also the power of imbibing water through the pores of its epidermis, a power taken advantage of by those Gooseberry growers who aim at size rather than flavour. They keep the calyx end of the berry dipped in a saucer of water.

Fruit for storing should be gathered before it is quite mature, for the ripening process—the formation of sugar, with its attendant exhalation of carbonic acid and water—goes on as well in the fruit-room as in the open air, at the season when the functions of the leaves have ceased, and the fruit no longer enlarges. In gathering fruit every care should be adopted to avoid bruising; and to this end, in the case of Apples, Pears, Quinces, and Medlars, let the gathering-basket be lined throughout with sacking, and let the contents of each basket be carried at once to a floor covered with sand, and taken out one by one—not poured out, as is too usual, into a larger basket, and then again from this into a heap; for, this systematic mode of inflicting small bruises is sure to usher in decay, inasmuch as that it bursts the divisional membranes of the cells containing the juice, and this being extravasated speedily passes from the stage of spirituous fermentation to that of putrefaction. To avoid this is the principal object of fruit storing, whilst, at the same time, it is necessary that the fruit shall be kept firm and juicy.

Now it so happens that the means required to secure the one also effects the other. To preserve the juiciness of the fruit, nothing more is required than a low temperature and the exclusion of the atmospheric air. The best practical mode of doing this is to pack the fruit in boxes of perfectly dried pit-sand, employing boxes or bins, and taking care that no two Apples or Pears touch. The sand should be thoroughly dried by fire heat, and over the uppermost layer of fruit the sand should form a covering nine inches deep. Sand operates as a preservative, not only by excluding air and moisture, but by keeping the fruit cool, for it is one of the worst conductors of heat, and, moreover, it keeps carbonic acid in contact with the fruit. All fruit in ripening emits carbonic acid, and this gas is one of the most powerful preventives of decay known.

Putrefaction requires indispensably three contingencies—moisture, warmth, and the presence of atmospheric air, or at least of its oxygen. Now burying in sand excludes all these as much as can be practically effected. The more minutely divided into small portions animal or vegetable juices may be, so much longer are they preserved from putridity: hence *one* of the reasons why bruised fruit decays more quickly than sound—the membranes of the pulp dividing it into little cells are ruptured, and a larger quantity of the juices is together; but this is only one reason for bruising allows the air to penetrate, and it deranges that inexplicable vital power which, whilst uninjured, acts so antiseptically in all fruits, seeds, and eggs. Bruises the most slight, therefore, are to be avoided; and instead of putting fruit in heaps to *sweat*, as it is ignorantly termed, but in fact *to heat*, and promote decay, fruit should be placed one by one upon a floor covered with dry sand, and the day following, if the air be dry, stored away as before directed. Fruit for storing should not only be gathered during the mid-day hours of a dry day, but after the occurrence of several such.

Although the fruit is stored in sand, it is not best for it to be kept there up to the very time of using, for the presence of light, warmth, and air is necessary for the elaboration of saccharine matter. A fortnight's consumption of each sort should be kept upon Beech, Birch, or Elm shelves, with a ledge all round to keep on them about half an inch in depth of dry sand. On this the fruit rests softly, and the vacancy caused by every day's consumption should be replaced from the boxes as it occurs. If deal is employed for the shelving, it is apt to impart a flavour of turpentine to the fruit.

The store-room should have a northern aspect, be on a second floor, and have at least two windows to promote ventilation in dry days. A stove in the room, or hot-water pipe with a regulating-cock, is almost essential, for heat will be required occasionally in very cold and in damp weather. The windows should have stout inside shutters.

The temperature of the fruit-room should never rise above 40°, nor sink below 34° of Fahrenheit's thermometer ; the more regular the temperature the better. Powdered charcoal is even a better preservative for packing fruit than sand, and one box not to be opened until April, ought to be packed with this most powerful antiseptic. If it were not from its soiling nature, and the trouble consequent upon its employment, we should advocate its exclusive use. We have kept Apples not usually good-keeping, perfectly sound in it until June.

It is not unworthy of observation, that the eye, or extremity furthest from the stalk, is invariably the first to ripen. This is most perceptible in Pears, especially in the *Chaumontellé*. That end, therefore, should be slightly embedded in the sand, as thus excluding it from the light checks its progress in ripening.

The perfecting of seed is a process very similar to the maturation of fruit—indeed, for the most part, whatever advances the one promotes the other. The chief difference is, that if seed be the exclusive object, less moisture and rich food should be supplied to the plants, inasmuch as that an abundant supply of these increases excessively the development of the succulent part of the fruit, and yet the vessels from this to the seed often wither and render it abortive. A similar defective fertility occurs if the female parent in animals is over-stimulated and fat.

Lastly, in this section of our researches we have to consider the ripening of seeds. This final operation of the plant's annual round of growth requires changes the exact reverse of those which have to be effected when the plant first commences existence —that is, when the seed germinates.

During a seed's germination, the usual chief operation is the conversion of starch into sugar; but during the seed's ripening the usual change is the conversion of sugar and gum into starch. During germination the necessary changes required carbon to be got rid of, and, consequently, as we showed whilst considering the phenomena, carbonic acid is emitted by the seed.

But during the ripening of seed—that is, during the conversion of its sugar into starch, no carbon need to be got rid of, for they are relatively composed as follows :—

	Carbon.		Hydrogen.		Oxygen.
Grape sugar	24	...	22	...	22
Starch.....................	24	...	20	...	20

So as the seed approaches to ripeness, we gradually find more oxygen and water emitted by a plant in proportion to the carbonic acid and water absorbed than during the period of growth and flowering. This coincides also with Liebig's statement, who, on the supposition that starch is formed by the plant from carbonic acid and water, says that there would be required thirty equivalents of carbonic acid, and thirty equivalents of hydrogen derived from thirty equivalents of water, with the separation of seventy-two equivalents of oxygen. Of the vital process by which this is effected we know nothing, and can only compare it to the action of chlorine gas, which when mixed with water combines with its hydrogen and sets its oxygen free.

We have said much relative to the seeds of plants when considering the phenomena of germination in our first chapter, and we will only add here some of the results of experience recorded by Mr. Knight; premising that, although his observations were made upon the seeds of fruit trees, yet they are equally applicable to the seeds of all cultivated plants.

New varieties of every species of fruit will generally be better obtained by introducing the farina of one variety into the blossom of another than by propagating from any single kind. When an experiment of this kind is made between varieties of different size and character the farina of the smaller kind should be introduced into the blossoms of the larger; for, under these circumstances, Mr. Knight generally (but with some exceptions), observed in the new fruit a prevalence of the character of the female parent; probably owing to the following causes. The seed-coats are generated wholly by the female parent, and these regulate the bulk of the lobes and plantule: and he observed, in raising new varieties of the Peach, that when one stone contained two seeds, the plants these afforded were inferior to others. The largest seeds obtained from the finest fruit, and from that which ripens most perfectly and most early, should always be selected.

The trees, from blossoms and seeds of which it is proposed to propagate, should have grown at least two years in mould of the best quality. During that period they ought not to be suffered to exhaust themselves, by bearing any considerable crop of fruit; and the wood of the preceding year should be thoroughly ripened (by artificial heat when necessary), at an early period in the autumn: and if early maturity in the fruit of the new seedling plant is required, the fruit within which the seed grows should be made to acquire maturity within as short a period as is consistent with its attaining its full size and perfect flavour: those qualities ought also to be sought in the parent fruits which are desired in the offspring; and the most perfect and vigorous offspring will be obtained, of plants as of animals, when the male and female parent are not closely related to each other.—(*Horticultural Society's Transactions*, i., 38, 165.)

THE DISEASES OF PLANTS.

