where 1° per x feet is the unknown gradient at the end of the Glacial period. At Port Jackson, b is 32°·5, and the gradient 1° per 80 feet. If t' be the corresponding value of t, we have

$$\frac{32{\cdot}5}{\sqrt{t'}} = \sqrt{(\pi\kappa)}\left(\frac{1}{x} - \frac{1}{80}\right),$$

and therefore

$$\frac{32{\cdot}5}{\sqrt{t'}} - \frac{19}{\sqrt{t}} = \sqrt{(\pi\kappa)}\left(\frac{1}{49} - \frac{1}{80}\right).$$

Lord Kelvin, making use of Forbes' observations, finds κ to be 400, so that the last equation reduces to

$$\frac{65}{\sqrt{t'}} - \frac{38}{\sqrt{t}} = 0{\cdot}56.$$

This is satisfied if t and t' are both 2325 years, but so small a length of post-Glacial time is of course inadmissible. But, if t be increased beyond this value by any amount, it may be shown that t' is increased by a smaller amount; that is to say, the length of post-Glacial time must be greater in the north of England than at Port Jackson.

The following table contains some numerical estimates of the relative lengths of post-Glacial time in these districts, calculated from the last equation :—

North of England. Years.	Port Jackson. Years.
10,000	4,800
20,000	6,100
30,000	6,900
40,000	7,500
50,000	7,900
100,000	9,100

Too much stress should not of course be laid on these figures. The second and third, especially, of the assumptions on which they are based, must certainly be far from true. But, at any rate, it seems clear that the ice must have left the neighbourhood of Port Jackson much more recently than it left the north of England.

Whether this conclusion points to an alternation of the Glacial periods in the two hemispheres, and so furnishes an argument in favour of Croll's theory, is perhaps doubtful. But it shows, I think, how important it is, from a geological point of view, that further temperature observations should be made in the coal-mines and other borings of Australia, New Zealand, and South Africa.

C. DAVISON.

PLANT-BREEDING.

WE are most of us now-a-days so much accustomed to see our gardens or our houses bedecked with flowers, and our tables supplied with vegetables and fruit, that we take these things for granted, and do not trouble to inquire whence they come or how they are produced. But if we look back even a few years, we shall see how much larger a share plants have now in our lives than they had then. We shall see, moreover, that while there has been enormous numerical increase, there has also been in many cases continued progression in form and other attributes. We are not concerned here with the introductions from foreign countries, important though they are; our business for the moment lies with the changes resulting from the natural processes of variation as controlled by the art of the gardener. The garden roses of to-day, for instance, are not the roses of a dozen years ago, and as to the sorts that were grown by our fathers and grandfathers, they have, with some few exceptions, utterly gone. It is the same with peas and potatoes, and with most other plants that are grown on a large scale. True, there are some exceptions; there are some "good old sorts," which seem to show by their persistence that they are the fittest to survive under existing conditions. The black Hambro' grape is an illustration, the old double white Camellia is another; but these plants are not reproduced by seed, and therefore do not invalidate the rule, that each succeeding generation of plants differs in some degree from its predecessor. At first the differences are slight, and it may be imperceptible to all but the trained expert; but they become more accentuated as time goes on, till at length they eventuate in forms so different from that from which they sprang, that they would undoubtedly be considered of specific, if not of generic, rank, were not their history known. The Jackman Clematis and its near allies may be cited as cases in point, and still more remarkable are the tuberous Begonias, which, like the Clematis just mentioned, have been created, so to speak, within the last quarter of a century, and which are so different from anything previously known amongst Begonias, that they have actually been raised to the dignity of a genus by M. Fournier, a French botanist. Pansies and Auriculas—garden productions both—are now, morphologically speaking, as good species as are most of the groups of individuals to which this rank is assigned by naturalists. Of their seedlings a large proportion comes true—that is, the parental characteristics are so far reproduced that there is no greater amount of variation among the offspring of many of these artificially-made species than there is in the progeny of natural species. If, as is the case in some Auriculas and the gold-laced Polyanthus, we find little change has occurred during the last few years, may not this relative invariability be the result of the gradual assumption of a degree of stability which we usually associate with the idea of a species? Again, it often happens that these high-bred, close-fertilised plants become sterile, so that their continuance can only be ensured by cuttings, or some means of vegetative propagation. Is not this analogous to the retrogression and ultimate extinction which occur in natural species? It is not necessary here to cite more illustrations; our concern lies rather with the way in which these changes are brought about. This leads us to what is called the improvement of plants, or plant-breeding. There seems to be a growing tendency to make use of the latter term; but if it is to be adopted, it must be taken in a broad sense, and not limited to the results of sexual propagation.

