the Saskatchewan River and the Arctic "Barren Grounds," and his collection of birds from the area drained by the Churchill River was the first to be made from that remote region. Of this collection a list is given at the end of the book, and birds predominate throughout the pages of what is really a naturalist's journal—unvarnished, graphic, and with a strong personal note. A chapter is given to the rare sandhill crane, which he saw and heard and stalked. He found the nest and saw the eggs through the field-glass, but, having waited overnight in the hope of the parents returning, he was baulked in the end, for the nest was empty in the morning.

A fine picture is given of Reindeer Lake, a vast sheet of water stretching 140 miles north and south, and 40 miles across at its widest. Its shores form the favoured winter-haunt of the barren-ground caribou (*Rangifer arcticus*), which digs through the snow to get at the white moss and marsh grass. Early in the year the does and yearling fawns begin to move northward, and the bucks follow later.

There is no weather-change urging the northward migration, so it is leisurely; moreover, many of the does are with young. The southward movement of great herds in the fall is largely conditioned by the absence of trees, for an icy crust, difficult to break, forms over the snow. "As the thermometer drops in the Far North and food and shelter become difficult to find, the animals will band together and grow restive, and pause from time to time to sniff the wind from the south with question on their countenance. And one day, with proud heads up and anxious eyes, they will commence their long travel through sheltering forests where snows are soft and food is plentiful beneath its yielding surface."

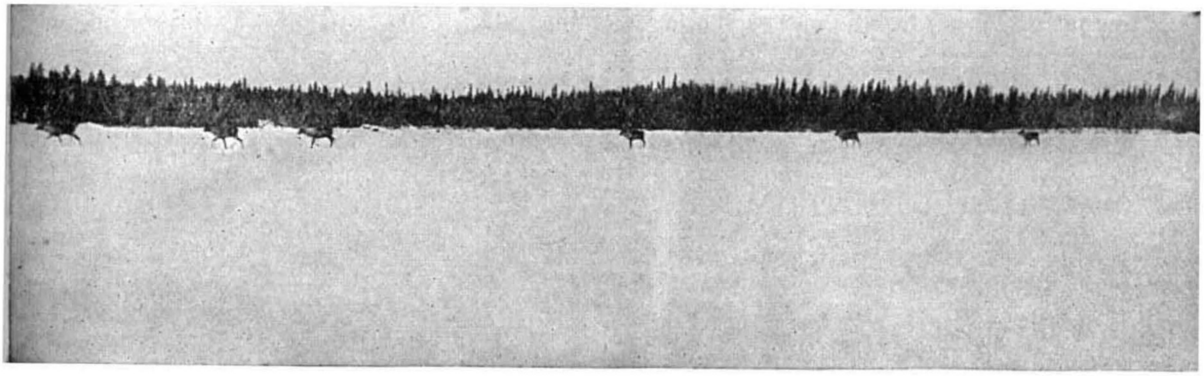

FIG. 2.—Caribou travelling in typical Indian file. From "Wild Life in Canada.'

The picture that the author gives of the caribou is a fine piece of work. Another chapter deals with the admirable sled-dogs, which will gamely do their best, for two or three days on end, in bitter weather and without food, to save an anxious situation. Very good reading, too, is Capt. Buchanan's appreciation of the Cree and Chipewyan Indians, "quaintly friendly and unselfish in their hospitality," "resourceful, magnificent fellow-travellers on the trail."

Tidal Power.

THE idea of utilising the rise and fall of the tides for power purposes has long been a favourite one. Up to the present, however, no power development of this kind, of any appreciable size, has been carried out. The comparatively recent arousing of interest in water-power development in general, and the great advance in the cost of fuel, have been accompanied by a corresponding interest in tidal-power schemes, and their commercial possibility is at the moment the subject of serious investigation in this country and in France.

The power which may be developed from a tidal basin of given area depends on the square of the tidal range, and since the cost per horse-power of the necessary turbines and generating machinery increases rapidly as the working head is diminished, the cost per horse-power of a tidal-power installation, other things being equal, will be smallest where the tidal range is greatest. It is for this reason that the western, and especially the south-western, coasts of Great Britain, and the western coast of France, are particularly well adapted for such developments, since the tidal range here is greater than in any other part of the world, with the possible exception of the Bay of Fundy, Hudson's Bay, and Port Gallelos, in Patagonia.

In Great Britain the highest tides are found in the estuary of the Severn, the mean range of the spring tides at Chepstow being 42 ft., and of the neap tides 21 ft. In France the maximum range occurs at St. Malo, where it amounts to 42·5 ft. at spring tides, and about 18 ft. at neap tides. The tidal range in the Dee is 26 ft. at springs, and 12 ft. at neaps, while the mean range of spring tides around the coast of Great Britain is 16·4 ft., and of neap tides 8·6 ft.

