What has gone before has been the progress of astronomy in the year just past.

In closing we cannot omit to offer our tribute to those that have past from the field, and to mention the honors that have been received by the living.

The death last May of the Rev. Charles Pritchard, D.D., F.R.S., late Savilian Professor of Astronomy and Director of the Observatory at Oxford, removed one who left a deep impression, if not in astronomical investigations, in his students that are taking up the work as he had taught them. Dr. Pritchard was a broad-minded man, honest in his purpose, upright in his character, sensitive to the feelings of his students and active in his investigations. Mr. W. E. Plummer has given in *Observatory* for July, 1893, a sketch of Dr. Pritchard's life, a pure, noble one.

In the death of Dr. Adolp Steinheil the astronomical world has lost one who was an authority upon the construction and grinding of object glasses. His death took place at Munich on Nov. 4 last.

On Dec. 6, death once more entered the flock and took from us that eminent astronomer, mathematician and historian of science, Dr. Rudolf Wolf, of the Zurich Observatory. Since 1855 he had been the Director of that observatory, as well as Professor in the Polytechnicum. Dr. Wolf's pen was well handled, as may be seen in his writings, embracing as they do researches in pure mathematics, astronomy, physics and the history of science. In 1852 appeared the first edition of "Taschenbuch of Mathematics, Physics, Geodesy and Astronomy"; in 1858–61 the four volumes of biographies of Swiss men of science; in 1869–72 his "Handbuch der Mathematik, etc.," in two volumes. Probably his most extensive work, the "Handbuch der Astronomie, ihrer Geschichte und Litteratur," has just been completed. All astronomers have at times turned with interest to his "Astronomische Mittheilaugen," commenced in 1856 and continued to the present time. In 1877 he published his "History of Recent Astronomy, Especially in Germany." Dr. Wolf won his reputation in his important discoveries and researches relative to the solar spots. In *Astronomical Journal* No. 309 will be found a very interesting sketch of his life, and from which we have drawn many of our statements as to his work in astronomy.

The December number of *L'Astronomie* conveys the information that the Academy of Sciences of France had decided to confer the Arogo gold medal upon Professor Asaph Hall for his discovery of the satellites of Mars, and upon Professor E. E. Barnard for his discovery of the fifth satellite of Jupiter. The Arogo medal has been conferred only once before, to the illustrious Leverrier, in recognition of his discussion that lead to the discovery of Neptune.

SUNSPOTS AND METEOROLOGY.

BY H. A. HAZEN, WASHINGTON, D. C.

THE spots on the sun are disturbances or storms largely of electric origin. They have a drift or motion along the surface at the equator of 867′ per day, and at lat. 14°, 851′. It is known that these spots have a definite period of about eleven years. They have an intimate relation to the fluctuations of magnetic declination, and to the appearance of auroras. An interesting discussion of the question as to the immediate transmission to the earth of an influence from a solar outburst will be found in recent numbers of *Nature*. From time to time serious efforts have been made to show that there is a close connection between sunspots and terrestrial disturbances. It should be noted that mere coincidences between phenomena, no matter how often they are observed, can have little weight in establishing a relationship, unless it can be shown, *a priori*, how or why there is a connection. On the strength of mere coincidences, the ancients were justified in holding the view that the earth was stationary, and all the universe rolled about it, producing the "music of the spheres."

In studies of coincidences, it is very easy to ignore the cases which disagree with a preconceived relation, and to magnify those that do agree. For example: it is believed by some that sunspots have an influence at the earth only as they first appear by rotation on the eastern limb of the sun, and this, too, in face of the fact that some of our most brilliant auroras have appeared with large spots near the centre of the sun's disc. In Nov., 1882, a spot at the centre of the sun could be seen with the unaided eye, and yet it was assumed that the aurora then seen, one of the finest, was due to a few small faculæ just appearing on the sun. No theory of this kind will hold unless it can be shown why the spot loses its influence after it is a few days old. The present writer is well aware that those who adopt this view, that the sunspot has influence only at the time of its first appearance by solar rotation, will not submit to the following crucial test, which is equally applicable to all discussions of this kind: Decide upon the three days in each rotation when the influence should have been the greatest, and also the three when it was weakest, then determine independently the actual meteorologic conditions over any definite portion of the earth, say, for the lake region, or the Ohio valley, or even the whole United States, as regards storms, cold waves, or any other definite phenomenon. A comparison of the data would at once show the value of this supposed influence and a relationship, if there is one.