Dr. Good, the distinguished medical writer, has remarked that the morbid affections to which the vegetable part of the creation is liable are almost as numerous as those which render decrepid and destroy the animal tribes. It would be difficult, perhaps, whatever system of nosology is followed, to place a finger upon a class of animal physical diseases of which a parallel example could not be pointed out among plants. The smut, which ravages our corn crops; the mildew, which destroys our Peas; the murrain of our Potatoes; the ambury, or clubroot, to which our Turnips and other species of Brassica are liable; the shanking, or ulceration, which attacks the stalks of our Grapes, are only a few of the most commonly observed diseases to which the plants we cultivate are liable.

Numerous as are the vegetable diseases, and destructive as they are to the interests of the cultivator, yet no subject connected with his art has obtained so little attention, and never was even trivial attention followed by benefit less important. The reason for this deficiency of benefit is not difficult of detection.

Common experience teaches us that diligence and perseverance, directed by judgment, are the essential preliminaries of success: and these are more particularly requisite in searching for the causes of the diseases and decay of vegetables, because we have fewer guides, and less assistance from the vegetable affected, than we have from a diseased animal—fewer symptoms marking the commencement or seat of the evil. Yet where is the cultivator who ever took a fraction of the care, or paid a decimal of the attention to discover the cause, progress, or remedy of one disease, sometimes bringing destruction upon his harvests, as he does to detect the disorder or discover the panacea for some miserable pig?

The subject is one beset with difficulties, but difficulty is very distinct from impossibility; and the importance of the research is a stimulus to exertion. Human knowledge being acquired by observation and experience—by conversing with the things about us—that is, by noticing them attentively, and recording and reflecting upon the facts they reveal—every gardener should do this, especially whenever he finds his crops diseased. He should record from what soil he obtained his seed; how and in what weather it was committed to the ground; the subsequent culture of the crop; the crops which preceded it; the thermometrical and hygrometrical registries of the seasons through which it has grown; the treatment of the soil; its drainage; the manures employed; the waterings; the pruning; and any other miscellaneous observations his own common sense may dictate. If this were done, vegetable medicine would soon advance more in one year towards that state of reasoned knowledge, which alone deserves the name of science, than it has done during the last century.

As observations multiply, chemistry and physiology will contribute and apply their improved stores of information, and if but few specifics for the diseases of plants resulted, yet we are quite satisfied that the causes of diseases will be more accurately ascertained: and every one is aware that to know the cause of an evil is the most important step towards the prevention of its occurrence.

It is a very important preliminary to the study of the diseases of plants that the nature of these be understood; for our ignorance of, or inattention to, the nature of these organised creatures, is one of the causes from whence arises the little progress made in this branch of natural philosophy.

Its students ought fully to understand that this part of the creation, even the commonest weed, is so highly organised—so exhibiting intimations of the functions, circulations, and secretions more highly developed in the superior animals, that it is not possible to point out where animal life terminates, and where vegetable life begins: the zoophytes connect the two kingdoms. It is absolutely necessary, we think, for this to be understood and felt by those who enter upon the investigation of vegetable diseases, because we have a strong opinion that these in very many instances, are caused by the plants which they infect being treated as if they were totally insentiate matter—scarcely more susceptible of injury at some periods of their growth than the soil from whence they partly derive their sustenance.

To determine the question whether plants possess a degree of sensation is not so easy as the cursory inquirer may believe; and Mr. Tupper is much nearer to truth when observing that it is as difficult to ascertain the nature of vegetable existence as to determine what constitutes the living principle in animals.

Dr. Darwin, by the aid of imaginary beings similar to the Dryads and other minor deities of the heathen mythology, raised plants to a position in the order of Nature superior even to that to which animals are entitled. Other philosophers, adopting a totally antagonistic opinion, estimate vegetables as bodies, only somewhat more organised than crystals; but like these entirely and uncontrolledly subject to chemical and mechanical changes.

Each of the foregoing extreme opinions, we think, similarly erroneous. The gradation from reason to instinct, from instinct to inanimation, might easily be shown to be as gradual as are the transitions of light in our climate from the noontide to the midnight of a summer's day. But we must confine our attention to that section of creation commencing from the close of the animal classes in the zoophyte, and terminating where inorganic matter commences in the crystal, and the details here given must be directed specially to demonstrate how closely it approaches, how indistinctly it is divided from, the former.

Let us first consider the comparative composition of animals and plants as revealed by the researches of the chemist, and it must be somewhat startling even to the most sceptical to find that their constitutents are identical. Carbon, hydrogen, oxygen, azote, sulphur, phosphorus, acids, alkalies, earths and metals are the components of both.

Azote was considered as a constituent, marking, by its presence, animal from vegetable matters; but this distinction is now admitted to fail; for although in the former it is usually most abundant, yet later researches show it to be present in all seeds, it is abundant in vegetable gluten, and pervades the whole frame of the Tobacco plant, yet is absent from some animal substances.

If we follow the above-named chemical bodies through their combinations we shall find that the similarity between animals and plants still obtains, being equally numerous and intricate in each.

Of the acids there are contained in

Animals.	Vegetables.
1. Sulphuric,	1. Sulphuric,
2. Phosphoric,	2. Phosphoric,
3. Muriatic,	3. Muriatic,
4. Carbonic,	4. Carbonic,
5. Benzoic,	5. Benzoic,
6. Oxalic,	6. Oxalic,
7. Acetic,	7. Acetic,
8. Malic,	8. Malic,

besides others still more numerous, peculiar to each.

Of the earths and alkalies, lime, magnesia, silica, soda, and potass are found in both classes; and of the metals, iron and manganese are their conjoint constituents. If we follow the two orders of organised creatures through their more compound constituents we shall find the close analogy still continues; for they contain in common sugar, mucus, jelly, colouring matters, gluten,* fibrin, oils, resins, and extractives.

The functions of animals and plants are in a like degree analogous. Animals take in their food by the agency of the mouth, and prepare it for digestion, either by various degrees of mastication, or by attrition, as in the gizzards of birds. In this they differ from plants; but these have a sufficient compensation, inasmuch as that they imbibe their food in a fluid form, liquid, or aëriform, and, consequently, in a state already of the finest possible division. Animal and vegetable remains are their common food, and salts of various kinds are their condiments and stimulants; plants having this advantage over animals, that as they absorb only the soluble and finer parts of their nutriments, and their absorbing organs have the power of rejecting that which is offensive, they have no offensive matters to separate such as appear in the excrements of animals.

In the animal stomach the food undergoes an extensive change, being reduced to a pulp of greater specific gravity, and being altered entirely both in taste and odour. In the sap-vessels of plants, which may be truly considered as their primary organs of digestion, their food or sap undergoes a change precisely similar; its colour and flavour are altered, and its specific gravity increased.

From its stomach the animal's food passes into the intestines, is there subjected to the action of the bile, and the chyle or nutritive portion is separated from that which is excrementitious.

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* The gluten of plants is the albumen of animals.

In its passage through the intestines, the chyle is absorbed by the lacteal vessels, and conveyed into the blood; and these mingled liquids are propelled by the heart into the lungs, to be there exposed to the action of the air. The vital liquid now changes its purple hue to a florid red, loses a portion of its carbon and watery particles, the former combining with the oxygen of the atmospheric air in the lungs, and being breathed forth in the form of carbonic acid gas. As plants take in as food no gross, unneeded ingredients, it is obvious that no process like the biliary operation is required in their course of digestion: But in them the food or sap, proceeding at once along the branches, is poured into the leaves, which are the very lungs of the vegetable world. Here, as is the blood, its colour is changed, and oxygen emitted from it during the light hours of the twenty-four; but carbonic acid is breathed forth during the night, and, at all periods, a considerable amount of watery vapour is emitted.