Many schemes of tidal-power development have been suggested from time to time. Briefly outlined, the more promising of these are as follows:—

(*a*) A single tidal basin is used, divided from the sea by a dam or barrage, in which are placed the turbines. The basin is filled through sluices during the rising tide. At high tide the sluices are closed. When the tide has fallen through a height the magnitude of which depends on the working head to be adopted, the turbine-gates are opened, and the turbines operate on a more or less constant head until low tide. The maximum output from a given area of basin is obtained when the working head is approximately one-half the tidal range, and the cycle of operations under these conditions, and with a constant rate of fall in the tidal basin, is shown in Fig. 1. Here the dotted sine curve represents the level of the sea on a time base. The working period extends from A to B.

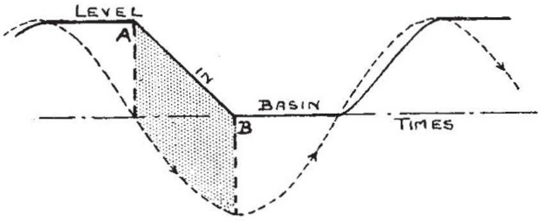

FIG. 1.

(*b*) A single tidal basin is used, with the turbines operating on both rising and falling tides. The cycle of operations is now indicated in Fig. 2. The working period per complete tide extends from A to B and from C to D. Slightly before low water, at B, the basin is emptied through sluice-gates, and at D, a little before high water, the basin is filled through the sluice-gates. With a working head equal to one-half the tidal range, the period of operation is approximately 50 per cent. greater than in system (*a*), and the work done per complete tide is approximately 50 per cent. greater.

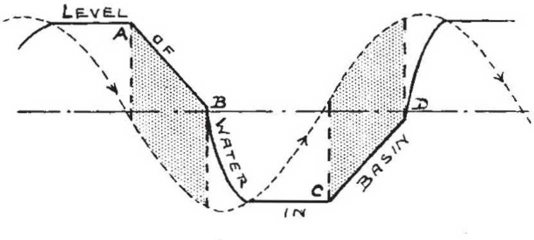

FIG. 2.

(*c*) A single tidal basin is used with the turbines operating on both rising and falling tides. Instead of filling and emptying the tidal basin through sluice-gates at high and low water, and working under an approximately constant head, the water is allowed to flow through the turbines and to adjust its own level. Under these conditions the rise and fall inside the basin are cyclical, with the same period as the tide, but with a smaller rise and fall and with a certain time-lag. The range in the basin and the time-lag depend on the ratio of the surface area of the basin and of the effective discharge area of the turbines. The working head during each tide varies from zero to a maximum. The cycle of operations is shown in Fig. 3. The working period is from A to B and from C to D, where the head at the points A, B, C, and D is the minimum under which the turbines will operate. The total working period per tide is greater than with either of the preceding systems, and the possible output is somewhat greater. On the other hand, the variation of head during any one tide is very large.

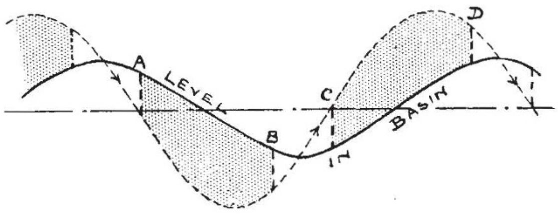

FIG. 3.

(*d*) Two tidal basins of approximately equal areas are used, with turbines in the dividing wall. Each basin communicates with the sea through suitable sluice-gates. In one of these basins, called the upper, the water-level is never allowed to fall below one-third of the tidal range, while in the lower basin the level is not allowed to rise above one-third of the tidal range. The working head then varies from 0·53 H to 0·80 H, and operation is continuous, as indicated in Fig. 4, which shows the cycle of operations. The upper basin is filled from the sea through the appropriate sluice-gates from A to B, and the lower basin discharges into the sea from C to D. For a given total basin area and a given tidal range the output is only about one-half that obtained in system (*a*), and one-third that obtained in systems (*b*) and (*c*), so that, except where the physical configuration of the site is particularly favourable, the cost per horse-power is likely to prove very high.

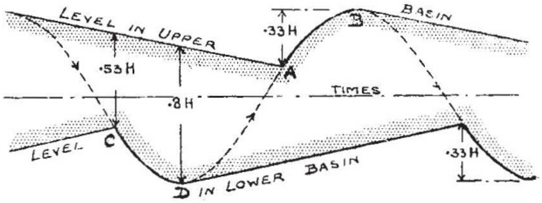

FIG. 4.