Attempt has been made also to determine a periodic effect from these spots, or from the source of energy behind them, at specific solar meridians. At first sight, since, as we have already seen, the spots have a different rotation period at different solar latitudes, it would seem as though such a period could not possibly be established. If, however, there are certain influences at specific solar meridians tending to increase spots independently of their drift, such influences may be felt at the earth and would also show themselves by an increase or diminution in the spots whenever that meridian of the sun was at the centre, though it should be noted that this influence can hardly concentrate itself at any one meridian, but must be felt over many days, unless we consider that the sun's influence has tides or blazes up at certain definite times in each rotation. Spots might drift at any velocity, but when they approached such a meridian they would show it in their appearance all the way from the sun's equator to their limits on either side. Various periods have been set for these meridians of maximum influence; some of these are as follows: 25, 25.5, 26, 27, 27 1/4 days, etc. In order to test this question, it has been customary to arrange spot areas according to the selected or determined period for 100 rotations or so, and then to average each day by itself. There is nothing so easy as to arrange figures in this way, but the procedure is fraught with grave danger, as we are liable to cover up just the most important fluctuations by an indiscriminate mean, and our final result shows such microscopic fluctuations that we are tempted to magnify them by an easy multiplication.

A common argument among advocates of such methods, to account for failures in obtaining a period in the past, is that the exact period has not been discovered. One investigator has developed a period of 27.27778 or 27 d. 6 h. 40 m.; another, in studying shorter periods, has made two, one of 7.26917 days (7d. 6.46 h.), and another of 6.16417 days (6 d. 3.94 h.) and so on. This point is not well taken, however, for a little experience with figures in a known period, by combining them according to a slightly different law, will show at once, not only that we have not the right period, but what that exact period is. For example, take 27 figures in a definite progression and arrange them according to a period of 27 1/3 days, average each 6 periods in succession by themselves and we shall find that each group has its maximum point retarded by two days from the preceding. In meteorologic work it is better to average in groups of 6 and 7 periods in each year, as this eliminates the seasonal effect.

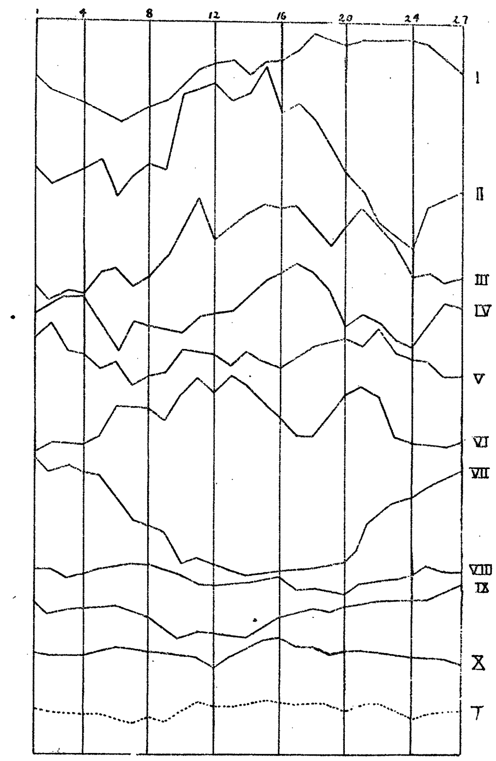
The best data to study the sunspot period are contained in photographs of the sun taken at Greenwich and in India, which together give a superb record for nearly every day of the year. We shall avoid difficulties if we average these figures in groups of ten rotations each, and we would naturally expect to find the influence in each group. If we do not find a thread running through all these groups, it would be pretty good evidence that we cannot get at the influence, even if there is any, in this way, but that it was either entirely masked by other forces, or else was too insignificant to show itself.

I have arranged the sunspot areas from April, 1881, to 1889 in different periods of 25, 25.5, 27 and so on days and in groups of ten rotations each, and have projected curves from these. The curves for the period of 27 days are given here. These curves present the actual data without smoothing or rounding, as this best shows the precise fluctuations. The light vertical lines show the first, fourth, eighth, etc., day of the rotation. Each group of ten rotations has a Roman numeral at the end, and the last (T) is the mean of the 10 groups, or of 100 rotations. We see at a glance that these groups have no common thread at any specific day of the period running through all, and this shows that nothing can be hoped for in this study unless we can first eliminate some of the influences which mask the real effect at the solar meridian. The more reasonable hypothesis is that there is no definite period in this influence.