From the lungs, by the agency of the heart, the blood is propelled through the arteries over the whole animal frame, supplying nourishment and warmth to all the parts, and where, by those being abstracted, it is again converted into purple or venous blood, and is returned by the veins to undergo a repetition of those changes already noted as being effected in the lungs. In plants the sap, after exposure to the action of the air in their leaves, is returned by another set of vessels, situated in the bark, ministering to the growth and support of the whole plant. It is true, that only under certain circumstances, detailed in another chapter, is heat evolved during the processes of vegetation; but the circulation of the sap in plants, beyond all doubt, enables them to resist the intense colds and heats of their native climates. In frosts, the most intense and prolonged, we find the interior of trees remain unfrozen; and, under the meridian sun of the tropics, the sap of the Palm and of all other trees retains coolness. This power to resist extremely elevated and depressed temperatures is characteristic of all animated nature.

Such is the close similarity in the digestive and circulatory processes characterising the members of the two great kingdoms of organised nature, a resemblance which obtains in all the other functions enjoyed by them in common. During respiration, the air inhaled by animals through the mouth and nostrils proceeds immediately to the lungs, and acts upon the blood; in plants, the air inhaled by their leaves operates instantaneously upon the sap. Oxygen is the vital air of animals, so that gas and carbonic acid gas are equally essential to plants. If animals be placed in a situation where they inhale pure oxygen, their functions are highly excited and increased in rapidity; but it is an exhiliration speedily terminating in exhaustion and death, if the inhalation be continued for a protracted time. So plants will flourish with increased vigour in an atmosphere containing one-twelfth of carbonic acid, but even this brings on premature decay; and if it exceeds that proportion, destruction is still more rapidly induced. During sleep, animals exhale less carbonic acid than during their waking hours, so plants emit a much diminished amount of oxygen during the night.

We might now proceed to enumerate the facts demonstrative that plants are gifted with sensation, if these had not already been stated when considering how salts affect plants. In addition to those facts we will only observe, that plants are obviously stimulated by light. Everybody must have observed, that they bend towards the point whence its brightest influence proceeds. M. Bonnet, the French botanist, demonstrated this by some very satisfactory experiments, in which plants, growing in a dark cellar, all extended themselves towards the same small orifice admitting a few illuminating rays.

Almost every flower has a particular degree of light requisite for its full expansion. The blossoms of the Pea and other papilionaceous plants, spread out their wings in fine weather, to admit the solar rays, and again close them at the approach of night. Plants requiring powerful stimulants do not expand their flowers until noon, whilst some would be destroyed if compelled to open in the meridian sun—of such is the night-blooming Cereus, the flowers of which speedily droop, even if exposed to the blaze of light attendant on Indian festivities.

From these and other facts incidentally mentioned in preceding chapters, and others which will be stated when considering the health of plants, without believing that they demonstrate sensation to exist in plants as acute as that possessed by the superior or more perfect classes of animals, yet they certainly are satisfactory evidence that some plants possess it to a degree nearly as high as that with which the zoophytes, or even the polypus and leech, are gifted. Some of these animals may be cut into pieces, and each section will become a perfect individual; of others, their heads being taken off, may be grafted upon other bodies; and a third class of them may be turned with their insides outwards, without any apparent inconvenience. If plants be endowed with no more or even less sensation than must be that of such animals as these, it explains the causes, and throws light upon the prevention of many diseases affecting those which we cultivate, and warns the cultivator from the late performance of many of his operations, as well as from being needlessly violent in his treatment. If a Grape Vine be pruned too late in the spring, the bleeding or effusion of sap has been known to be so excessive, that the tree has died from absolute exhaustion. Stone-fruit trees, if severely bruised, are frequently destroyed by the inroads of a disease, resembling, in all its characteristics, the cancerous affections of animals; and we have known a whole crop of Wheat affected with a swelling of the stem or culm, evidently caused by an extravasation of the sap from its ruptured vessels, owing to a heavy roller being passed over the crop, when of a forward growth.

We shall confine our special remarks upon the diseases of plants to one class, for it is the only one towards which scientific investigation has been directed.

CANKER AND ULCER.—Whatever may be the disease under which a plant is suffering, it is too usual for the cultivator to confine his attention to the part immediately affected. It is looked upon as a strictly local derangement, and the remedies are as erroneously topical. To consider that because a bud, a branch, or a root is diseased, that the cause of the disorder is to be sought for there, is as sensible as to suppose that every local pain endured by the human frame arises from a disorganisation of that part. On the contrary, we know that the diseases of animals arise almost universally from the stomach; and, as Addison remarked, "that physic is generally the substitute for temperance or exercise." The functions of the stomach, by whatever cause deranged, render digestion imperfect and the secretions defective; the bile is superabundant or deficient in quantity, and headache is the result; the liver is diseased, and it causes a pain the most acute between the shoulders; the blood is ill elaborated, and eruptions are thrown out on the surface of the body.

With plants it is the same. It may be laid down as an axiom without exception, that all vegetable diseases, unpreceded by external injury, arise from the unhealthy state of the sap—a state brought about conjointly or separately by the deficient, excessive, or improper food imbibed, and the deranged digestive power of the leaves and other organs. That this is so will not appear strange when we reflect that from the sap all parts of the plant are formed, and are continually increased in number and size. The solid substance of the wood, and the temporary tender blossoms, are alike extracted from that circulating fluid If the constituents for these are wanting, or if improper components are introduced, disease is the necessary consequence. Disease, which in youth and manhood usually arises from intemperance and over-excitement, visits old age as a consequence of its decayed vital powers; and, "if the silver cord has not been loosed," or "the golden bowl broken" by the short-sighted indulgence of early years, man gradually declines into the grave, as the vital organs cease to perform their offices, because the limit of existence natural to his species has been attained.

Some diseases peculiar to old age are prematurely induced in the usually vigorous period of life by indulgences individual or hereditary. Ossification of the vascular system is an example. In the vegetable part of the creation the *canker* or *ulcer*, to which our Apple, Pear, Elm, and other trees are subject, is a somewhat parallel instance. This disease is accompanied by different symptoms, according to the species of the tree which it infects. In some of those whose true sap contains a considerable quantity of free acid, as in the genus Pyrus, it is rarely accompanied by any discharge. To this dry form of the disease it would be well to confine the term *canker*, and to give it the scientific name of *Gangræna sicca.* In other trees, whose sap is characterised by abounding in astringent or mucilaginous constituents, it is usually attended by a sanious discharge. In such instances, it might strictly be designated *ulcer*, or *Gangræna saniosa.* This disease has a considerable resemblance to the tendency to ossification which appears in most aged animals, arising from their marked appetency to secrete the calcareous saline compounds that chiefly constitute their skeletons. The consequence is an enlargement of the joints, and ossification of the circulatory vessels and other parts — phenomena very analogous to those attending the cankering of trees. As in animals, this tendency is general throughout their system; but, as is observed by Mr. Knight, "like the mortification in the limbs of elderly people," it may be determined as to its point of attack, by the irritability of that part of the system.

This disease commences with an enlargement of the vessels of the bark of a branch, or of the stem. This swelling invariably attends the disease when it attacks the Apple tree. In the Pear the enlargement is less, yet is always present. In the Elm and the Oak sometimes no swelling occurs; and in the Peach we do not recollect to have seen any. We have never observed the disease in the Cherry tree, nor in any of the Pine tribe. The swelling is soon communicated to the wood, which, if laid open to view on its first appearance, by the removal of the bark, exhibits no marks of disease beyond the mere unnatural enlargement. In the course of a few years, less in number in proportion to the advanced age of the tree, and the unfavourable circumstances under which it is vegetating, the swelling is greatly increased in size, and the alburnum has become extensively dead; the superincumbent bark cracks, rises in discoloured scales, and decays even more rapidly than the wood beneath. If the caries is upon a moderately-sized branch, the decay soon completely encircles it, extending through the whole alburnum and bark. The circulation of the sap being thus entirely prevented, all the parts above the disease necessarily perish.