The two methods, made use of by gardeners and plant-raisers for the improvement of plants, are selection and cross-breeding—the latter, as far as results are concerned, only a modification of selection. The natural capacity for variation of the plant furnishes the basis on which the breeder has to work, and this capacity varies greatly in degree in different plants, so that some are much more amenable and pliant than others. The trial-grounds of our great seedsmen furnish object-lessons of this kind on a vast scale. Very large areas are devoted to the cultivation of particular sorts of cabbage, of turnips, of peas, of wheat, or whatever it may be. The object is two-fold—primarily to secure a "pure stock," and secondarily to pick out and to perpetuate any apparently desirable variation that may make itself manifest.

The two processes are antagonistic—on the one hand, every care is taken to "preserve the breed," and to neutralise variation as far as possible, so that the seed may "come true"; on the other hand, when the variation does occur, the observation of the grower marks the change, and he either rejects the plant manifesting it as a "rogue," if the change is undesirable, or takes care of it for further trial, if the variation holds out promise of novelty or improvement. It is remarkable to note how keen the growers are to observe the slightest change in the appearance of the plants, and to eliminate those which do not come up to the required standard, or which are not "true." Where the flowers lend themselves freely to cross-fertilisation by means of insects, as is the case with the species and varieties of Brassica, it is essential, in order to maintain the purity of the offspring, to grow the several varieties at a very wide distance apart. In passing along the rows or "quarters," the plant-breeder not only eliminates the "rogues," and retains what he thinks may be desirable variations, as we have said, but he specially marks those plants which most conspicuously show the characteristic features of the particular variety he desires to increase, and he takes care to obtain seed from the plants so marked. The variety thus becomes "fixed," but it is obvious that that word is only used relatively; really, there is a constant change, which may be either in a retrograde direction, or which may be looked on as an amelioration. Thus, in the seedsmen's advertisements we see announcements of this character: "So-and-so's *Improved* Superlative Cucumber" or whatever it may be. This "improvement," when it exists, is the result of the careful scrutiny, elimination, and selection exercised by the raiser. These are repeated season after season, till a degree of fixity is attained and a good "strain" is produced.

Fierce competition and trade rivalry forbid the growers to relax their efforts, and thus it happens that the pea or the potato of to-day is not the same, even though it may be called by the same name as its predecessors. To the untrained eye, the primordial differences noted are often very slight; even the botanist, unless his attention be specially directed to the matter

fails to see minute differences which are perceptible enough to the raiser or his workmen. Nor must it be thought that these variations, difficult as they are to recognise in the beginning, are unimportant. On the contrary, they are interesting, physiologically, as the potential origin of new species, and very often they are commercially valuable also. These apparently trifling morphological differences are often associated with physiological variations which render some varieties, say of wheat, much better enabled to resist mildew and disease generally than others. Some, again, prove to be better adapted for certain soils or for some climates than others; some are less liable to injury from predatory birds than others, and so on. These co-relations, then, are matters of the greatest importance to the biologist intent upon the study of progressive modification, and to the merchant and the cultivator for practical reasons.

So far we have been alluding to variations in the plant as grown from seed, but similar changes are observable in the ordinary buds, and gardeners are not slow to take advantage of these variations. The buds taken from the base of a plant not unfrequently differ from those which are developed higher up, and these differences are perpetuated by propagation by means of cuttings or grafts. An interesting illustration of the variability in flower-buds is furnished by the gigantic Chrysanthemums which attract so much attention in late autumn. Without entering into technical details, it may be briefly stated that the cultivator selects certain buds, or one bud occupying a special position, and pinches off and rejects most or all the others. The result is not only a flower-head of large size, such as we might expect under the circumstances, but also, in very many cases, one which presents different characteristics to those which are manifested by the other buds when allowed to develop themselves. "As like as two peas in a pod" is, therefore, a motto which has not the significance it had before we had observed that the peas are mostly different, sometimes very much so, and the same thing happens, as has been shown, in the ordinary leaf- and flower-buds; doubtless each cell has its peculiarity, which only awaits a Röntgen ray or some other means to become visible.

Before we leave the subject of buds, some mention may be made of that form of bud-variation which the gardeners speak of as "sporting." Sports are bud-variations which occur suddenly, without assignable cause, and often simultaneously in different regions widely separate. Thus we get peaches and nectarines on the same bough, black and white grapes on the same shoot, or even in the same bunch, finely-cut leaves on a branch that normally produces broad or entire leaves, and so on. The gardener who is on the alert takes care to remove such buds, and to propagate them by cuttings or grafts. If raised from cuttings or layers, the duration of the sport is indefinite; if propagated by grafting, their duration is naturally conditioned by the life of the stock. The problems afforded by sports are of great interest, and are by no means fully solved. Many of them may arise from atavism, or a reversion to an ancestral condition; but of this there is no proof, neither can we appreciate the reason why such reversion should take place. Some may be the result of the dissociation of previously mixed characteristics. Of this we frequently see unmistakable evidence. Thus hybrid berberries frequently show on the same plant an un-mixing or separation of the characters belonging to the two parent-forms.