But this is not all. The last curve (T) shows how exceedingly slight the effect must be, and a few more groups would have practically removed even these slight fluctuations. Again, we see that the maximum and minimum points in (T) are often due to a marked fluctuation in one, or at most in two, of the individual groups, for example: the maximum point in (T) near the 16th day is due entirely to the marked fluctuation in II. at the same day, and, if that group, or perhaps two rotations of the ten in the group, were omitted, this fluctuation would practically disappear. It would seem as though the evidence was conclusive that these crests and hollows in (T) are entirely fortuitous and do not show any influence recurring from rotation to rotation or any physical connection in the fluctuations of the different groups.

Precisely the same reasoning will apply with still greater force to similar studies of meteorologic elements. Here we have a great many local causes modifying the original cosmical influence, and these must be eliminated first. The temperature of the air, for example, is affected by the onward progress of hot and cold waves, by clouds, which serve to diminish the sun's heat by day and terrestial radiation by night, by moisture, by rainfall, by wind, etc. Before we could attempt a study for periods in this element, it would be necessary to take out these effects or to show that they are overborne by the greater cosmic influence.

I do not think that this negative result should lead us to conclude that extra terrestrial forces, aside from heat, have no marked effect upon our weather, but simply that this is not the proper method of getting at these influences. The evidence of such effects is overwhelming, and we may hope for the greatest advances in meteorology in the near future along these lines of research, that is, in developing extra terrestrial influences. Whence comes the enormous amount of electricity stored in the atmosphere at heights of 5,000 to 10,000 ft.? An answer to this single question would be of inestimable value to meteorology. It would seem to be a direct effect from the sun. The present lively discussion and most careful studies upon the influence of electricity in vapor condensation are gratifying and give an earnest of what may still be hoped for. The recent pilot balloon ascensions in Paris up to nearly 10 miles open up a new field for the meteorology of the future. These conditions at 10 and 15 miles must be due to extra terrestrial forces. It is claimed by many that the heat of the sun has no effect upon the air at these enormous heights, and yet, there are indications of most marked fluctuations of temperature on the passage of high and low areas. It has been well established that on the



approach and passage of a low area over Pike's Peak, Sonnblick and other high mountains there is a marked rise in temperature, and the fluctuation is generally greater above than below.

On Mar. 21, 1893, in Paris, a balloon reaching nearly ten miles in the centre of a high showed a diminution of 1° F. in 310 ft. Sep. 17, the same balloon near a low showed a diminution of 1° F. in about 380 ft., or pecisely the same law as on mountains.

Meteorology has been woefully hampered in the past by the theory that all weather changes are due to the heating or cooling, and flowing, or drifting of masses of air comparatively near the earth. Let us look away from these minor conditions and get an insight into the real causes of these conditions, or what is back of them. Let us broaden our view and see how extra terrestrial forces are continually acting upon the upper limits of our atmosphere as well as upon the lower layers and are feeding or generating our storms, cold waves, etc. Let us cut loose from the idea that all our weather conditions are borne along by air currents, for it is plain that this is impossible, since the velocity of these currents at 5,000 ft. is double that at the earth, and any storm or high area would be very quickly disintegrated by such action.

AUTUMN COLORING OF LEAVES.

BY G. W. M'CLUER, CHAMPAIGN, ILL.

THE subject of this paper was suggested to me more than a year ago by some highly colored leaves of the common red currant that I noticed while rambling in the woods near Urbana.

I shall not take up my notes in the order in which they were made, or of their importance, but shall begin with the smallest.

In the leaves of several species of trees where a principal vein has been broken, the part toward the tip of the leaf has colored earlier and more highly than the rest. Not unfrequently, in lobed leaves, the lobe with the broken rib has been the only part of the leaf that showed any coloring. Leaves torn from the margin to the midrib were not changed as a result of the injury.

The species in which parts of leaves have been seen to color as a result of this injury are soft and hard maple, tulip, white, red and scarlet oak and cottonwood, and blackberry. Probably all plants that color at all would show the same thing.