In the Apple and the Pear the disease is accompanied by scarcely any discharge; but in the Elm this is very abundant. The only chemists who have examined these morbid products are Sir H. Davy and Vauquelin; the former's observations being confined to the fact, that he often found carbonate of lime on the edges of the canker in Apple trees.[*]

Vauquelin has examined the sanies discharged from the canker of an Elm with much more precision. He found this liquor nearly as transparent as water, sometimes slightly coloured, at other times a blackish brown, but always tasting acrid and saline. From this liquor a soft matter, insoluble in water, is deposited upon the sides of the ulcer. The bark over which the transparent sanies flows attains the appearance of chalk, becoming white, friable, crystalline, alkaline, and effervescent with acids. A magnifier exhibits the crystals in the forms of rhomboids and four-sided prisms. When the liquid is dark-coloured, the bark appears blackish and seems as if coated with varnish. It sometimes is discharged in such quantities as to hang from the bark like stalactites. The matter of which these are composed is alkaline, soluble in water, and with acids effervesces. The analysis of this dark slimy matter shows it to be compounded of carbonate of potass and ulmin—a product peculiar to the Elm. The white matter deposited round the canker was composed of—

Vegetable matter	60.5
Carbonate of potass	34.2
Carbonate of lime	5.0
Carbonate of magnesia	0.3
	100.0

Vauquelin calculated, from the quantity of this white matter that was found about the canker of an Elm, that 500 lb. weight of its wood must have been destroyed.[†] There is no doubt that such a discharge is deeply injurious to the tree, but the above learned chemist appears to have largely erred; for he

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[*] Elements of Agric. Chemistry, 2nd. ed., p. 246.

[†] Annales de Chimie, xxi. 30.

calculated from a knowledge of the amount of the saline constituents in the healthy sap, whereas in its diseased state these are much and unnaturally increased. We once were of opinion, that this disease does not arise from a general diseased state of the tree, but that it is brought on by some bruise or injury, exasperated by an unhealthy sap consequent to an unfavourable soil, situation, and culture; but more extensive and more accurate examinations convince us that the disease is in the tree's system ; that its juices are vitiated; and that disease will continue to break out independent of any external injury, so long as these juices continue peccant and unaltered.

The disease is not strictly confined to any particular period of the tree's age. We have repeatedly noticed it in some of our lately introduced varieties that have not been grafted more than five or six years. Although young trees are liable to this disease, yet their old age is the period of existence most obnoxious to its attacks. It must be remembered, that that is not consequently a young tree which is lately grafted. If the tree from which the scion was taken be an old variety, it is only the multiplication of an aged individual. The scion may for a few years exhibit signs of increased vigour, owing to the extra stimulus of the more abundant quantity of healthy sap supplied by the stock; but the vessels of the scion will, after the lapse of that period, gradually become as decrepid as the parent tree. The unanimous experience of naturalists agrees in testifying that every organised creature has its limit of existence. In plants it varies from the scanty period of a few months to the long expanse of as many centuries; but of all, the days are numbered; and although the gardener's, like the physician's skill, may retard the onward pace of death, he will not be permanently delayed. In the last periods of life, plants show every symptom that accompanies organisation in old age,—not only a cessation of growth, but a decay of former development, a languid circulation, and diseased organs.

The canker, as already observed, attends especially the old age of some fruit trees, and of these the Apple is most remarkably a sufferer. "I do not mean," says Mr. Knight, "to assert that there ever was a time when an Apple tree did not canker on unfavourable soils, or that highly cultivated varieties were not more subject to the disease than others where the soil did not suit them. But I assert, from my own experience and observation within the last twenty years, that this disease becomes progressively more fatal to each variety, as the age of that variety, beyond a certain period, increases; that if an old worn-out orchard be replanted with fruit trees, the varieties of the Apple which I have found in the catalogues of the middle of the seventeenth century, are unproductive of fruit, and in a state of debility and decay."*

Trees injudiciously pruned, or growing upon an ungenial soil, are more frequently attacked than those advancing under contrary circumstances. The oldest trees are always the first attacked of those similarly cultivated. The Golden Pippin, one of the oldest existing varieties of the Apple, is more frequently and more seriously attacked than any other.

The soil has a very considerable influence in inducing the disease. If the subsoil be a ferruginous gravel, or a wet clay, or if it is not well drained, the canker, under any one of these circumstances, is almost certain to make appearance amongst the trees, however young and vigorous they were when first planted.

Pruning has a powerful influence in preventing the occurrence of the canker. We remember a standard Russet Apple tree,

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* Some doubts as to the efficacy of Mr. Forsyth's Plaster, by T. A. Knight, Esq., P.L.H.S., &c., 1802.

of not more than twenty years' growth, with a redundancy of ill-arranged branches, that was excessively attacked by this disease. We had two of its three main branches and the laterals of that remaining carefully thinned; all the infected parts being at the same time removed. The result was a total cure. The branches were annually regulated, and for six years the disease never re-appeared. At the end of that time the tree had to be removed, as the ground it stood upon was required for another purpose. John Williams, Esq., of Pitmaston, from long experience, concludes that the Golden Pippin and other Apples may be preserved from this disease, by pruning away every year that part of each shoot which is not perfectly ripened. By pursuing this method for six years, he brought a dwarf Golden Pippin tree to be as vigorous and as free from canker as any new variety.[*]

All these facts unite in assuring us that the canker arises from the tree's weakness, from a deficiency in its vital energy, and consequent inability to imbibe and elaborate the nourishment necessary to sustain its frame in vigour, and much less to supply the healthy development of new parts. It matters not whether its energy be broken down by an unnatural rapidity of growth, by a disproportioned excess of branches over the mass of roots, by old age, or by the disorganisation of the roots in an ungenial soil; they render the tree incapable of extracting sufficient nourishment from the soil, consequently incapable of developing a sufficient foliage,[†] and, therefore, unable to digest and elaborate even the scanty sap that is supplied to them.

The reason of the sap becoming unnaturally saline appears to be, that in proportion as the vigour of any vegetable declines, it

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[*] Trans. London Horticultural Society, vi. Art. 64.

[†] No symptoms of a cankered tree are more invariable than a deficiency of leaves.

loses the power of selecting by its roots the nourishment congenial to its nature. M. Saussure found in his experiments, that the roots of plants, growing in saline solutions, absorbed the most of those salts that were injurious to them, evidently because the declining plant lost the sensitiveness and energy necessary to select and to reject.

M. Saussure also found, that, if the extremities of the roots were removed, the plants absorbed all solutions indiscriminately.*

An ungenial soil would have a debilitating influence upon the roots in a proportionate, though less violent, degree than the sulphate of copper; and as these consequently would absorb soluble bodies more freely, and without that discrimination so absolutely necessary for a healthy vegetation, so the other most essential organs of nutrition—the leaves of the weakened plant, would promote and accelerate the disease. These, reduced in number and size, do not properly elaborate the sap; and we have always found that, under such circumstances, these stunted organs exhale the aqueous particles of the sap very abundantly, whilst their power of absorption is greatly reduced. The sap, thus deficient in quantity and increased in acridity, seems to corrode and affect the vascular system of the tree in the manner already described.

These facts afford us most important guides in attaining the desired objects—the prevention and cure of the disease.