(*e*) Two tidal basins of approximately equal size are used. Turbines are installed in the walls dividing the sea from each basin. Fig. 5 shows the cycle of operations. From A to B the upper basin discharges through its turbines into the sea. From B to E the sea enters the lower basin through its turbines. The upper basin is filled from the sea through its sluice-gates between C and D, and the lower basin is emptied through its sluice-gates from F to G. The head varies from 0·25 H to 0·62 H, and the output is some 25 per cent. greater than in system (*d*), but the number of turbines required is much greater than in (*d*).

It is possible, at the expense of additional complication, to arrange in each of these systems that the head shall be maintained constant during any one working period, but since this means that the working head must then be the minimum obtaining during the period, a loss of energy is involved, with a great additional cost of construction and complication in manipulation, and with little compensating advantage.

The great difficulty in developing a tidal scheme as compared with an orthodox low head water-power scheme arises from the relatively great fluctuations in head. In any scheme in which the working head is a definite fraction of the tidal range, the working head at spring tides is much greater than at neap tides. In the case of the Severn, for example, the working head at springs would be twice as great as at neaps, and the energy output per tide would be four times as great at springs as at neaps, while at St. Malo the output would be 5·5 times as great at springs as at neaps.

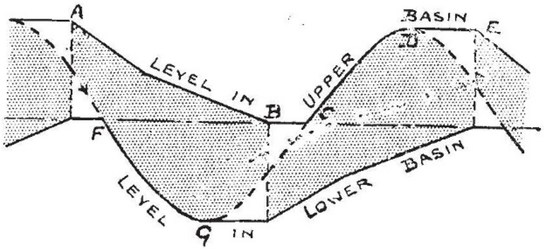

FIG. 5.

Not only is the installation subject to this cyclical fluctuation of head, but in any simple scheme the turbines also cease to operate for a more or less extended period on each tide; and as this idle period depends on the time of ebb or flood tide it gradually works around the clock, and will, at regular intervals, be included in the normal industrial working day. It is true that schemes of operation such as have been indicated are feasible in which this idle period may be eliminated and continuous operation ensured, but only at a considerable reduction of output per square mile of tidal basin area. Even in such schemes, unless the working head is fixed with reference to the tidal range at neap tides, the variation of head between springs and neaps causes the output to be very variable.

In any installation, then, designed for an ordinary industrial load, unless the output is cut down to that obtainable under the minimum head available at the worst period of a neap tide, in which case only a very small fraction of the total available energy is utilised and the cost of the necessary engineering works per horse-power will, except in exceptionally favourable circumstances, be prohibitive, some form of storage system forms an essential feature of the scheme.

Various storage systems have been suggested. Electrical accumulators must be ruled out, if only on account of the cost, and the same applies to all systems making use of compressed air. The only feasible system appears to consist of a storage reservoir above the level of the tidal basin. Whenever the output of the primary turbines exceeds the industrial demand, the excess energy is utilised to pump water into the reservoir, and when the demand exceeds the output from the primary turbines it is supplied by a series of generators driven by a battery of secondary turbines operated by the water from the storage reservoir.

Evidently this method is available only when the physical configuration of the district affords a suitable reservoir site within a reasonable distance of the tidal basin. Unfortunately also, considerable losses are inevitable in the process, and the energy available at the switchboard of this secondary station is only about 50 per cent. of the energy of the water utilised by the primary turbines. Where two tidal schemes at some distance apart differ sufficiently in phase, it is possible, by working the two in conjunction, to reduce or eliminate the idle period between tides, and thus to reduce the necessary storage somewhat; but this does not affect the necessity of storage as between spring and neap tides.

Since storage reduces the available output by one-half, and at the same time complicates the system, besides adding considerably to the first cost and maintenance charges, the prospects of tidal-power schemes would be much more promising if the whole of the output could be utilised as it is generated. By feeding into a distributing main in conjunction with a large steam station and/or inland water-power scheme, and delivering to an industrial district capable of absorbing a comparatively large night load, such a state of affairs might be realised, at all events approximately. There is also the possibility that the intermittent operation of certain electro-chemical processes may be developed so as to enable any surplus power to be absorbed as and when available, and, if so, power developed tidally will probably prove cheaper in this country than that developed from any other source.