This brings us to the subject of cross-breeding as a means of obtaining new or improved varieties. Cross-breeding may occur in all degrees from the case where the pollen of one flower is transferred, by insect or other agency, to the stigma of another on the same branch, to that in which the pollen is transferred to the flower on a plant of a different species. Watch a bee travelling over the great disc of a sun-flower, and it will become obvious that (always provided the stigmas be in a receptive condition) cross-fertilisation of neighbouring flowers must take place.

There are endless adaptations which ensure cross-fertilisation, and on the other hand there are very numerous structural arrangements which necessitate close fertilisation, or the fertilisation of a flower's ovules by pollen produced in the same blossom. In view of the copious literature on this matter, it is not necessary here to enter into further detail. It is enough to say that some of the most astonishing results of the gardener's art are due to this practice of repeated cross-fertilisation. When the cross is effected between plants of two different species the term "hybridisation" is made use of, but it is obvious that there is only a difference of degree between the fertilisation of different flowers on the same plant and that of flowers belonging to different species, or even genera.

The tuberous Begonias, before alluded to, are the results of the successive intercrossing or hybridisation of several species, and the result is the production, within little more than a quarter of a century, of a race or garden-group, not to be matched in nature, and so distinct as to have been thought worthy not merely of specific but of generic rank.

Many recognised genera, we might even say most, are not so sharply differentiated as are these Begonias from others of the same family. These extreme crosses apparently are not effected under natural conditions, and some botanists even hesitate to admit the occurrence of hybrids in nature except under very exceptional circumstances. The gardeners and cultivators, however, have long considered certain forms to be of hybrid origin, and one of the most interesting things in this connection of late years is the positive evidence which cultivators have been able to bring forward as to the existence and the parentage of natural hybrids. Certain orchids, now rather numerous, were, from the appearances they presented, assumed to be "natural hybrids" between certain species. That such assumptions were correct has now been proved by the production in our orchid houses of forms indistinguishable from those met with in a wild condition, as the direct consequence of the designed fertilisation of one flower by the pollen of another.

Fairchild, a nurseryman at Hoxton, and the founder of the Flower-sermon, was the first on record to raise a hybrid Pink. Indeed, this is the first artificial hybrid of any kind on record, and it dates from 1719. From that time to this gardeners have gone on selecting, cross-breeding, hybridising. At one time some good folk looked askance at such operations as an interference with the laws of Providence. So much was this the case, that one eminent firm of nurserymen in the early part of the century led their customers to believe that certain heaths (Ericas), which they had for sale, were imported direct from the Cape of Good Hope, instead of having been raised by cross-fertilisation in their own nurseries at Tooting!

Gardeners for the most part pursue their experiments with no scientific aim. The names of Philip Miller, Thomas Andrew Knight, and of Dean Herbert, amongst others, suffice to show that some gardeners appreciate the deep scientific value of these every-day procedures. From the labours of these men and their successors it is made obvious that the cultivator, by availing himself of natural tendencies and natural agencies, and by his power of eliminating conflicting or unpropitious elements, does actually bring about, in a relatively very short period, the same results that occur under natural conditions only after the lapse of a prolonged period. Do not these facts show the desirability for our own biologists to study carefully the results obtained by the gardener, and better still to enter, as their great leader Darwin did, the field themselves as experimenters.

There can be few departments in which greater promise of important results can be held out.

MAXWELL T. MASTERS.

THE ROYAL OBSERVATORY, GREENWICH.

ON Saturday last, the Astronomer Royal presented his annual report to the Board of Visitors of the Royal Observatory, Greenwich. Following the usual custom, a number of astronomers and other men of science were invited to inspect the buildings and instruments of the observatory. The subjoined extracts from the report give a general idea of progress made in some departments since the middle of May last year.

Work with Equatorials.

The new equatorial with photographic telescope of 26 inches, presented by Sir Henry Thompson, is now nearly finished and ready for inspection at Sir Howard Grubb's works. Sir Henry Thompson has completed his valuable gift by the addition of a Cassegrain reflecting telescope of 30 inches aperture, to be carried in place of the counterpoise at the other end of the declination axis.

The 28-inch refractor has been in constant use for micrometric observations during the year, and for spectroscopic observations till November last year.

The measures of the dimensions of Saturn and his rings,