If superluxuriance threaten its introduction, the best remedy is for the cultivator to remove one of the main roots of the tree, and to be particularly careful not to add any fertile addition to the soil within their range. On the contrary, it will be well, if the continued exuberant growth shows its necessity, for the staple of the soil to be reduced in fertility by the admixture of one less fertile, or even of drift sand.

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* Saussure's Recherches Chimiques sur la Vegetation, 260.

If there be an excess of branches, the saw and the pruning knife must be gradually applied. It can be only trees of very weak vital powers, such as is the Golden Pippin, that will bear the general cutting of the annual shoots, as pursued by Mr. Williams. A new vigorous variety would exhaust itself the following year in the production of fresh wood. Nothing beyond a general rule for the pruning can be laid down; and it amounts to no more than the direction to keep a considerable vacancy between every branch both above and beneath it, and especially to provide that not even two twigs shall chafe against each other. The greater the intensity of light, and the freer the circulation of air amongst the foliage of a tree, the better the chance for its healthy vegetation.

If the disease be in a fruit tree, it is probably a premature senility induced by injudicious management, for very few of our varieties are of an age that insure to it decrepitude. We have never yet known a tree, unless it was in the last stage of decay, that could not be recovered by giving it more air and light, by careful heading-in, pruning, improvement of the soil, and cleansing the bark.

If the soil by its ungenial character induces the disease, the obvious and only remedy is its amelioration, and if the subsoil be the cause of the mischief, the roots must be prevented striking into it. In all cases, it is the best practice to remove the tap root. Many orchardists pave beneath each tree with tiles and broken bricks. If the trees are planted shallowly, as they ought to be, and the surface of the soil kept duly fertile, there is not much danger of the roots striking into the worse pasturage of the subsoil.

Having noticed the gangrene as it appears in various forms upon our trees, we may now turn to a few of the many instances where it occurs to our fruits and flowers, for it is not too much to say that scarcely a cultivated plant is within our enclosures that is not liable to its inroads. It assumes different aspects, and varies as to the organs it assails, yet still in some mode and in some of their parts all occasionally suffer, for it is the most common form of vegetable disease.

The canker in the *Auricula* is of this nature, being a rapidly spreading ulcer, which, destroying the whole texture of the plant where it occurs, prevents the rise of the sap. Some gardeners believe it to be infectious, and, therefore, destroy the specimen in which it occurs, unless it be very valuable; but this we believe to be an erroneous opinion—the reason of its appearing to be infectious or epidemic, being that it occurs to many when they are subjected to the same injurious treatment which gives birth to the disease.

It appears to be caused by the application of too much water, especially if combined with superabundant nourishment: therefore, although cutting out the decaying part when it first appears, and applying to the wound some finely powdered charcoal, will effect a cure if the disease has not penetrated too deeply, yet it will be liable to return immediately if a less forcing mode of culture be not adopted. No Auricula will suffer from this disease if it be shifted annually and the tap root at the time of moving be shortened, a thorough system of draining being adopted, such as having the pot used one-fourth filled with pebbles, and excessive damp during the winter being prevented by proper shelter.

Parsley grown in a poor soil is also liable to *canker* in the winter. Mr. Barnes says he never found any application which eradicated this disease so effectually as a mixture in equal parts of soot and slaked lime sown over the plants. The cure is complete in a few days, and the vigour of the plants restored, indicating that this species of ulceration, like that which is found in the dwellings of the poor, arises from deficient nourishment.

The spot, as it is technically termed, occurring on the leaves of the *Pelargonium*, is a dry gangrene, occasioned by an irregularity in the supply of moisture and vicissitudes of temperature, but especially if one of the extremes is much below the degree of heat most favourable to the healthy growth of that plant. The reason of this is very obvious. If a Pelargonium, or any other plant, be placed in a highly stimulating heat, and is abundantly supplied with root moisture, it immediately increases its surface of leaf to elaborate and digest the large amount of sap forwarded from the roots. If this amount of sap is subsequently reduced, by lowering the temperature and adding water to the soil less freely, the increased surface of the leaf is no longer required, and it is a law pervading all the vegetable creation, that the moment any of the parts of a plant are unnecessary to it, that moment those parts begin to decay. We placed a plant of the Marvel of Peru, or *Heliotrope*, in a high temperature, and supplied it abundantly with water until its leaves were much increased in size; the temperature and moisture were then much reduced, and the leaves in a few days were completely decayed round their edges, and in spots upon their surfaces. The extent of leaf was accommodated to the amount of sap to be elaborated.

The *spot* and *shanking* of Grapes as was formerly mentioned, is an ulceration arising from the roots failing to afford a due supply of sap to the bunches.

DEATH AND DECOMPOSITION.

As in the animal creation the period of life varies from a few hours in the ephemeron, to hundreds of years in the tortoise, so among the vegetable tribes, though it is circumscribed to a few months in some of our annuals, yet it extends to centuries in the Oak, the Chestnut, the Wellingtonia, and the Adansonia. But however varied in space, each has its limit of existence; and death, though its inroad may be delayed, finally effects a conquest over all.

Now, what is the death of a plant? and though this query admits of the ready answer that it is a want of the power to vegetate, though the requisites for vegetation are present, yet one question more difficult of solution follows upon this reply— What is that power of which death is the negation? and although neither the chemist nor the physiologist has ever succeeded—probably never will succeed—in penetrating further than to an acquaintance with the phenomena of that power, yet these we have already seen are intimately connected with the gardener's art, and the phenomena attending its absence are well worthy of his study.

Some of the phenomena of that power which is justly called vegetable life, have just been traced through the development of parts—the circulation of the sap, the progress of growth, the indications of sensation, and the inroads of disease. We will now trace the phenomena of the plant's decline and final decay.

The first symptom of that decline is a deficiency of the usual annual development of parts. A permanently lessened production of shoots, or leaves, or fruit, or all of these, becomes apparent; and this non-production arises from a diminished power in the roots to imbibe, and of the vessels of the stem and branches to impel, the sap.

Thus Hales always found that the two, three, and four-year-old branches of trees imbibed water with much greater force than those of greater age; and that young vigorous Vines usually exuded their sap with much greater force than the older and less robust. So we have found that our annuals, such as the Dwarf Kidney Bean, Mignonette, Clarkias, and others, imbibed water with more than twofold rapidity when in full bloom, than other plants of the same species and size did in the autumn, though they were still growing and verdant.

Now, what is the cause of this deficient power—this decline of vigour? There appears little doubt that it is the exhaustion consequent upon the production of seed. Scarcely an annual exists which usually dies at the close of the season, after ripening its seed, but may be made to retain a vigorous existence if its inflorescence be removed as speedily as formed. Mignonette is a very familiar example; for this may be allowed to bloom, but if its flower-stalks be cut down before the seed-vessels are perfected, it becomes woody and shrubby, and will live and bloom for three or more successive years. If allowed to ripen its seeds, it dies the same autumn. The common Nasturtium is an annual; but the double Nasturtium, says M. De Candolle, has become a perennial, because its flowers, deprived of the faculty of producing seeds, do not exhaust the plant, and it is probable that every annual rendered double by cultivation will become a perennial.

This explains why fruit trees are weakened, or rendered temporarily unproductive, and even killed, by being allowed to ripen too large a crop of fruit, or to "overbear themselves," as it is emphatically termed by the gardener.