Owing to the relatively large variations in working head in any simple scheme, and to the small working heads, the design of hydraulic turbines capable of giving constant speed with reasonable efficiencies, and of moderately high speeds of rotation, is a matter of considerable difficulty. Modern developments, however, promise much better results in both these respects than would have appeared possible only a few years ago, and turbines are in existence which are capable of operating under a variation of head equal to 50 per cent. on each side of the mean, with efficiencies which do not fall below 70 per cent. over this range, and with reasonably high speeds of rotation under the heads available.

Even with such turbines, the number of technical problems to be solved before a tidal scheme of any magnitude can be embarked upon with confidence is large. The questions of single- *versus* double-way operation, of storage, of the effect of sudden changes of water-level due to strong winds, of wave effects, of silting in the tidal basin and of scour on the down-stream side of the sluices, of the best form of turbine and of generator, and of their regulation and of that of the sluice-gates, are probably the most important, though not the only, subjects to consider.

On the other hand, the possibilities of tidal power, if it can be developed commercially, are very great. Assuming a mean tidal range of only 20 ft. at springs, and 10 ft. at neaps, and adopting the single-basin method of development with operation on both rising and falling tides, each square mile of basin area would be capable, without storage, of giving an average daily output of approximately 110,000 horse-power-hours. In such an estuary as the Severn, where an area of 20 square miles could readily be utilised with a spring tidal range of 42 ft., the average daily output, without storage, would be approximately 10,000,000 horse-power-hours.

At the present time it is difficult to obtain an even rough estimate of the total cost of such a scheme, owing to the uncertainty regarding many of the factors involved. The whole question would appear to merit investigation, especially on matters of detail, by a technical committee with funds available for experimental work. As a result of such an investigation, it is at least possible that a definite working scheme could be formulated capable of generating power at a cost at least as small as, and possibly much smaller than, that of power generated from any coal-fired installation.

Obituary.

PROF. C. A. TIMIRIAZEFF, FOR.MEM.R.S.

THE death is announced of Clement Arkadievitch Timiriazeff, emeritus professor of botany in the University of Moscow. Timiriazeff was the only Russian botanist who was at all a familiar figure in England. In earlier days he came to England and saw Charles Darwin, while his last visit was made as a delegate to the Darwin celebration in Cambridge in 1909. His earliest publication appeared in 1863—a Russian book on "Darwin and his Theory," which ran through five editions. Here he made his mark as an attractive expounder of science for the general reader, and he followed this work with books on "The General Problems of Modern Science," "Agriculture and Plant Physiology," and "The Life of the Plant." The last was in great demand, there being seven Russian editions between 1878 and 1908, while in 1912 it was translated into English, and is widely read to the present day. Its characteristic note is an exposition of plant structure and function based on the chemical and physical processes at work in the living plant. Without comparison of the early editions we cannot tell at what date this book took the form in which it appeared in English, but it looks as if Timiriazeff was one of the earliest writers to take up this essentially modern outlook. His attitude was no doubt an expression of his early training under chemists and physicists. Born in 1843, he studied under Bunsen, Kirchhoff, Helmholtz, and Berthelot before working with Boussingault.

Timiriazeff made himself famous by work on one single problem—the participation of the different rays of the visible spectrum in the photosynthetic activity of the green leaf. The technique which he brought to the attack on this problem seems almost an exact expression of the combined influence of his teachers: good methods of gas-analysis, pure spectral illumination, and experimentation on isolated leaves; combined with the sound conception that rays utilised for work in the chloroplast must be rays abundantly absorbed by the pigment chlorophyll. Working with a micro-eudiometer, concentrated sunlight, and a narrow spectroscope slit, he was able to disprove the accepted view that the yellow region, which is so bright to the eye, is the most effective region of the solar spectrum, and to locate the efficiency in the red region where absorption by chlorophyll is greater. Afterwards he demonstrated the secondary maximum of photosynthetic effect in the blue region, where also absorption is great.

This work was published in different forms, at various dates, in scientific journals of most European countries, the final presentation being the Croonian lecture to the Royal Society in 1903. The actual experimental work seems to have been all done between 1868 and 1883. There is no evidence that he published research work on any other subject, so that we have in Timiriazeff the remarkable case of a man who, having achieved fame by one important line of research at forty, was content to devote the remaining half of his life to teaching and exposition.

THE announcement of a new book, "A Nation's Heritage," by HARDWICKE DRUMMOND RAWNSLEY, sadly coincides with the record of its author's death. Born on September 28, 1851, the distinguished canon died on May 28, to the last pursuing the self-imposed task of persuading his fellow-countrymen to take care of their own treasures. His mother was a niece of Sir John Franklin, the Arctic explorer. In education Canon Rawnsley had the good fortune to be at Upping-