Carrying the observation a little further, branches of many kinds of trees and shrubs that have been girdled or otherwise injured, have been found to color earlier and usually, though not always, much more highly above the injured or girdled part than below, or than other branches on the same tree that were not injured. As noticed before, the thing that first called my attention to this subject was finding a clump of the common red currant with the leaves on the tips of several twigs colored dark crimson. An examination showed that all the twigs with colored leaves had been girdled by some insect while none of those still green were. Girdled grape branches frequently have very highly colored leaves, but I have never seen them colored on branches that were not injured. Girdled or injured branches with highly colored leaves have been noticed on all our native maples, on cottonwood, elm, wild black cherry, oak, pear and plum.

A large branch on a hard maple on one of our streets used to attract my attention, and I sometimes wondered if its habit of early coloring could not be perpetuated by budding from it. It was finally broken off and was found to be eaten by borers and partly decayed. Branches on some of the hard maples round which wires have been tightly drawn have colored earlier than the rest of the trees. In a few cases where forked branches have split, the one nearest off has been found to be colored more than the other.

The next step would be to find the whole tree more highly colored than those around it on account of some injury to the trunk. Believing that a variety of trees might be produced and propagated that would color regularly every fall, I have watched for such as might offer a good chance to try the experiment. In the artificial forest belonging to the University is a plat of hard maple that has attracted my attention several times, but in looking at trees that were especially brilliant, it was found that all of them had some noticeable defect in the trunk; usually a place where the bark had been destroyed on one side of the tree and the wood left exposed so that it died. In a group of hard maples like these there will frequently be found in the fall all gradations of color from plain green to bright yellow or red, at the same time. There is an individuality in time, depth, and shade of color that is entirely independent of the condition of the tree itself.

Of four young soft maple trees near my house that were planted at about the same time, one has been allowed to get full of borers, and the trunk is so badly eaten that the tree will probably die before a great while, but last fall it was more highly colored than I had ever seen a soft maple before, and the leaves were all off of it before the others had fairly begun to turn. The brightest colored red oak yet seen had a barbed wire drawn tightly around it at about three feet from the ground, and the brightest Virginia creeper had had the bark knocked off in some way.

It is now only one more step to the roots of the trees. We have on the University farm a plat of two year old white oaks that have been grown for planting in the artificial forest. As a preparation for their removal, the top roots were cut last fall. The work was begun while the leaves were still green; when it was about half done, it was stopped and not completed until two weeks later. Within a week after the roots of the first had been cut, there was a very marked change in the foliage. The root pruned trees were all highly colored, while of those not pruned there was only occasionally one that had begun to color.

It is a matter of common observation that trees on hilly land color more deeply than those on level land, but it is not so frequently reported that they also color earlier, though the latter is just as much a fact as the former. Trees on thin land color earlier than the same species on rich land.

It is a common practice among nursery men to stop cultivation before the end of summer and allow the weeds and grass to grow, so that the trees will ripen up their wood earlier and more perfectly. Cultivated land holds moisture longer than uncultivated, and when the uncultivated land has a coat of weeds and grass, the loss of moisture is still more rapid.

It is a very common thing to see a clump of wheat or oats standing out at the edge of a field where it has things more to itself, that is much greener than the general field; or to see thick and thin spots in a field, and the thick always ripe earlier than the thin. Corn grown very thick ripens earlier than corn grown thin. A plat of corn on the Experiment Station grounds, that had no cultivation this past year, the weeds being allowed to grow at will, ripened earlier than cultivated plats of the same variety on each side of it. This shows that the time of ripening depends on other circumstances than the individual character of the plant.

It is not uncommon for our apple trees to shed many of their leaves during a season of severe drouth. If this is followed by heavy rains and warm weather, blossoms and new leaves are very apt to make their appearance. The age of a tree makes a difference in the length of time it uses to complete its season's growth. Young trees, under like conditions, grow longer than older ones, and this is not a matter of shade either, for it is seen more decidedly in nursery stock, as compared with older orchard trees, than in trees in the forest. Sprouts from the stump of a tree that has been cut down grow later than trees of the same species near then. Water-sprouts in apple and other trees grow later than the normal branches; in fact there is but little difference in this respect between the water-sprout and the nursery grown apple tree. Both may be seen until the early winter with tufts of unripened leaves still adhering to their tips.

This thought leads naturally to the subject of determinate and indeterminate growth of plants.

Some species, as the oaks and ashes, will start out a shoot in the spring that reaches its full length in a short time, and the leaves expand and the wood hardens after-