The thinning of fruit is, consequently, one of the most important operations of the garden, though one of the least generally practised. On the weaker branches of the Nectarine and Peach, an average space of nine inches should be between each brace of fruit, and on the most vigorous wood of the most healthy trees they should not be nearer than six inches. This enforcement of the importance of thinning fruit is not intended to be confined to the two trees specified; it is equally important to be attended to in all other fruit-bearers, but especially the Vine, Apricot, Apple, and Pear. It should be done with a bold, fearless hand, and the perfection of that which is allowed to remain will amply reward the grower in the harvest time for the apparent sacrifice now made. But he will not reap his reward only in this year; for the trees thus kept unweakened by over-production, will be able to ripen their wood and deposit that tore of inspissated sap in their vessels so absolutely necessary for their fruitfulness next season.

The berries of the Grape Vine are best thinned from the branches with a sharp-pointed pair of scissors, care being taken to remove the smallest berries. This increases the weight and excellence of the bunches; for two berries will always outweigh four grown on the same branchlet of a bunch, besides being far handsomer, and having more juice as compared with the skins. The average weight of the bunches on a Vine may be taken, when ripe, at half a pound each, and with this data it is easy to carry into practice Mr. Clement Hoare's excellent rule for proportioning the crop to the size of the Vine.

If its stem, measured just above the ground, be three inches in circumference, it may bear 5 lbs. weight of Grapes.

3½ inches	10 lbs.
4	15
4½	20
5	25

And so 5 lbs. additional for every half inch of increased circumference.

Although fruit-bearing is the most influential curtailer of a plant's longevity, there are others of scarcely less fatal efficiency, among which are improper supplies of moisture, obnoxious soils, deleterious food, uncongenial temperatures, and deficient light. These all tend to shorten a plant's existence, or even at once to destroy it if administered in a violent or protracted degree.

Excessive moisture induces that over-succulency which is ever attended by weakness, unnatural growth, and early decay. Such plants more than any others are sufferers by sudden vicissitudes in the hygrometric state of the atmosphere, and are still more fatally visited if exposed to low reductions of temperature.

Soils containing obnoxious ingredients are certain introducers of disease and premature death. An excess of oxide of iron—as when the roots of the Apple and Pear get into an irony red, gravelly subsoil—always causes canker to supervene. In the neighbourhood of copper-smelting furnaces, not only are cattle subjected to swollen joints, and other unusual diseases, causing decrepitude and death, but the plants also around are subject to sudden visitations, to irregular growths, and to unwarned destruction; and a crop once vigorous will suddenly wither as if swept over by a blast. There is no doubt of this arising from the salts of copper which impregnate the soil irregularly as the winds may have borne them sublimed from the furnaces, and the experiments of Sennebier have shown that of all salts those of copper are the most fatal to plants.

That they can be poisoned, and by many of those substances, narcotic as well as corrosive, which are fatal to animals, has been shown by the experiments of M. F. Marcet. The metallic poisons being absorbed are conveyed to the different parts of the plant, and alter or destroy its tissue. The vegetable poisons, such as opium, strychnia, prussic acid, belladonna, alcohol, and oxalic acid, which act fatally upon the nervous system of animals, also cause the death of plants. Does not this favour the opinion of those who believe that there is something in plants analogous to the nerves in animals? is the naturally suggested inquiry made by Dr. Thomson, formerly the Glasgow Regius Professor of Chemistry.

The poisonous substance is absorbed into the plant's system, and proves injurious when merely applied to its branches or stem, almost as much as if placed in contact with the roots. Ulcerations and canker are exasperated if lime be put upon the wounds; and when Dr. Hales made a Golden Reinette Apple tree absorb a quart of camphorated spirits of wine through one of its branches, one half of the tree was destroyed.

An uncongenial heat is as pernicious to vegetables as to animals. Every plant has a particular temperature, without which its functions cease; but the majority of them luxuriate most in a climate of which the extreme temperatures do not much exceed 32° and 90°. No seed will vegetate, no sap will circulate, at a temperature at or below the freezing-point of water; yet the juices of the plant are not congealed even at a temperature far more depressed; and we know of no other more satisfactory proof, that like a cold-blooded animal—the frog and the leech for example—it becomes torpid, though life is not extinct, until excited by a genial temperature. No cultivation will render plants, natives of the torrid zone, capable of bearing the rigours of our winters, although in some instances their offspring raised from seed may be rendered much more hardy than their parents. When a new plant arrives from such tropical latitudes, it is desirable to use every precaution to avoid its loss; but so soon as it has been propagated from, and the danger of such loss is removed, from that moment ought experiments to commence to ascertain whether its *acclimatisation* is attainable. That this should be done is self-evident; for the nearer such a desirable point can be attained, the cheaper will be its cultivation, and consequently the greater will be the number of those who will be able to derive pleasure from its growth: hence, it is very desirable that an extended series of experiments should be instituted, to ascertain decisively whether many of our present greenhouse and stove plants would not endure exposure to our winters, if but slightly or not at all protected. It may be laid down as a rule, that all Japan plants will do so in the southern-coast counties of England, but it remains unascertained to what degree of northern latitude in our islands this general power of endurance extends. "Foregone conclusions" should have nothing to do with this matter. Experiment, and experiment only, ought to be relied upon; for we know that the Larch was once kept in a greenhouse; and only recently has it been proved that such South American plants as *Tropæolum pentaphyllum* and *Gesnera Douglasii* have been found to survive our winters in our garden borders; the first in Scotland and Suffolk, and the second in Herefordshire.

Another fact is, that many tropical plants of every order and species have been found to require much less heat, both during the day and during the night, than gardeners of a previous century believed. Other plants than those already noticed have passed from the tropics to our parterres, and even to those of higher northern latitudes. The Horse Chestnut is a native of the tropics, but it endures uninjured the stern climate of Sweden. *Aucuba Japonica*, *Pæonia Moutan*, we all remember to have passed from our stoves to the greenhouse, and now they are in our open gardens.

Every year renders us acquainted with instances of plants being acclimatised; and, in addition to those already noticed, we find that Mr. Buchan, Lord Bagot's gardener, at Blithfield House in Staffordshire, has an old Cinnamon tree (*Laurus Cinnamomum*), under his care, which ripens seed: from these many plants have been raised that endure our winters in a conservatory without any artificial heat. Then, again, there is no doubt that all the *Coniferæ* of Mexico, which flourish there at an elevation of more than 8000 feet above the sea's level, will survive our ordinary winters in the open air. Among these are *Pinus Llaveano*, *P. Teocote*, *P. patula*, *P. Hartwegii*, *Cupressus thurifera*, *Juniperus flaccida*, *Picea religiosa*, and some others.

Closely connected with the consideration of acclimatisation of plants is the fact that they retain habits long after their removal to situations in which these habits are unsuitable. Thus the *Hyacinth*, a native of Southern Asia, begins to shew symptoms of vegetation here in autumn, which answers to the spring of its long-left native clime. So the *Fuchsia*, although it accommodates itself to our hemisphere, and submitting to remain dormant during the winter, will revive in the spring; yet the season during which it will grow most vigorously, if placed in a suitable temperature, is the winter, for this is the spring-time of its native country, Chili.

In the next place, let us consider what circumstances render a plant most liable to suffer from frost; and let it be observed once for all, that to avoid such circumstances is by so much to render plants capable of enduring our climate.

First. Moisture renders a plant susceptible of cold. Every gardener knows this. If the air of his greenhouse be dry, the plants within may be submitted to a temperature of 32° without injury, provided the return to a higher temperature be gradual.

Secondly. Gradual decrements of temperature are scarcely felt. A Myrtle may be forced, and subsequently passed to the conservatory, cold pit, and even thence to an open border if in the south of England, without enduring any injury from the cold of winter, but it would be killed if passed at once from the hothouse to the border.

Thirdly. The more saline are the juices of a plant the less liable are they to congelation by frost. Salt preserves vegetables from injury by sudden transitions in the temperature of the atmosphere. That salted soils freeze with more reluctance than before the salt is applied is well known, and that crops of Turnips, Cabbages, Cauliflowers, &c., are similarly preserved is equally well established.

Fourthly. Absence of motion enables plants to endure a lower degree of temperature. Water may be cooled down to below 32° without freezing, but it solidifies the moment it is agitated.

Some plants, like some animals, are able to endure a very high degree of temperature. Sir Joseph Banks and others have breathed for many minutes in an atmosphere hot enough to cook eggs. So do certain plants flourish in hot-water springs of which the temperature varies between the scalding heats of from 150° to 180° of Fahrenheit's thermometer; and others have been found growing freely on the edge of volcanoes in an atmosphere heated above the boiling-point of water. Indeed it is quite certain that most plants will better bear for a short time an elevated temperature which, if long continued, would destroy them, than they can a low temperature. Thus a temperature rather above the freezing-point of water to Orchidaceous and other tropical plants is generally fatal if endured by them for only a few minutes, whereas a considerable elevation above a salutary temperature is rarely injurious to plants. But this is not universally the case; for the elegant *Primula marginata* is so impatient of heat, that although just about to bloom, it never opens a bud if brought into a room in which there is a fire.

Plants, generally, have the power of preventing their sap attaining to the unnatural elevation of temperature of the atmosphere around them. This in some degree may depend upon the bark and wood being bad conductors of heat, but they have a power of resisting heat quite independent of that; for the Pine Apple, though growing for months in a minimum temperature of 60°, never has that of its flesh whilst growing elevated above 50°. Now the worst of conductors would have conveyed heat through them in that time. This is only analogous to what occurs in the animal economy. Sir Joseph Banks, Sir Charles Blagden, and Dr. Solander, in the case already alluded to, remained several minutes in a room heated to 212°—the boiling-point of water, and though unpleasant sensations were produced, yet the air was easily borne, and the temperature of the body was very little elevated. If they breathed on the thermometer it sank several degrees; every expiration was cool to the nostrils, previously heated by the air inspired; the body felt cold as a corpse to the touch of the fingers, and the heat of the skin under the tongue was only 98°. A dog was exposed to a temperature of 220° for ten minutes, but its body's heat did not rise above 110°, being only 9° above its natural warmth. In these rooms an egg was cooked quite hard in twenty minutes. But though plants have the power of preserving an internal temperature, differing from that of the external air in which they are vegetating, yet they have no more power than have animals to escape from the injurious excitement occasioned by being compelled to live for any protracted time in a temperature uncongenially elevated. In such a temperature, youthful and growing animals are stimulated to an excessive rapidity of growth, so attenuating, that nothing but removal to a colder climate can preserve them from premature death; and the same phenomena attend upon plants. These, over-excited by heat, acquire rapidly an unnaturally elongated growth, attended by a weakness of texture, that hastens them to decay, unless checked by a gradual reduction of temperature. The roots in such a heat absorb water with unnatural rapidity, and this is commensurately hurried through the sap-vessels of the stem and branches, so that the over-watery sap arrives at the leaves much too fast for them to elaborate it sufficiently, though an extra effort is made by preternaturally enlarging the leaves. The water transpired is excessive, but very little carbonic acid is inhaled, and consequently the quantity of carbon assimilated is very deficient. The whole structure of the plant is, therefore, watery and weak; and if a supply of water to the roots is withheld but for a few hours, the leaves wither and shrivel past revival. These organs not only lose the power to decompose carbonic acid, but also to decompose water, though the light to which they are exposed be the brightest sunshine; and thus deficient of carbon and hydrogen, the chief constituents of their colouring matter, they become unnaturally pale.

It must not be omitted to be observed, that all plants have great capability of resisting the reduction, as well as the elevation, of their internal temperature, however low may be that of the air which surrounds them. In the polar regions, and even in those of less northern latitudes, they have to endure a temperature very far below the freezing-point of water—yet their sap is never known to freeze. If water does congeal in the texture of a plant it rifts it, but this never occurs unless extraneous moisture has penetrated through some wound or decayed part. We have seen trees so torn, but never without finding a mass of ice within the trunk or branch traceable to some outward fissure. This is entirely in accordance with the experiments of Mr. John Hunter; and other experiments which we have tried, confirm us in acceding to the conclusion to which that distinguished anatomist, as well as Sprengel, Schubler, and others have arrived, that the sap of plants never congeals in the climate and soil of which they are native, however low the temperature to which they are exposed. Even in a temperature 15° below that at which the sap, if taken from the tree, would freeze, yet, in the living plant, it remains uncongealed. This has been tried with the Vine, Walnut, Elm, and Red Pine.

These experiments also determine that plants have but a slight power of generating heat; for the thermometer, placed within their stems, in winter sinks gradually nearly to the temperature of the exterior air; and in the spring or summer that instrument so placed does not follow implicitly the atmospheric variation; but this is not merely because wood is a bad conductor of heat. It is evident that a living plant has the power of preventing the congelation of its juices, and it is impossible to account for this phenomenon without connecting it with the plant's vitality; and we see no reason for concluding that plants, differing from animals, do not, during their respiratory function converting oxygen into carbonic acid, set free its latent heat, and thus preserve their temperature. It is beyond a doubt, that, by this chemical change, some plants at one period of their vegetation generate a considerable degree of heat. The stamens of *Arum cordifolium* emit so much heat at the time they shed their pollen, that twelve of them placed by M. Hubert round a thermometer raised the mercury from 79° to 143°. Under similar circumstances, M. Sennebier observed the stamens of the *Arum maculatum* were nearly 16° hotter than the surrounding air. The flowers of *Caladium pinnatifidum*, when emitting a strong ammoniacal smell, were observed by Dr. Schultz to be as hot as 81°, though the atmospheric temperature was but 61.25°. The stamens of the *Pompion* (*Cucurbita Pepo*), *Bignonia radicans*, and *Polyanthes tuberosa* have also been observed to elevate the mercury at the time of shedding their pollen, but in a much slighter degree. In every instance this evolution of heat is occasioned by a proportionate absorption of oxygen gas by the stamens and pistils at the instant of fecundation. The stamens of the *Arum maculatum*, for instance, have been shown by M. Saussure to absorb at that time two hundred times their bulk of oxygen gas, converting it into carbonic acid.

Although some plants thus cause a great extrication of heat, and others are capable of resisting the greatest known cold to which they can be exposed, yet all have degrees of temperature most congenial to them, and if subjected to lower temperatures are less or more injured proportionately to the intensity of that reduction. If the reduction of temperature be only slightly below that which is congenial, it only causes the growth of the plant to diminish, and its colour to become more pale; this effect being in such case produced by the plant's torpidity or want of excitement to perform the requisite elaboration of the sap, as it is by over-excitement when made to vegetate in a temperature which is too elevated. If blossoms are produced at all, they are unfertile, and the entire aspect of the plant betrays that its secretions are not healthy and its functions are deadened. Mr. Knight says, that Melon and Cucumber plants, if grown in a temperature too low, produce an excess of female blossoms; but if the temperature be too high, blossoms of the opposite sex are by far too profuse.

If plants be frozen—and though some defy the attacks of frost, others are very liable to its fatal influence—death is brought upon them, as it is in the animal frame, by a complete breaking down of their tissue, their vessels are ruptured, and putrefaction supervenes with unusual rapidity. As already observed when considering the means of acclimatising plants, the more abundant is the water present in their vessels, the more apt are they to be injured by frosts; whence the young shoots are often destroyed, whilst the older branches remain uninjured, and crops on ill-drained soils suffer more severely in winter than those where the drainage is more perfect.

Deficiency of light is another contingency most influential in promoting the decline and death of plants. In proportion as they are deprived of this stimulus, they become unable to elaborate their juices, and, deficient in colour, weak, and of unnatural height, they die prematurely, and decompose more rapidly than those whose fibres, more firm and robust, are less combined with an excess of watery sap.

Finally, the unhealthy vicissitudes to which plants, in common with all other organised forms, are exposed, inevitably bring upon them death; and it would be mere waste of time to argue against those physiologists who maintain that, in favourable circumstances, the life of plants may be prolonged indefinitely. Those who choose to surmise that some plants would endure throughout all time, if unfailingly preserved from all things offensive, and supplied without failure with all things agreeable, amuse themselves with imagining what would occur under circumstances of impossible attainment.

A plant must be subjected to unfavourable contingencies; and the greater the amount and frequency of their occurrence, the more speedily do they bring its life to a close—for the more do they aid chemical affinities in breaking down that resistance of their efforts which is the chief characteristic of vitality.

So long as a plant lives it triumphs over those affinities. Its roots overcome the affinity of the soil and take from it its moisture; its leaves overcome the affinity of the atmosphere, and deprive it of the watery vapour it has in solution; the internal vessels overcome numerous affinities, and, by the decomposition of carbonic acid and water, perform within their simple tubes that which can only be effected by the chemist's most powerful agents. These triumphs over chemical affinities, and that most characteristic of triumphs—its avoidance of putrefaction, endure in the same individual often for centuries of years; it is the most marked of the triumphs of vitality—its prime distinction as a creature, capable, for a time, of defying the laws which doom all organic matters to return to the dust from which they were created; for no sooner does that vitality cease, than the heat, the moisture, and the gases which vitality compelled to minister to the plant's luxuriance and health, now triumph in their turn, and serve to destroy that form which they had aided to sustain.

That heat is necessary to putrefaction appears from the fact, that no vegetable matter kept at the freezing temperature of water will decay. Advantage of which is taken by the gardener occasionally to preserve his summer fruits and vegetables in the ice-house; and Apples, Pears, and Grapes are borne unchanged half round the globe in the ice-ships which annually visit India from North America.

That dryness effectually prevents vegetable putrefaction we see every day in the fact that our furniture does not decay; and the gardener knows that moisture is fatal to his stores in the fruit-room.

Putrefaction is also prevented by the exclusion of the atmospheric air, or, if it proceeds, it is by very slow degrees. An example of this is familiarly presented in a very effective mode adopted to preserve green Peas. These are put into dry glass bottles, and the bottles placed in water, then gradually made to boil. The chief part of the air is thus driven from the bottles and they are corked down tightly, and the cork rosined over whilst thus heated. What little oxygen remains in the bottles is absorbed by the Peas, and these remain green and unaltered for months, requiring only the addition of a little soda to the water in which they are boiled, to be as tender and as green nearly as when first gathered.

When a temperature of 45°, moisture, and atmospheric air occur to dead vegetable matters, these absorb large quantities of oxygen, evolving also an equal volume of carbonic acid. If composed of carbon, hydrogen, and oxygen only, the fumes they emit are not offensive; but if, as in the case of Onions and the Cabbage tribe, they contain a considerable portion of azote and sulphur, the smells emitted are disgusting.

As in all other instances where vegetable substances absorb and combine oxygen gas in large quantities, much heat is evolved by them when putrefying; it is, in fact, a form of slow combustion or burning, and advantage is taken of this by employing leaves, stable-litter, and tan, as sources of heat in the gardener's forcing-department.

When the putrefactive process of plants is completed, there remains a soft black mass, known as vegetable mould, or *humus.* One hundred parts of the humus of Wheat straw have of extractive or apotheme rather more than twenty-six parts, and the residue is lime, peroxide of iron, phosphate of lime, and carbonaceous matter. This apotheme is identical with the humic acid of Liebig, the ulmic acid of Braconnot, and the geic acid of Berzelius. It contains

Carbon	46·6
Hydrogen	20·0
Oxygen	33·4
	100·0

It was once believed—indeed is still believed by a few men of science, that this apotheme is the immediate fertilising component of organic manures, being soluble under some circumstances, and entering at once into the roots of plants dissolved in the moisture of the soil. But every relative research of more modern chemistry is against this conclusion, and it is now tolerably certain that a chief nutritive portion of vegetable manures are their carbon converted into carbonic acid, absorbed, either in solution with the earth's moisture, or in a gaseous form, by the roots. Apotheme is only one of the products formed during the progress of putrefaction, and is in its turn a source of carbonic acid. Carbonic acid has been long since shown to be beneficial if applied to a plant's roots. It abounds in the sap of all vegetables, though this be drawn from their very lowest parts; whereas apotheme is injurious to them if they are growing in a solution of it, and analysers have failed to detect it even within the extreme vessels of roots.

Acids are antiseptic, and retard the decay of vegetable matters, which explains why the woody fibre in peat soils remains so long unchanged, for those soils abound in gallic and other acids.

Alkalies, on the other hand, accelerate vegetable decomposition; and these being present in calcareous soils, is one reason that manures are sooner exhausted in them than in any other. Another reason for this rapid consumption is, that into calcareous and siliceous soils the air easily penetrates, and the rapid progress of decay depends in a great measure upon the free access of oxygen gas. Such access is less easy to manures buried in clayey soils; and, as a consequence, manures in them are much more permanent.

Such is the progress, such the phenomena, attendant upon the death of plants; and but one more relative question remains for our consideration, Can death be averted from plants—can they be made, by man's devices, an exception to that decree of limited existence, which extends over all other organised creatures?

Those who assert that grafting completely renovates the scion maintain the affirmative. From these we differ; for though it is happily true that grafting upon a young and vigorous stock imparts to the scion a supply of sap of which the parent stem is incapable, yet this incapacity is only premonitory of the departure of power, which will, after a transient increase of strength, occur to its removed member. Every subsequent scion, however frequently, and whilst in apparent health, removed to another youthful stock, will be found to have a period of renewed vigour and productiveness of shorter duration than its predecessor. The Golden Pippin is occasionally quoted as a contrary proof: but this example has no such weight; for, supposing that this fruit yet exists, still it has not passed the age beyond which the period of unproductiveness and death in the Apple tree may be delayed by grafting; for we have no mention of this fruit that at all justifies the conclusion that the Golden Pippin existed much more than three centuries ago. A Pearmain Apple is mentioned in records as old as King John (A.D. 1205); but the Pippin is not noticed by any authority earlier than the reign of Henry the Eighth (1509). Lambard mentions that Tenham in Kent, famous for its Cherry gardens and Apple orchards, was the place where that king's fruiterer first planted Cherries, Pippins, and the Golden Reinette.

Supposing, then, that the Golden Pippin of our days is a genuine portion of the Tenham trees, handed down to us by successive graftings, yet still, it has not exceeded the age assigned by naturalists as that beyond which the life of the Apple does not extend. But then another question will arise—Supposing our Golden Pippin does appear to survive the allotted period, who will undertake to demonstrate that the Golden Pippin of Tenham still exists? It is quite certain that a majority of the Apples for which the title of Golden Pippin is claimed have no pretensions to the distinction, and more than one old person with whom it was once a favourite fruit, now declare that it is no longer obtainable.

Be this as it may, even if the variety in question has not departed, yet no organised creature shall endure through all time. Grafting may postpone the arrival of death, as the transfusion of blood will revive for a while the sinking animal, but the postponement cannot be for a time indefinite: the day must come in both the animal and the scion when its vessels shall be without the energy to propel or to assimilate the vital fluid, though afforded to it from the most youthful and most vigorous source. The scion may be made to grow vigorously, but who will venture to assert that the parent from which that scion was taken is existing, and can be made to exist on its own roots through an infinity of years?

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