of the several quantities are chosen so as to make the equation true, the amount of the force is numerically equal to $(MV_2 - MV_1) \div T$, or to the rate of change of momentum.

Let $T = 1$ second, $V_1 = 0$, $V_2 = 32.2$, $W = 1$ lb., $M = 1/32.2$, then the equation reduces to $1 = 1/32.2 \times 32.2$, or force = mass $\times$ acceleration, and it is correct, but if the unit of M is taken as 1 lb. then we have $1 = 1 \times 32.2$, which is incorrect.

The "correct, competent and complete" definition that force *is* the rate of change of momentum, no doubt is a metaphysical deduction from the formula, but it is neither correct, competent nor complete, and is not a definition at all. It assumes that we can translate the sign of equality (=), which really means "is numerically equal to" by the word "is." It is not true even as to equality except under certain limited conditions, viz., 1, that the units have certain values, such as $M =$ lbs. $\div g$, and 2, that the body is free to move. It is not true when a force is applied to a body not free to move, nor when a force is being applied to cause a body to move at a constant speed against a constant resistance, as when a canal boat is being towed, nor when a force is applied to a body moving with increasing speed with decreasing acceleration, as when an engine is bringing a train up to full speed.

"The debt that physics owes to metaphysics" is a sound castigation, for having introduced into physics such bad logic as that of making "equals" equivalent to "is," "darkening counsel with words," and substituting metaphysical deductions and complex concepts for simple definitions and concepts; and for introducing ideas that are so far from being "clear, sharp and definite" that they have to be unlearned or forgotten before the student can make satisfactory progress in engineering mechanics, and that they are discouraging even the high-school physics teachers themselves from teaching elementary dynamics, as was shown in Professor Edwin Hall's paper in Science of October 29, 1909. What is needed is a return to the good old definitions of Weisbach and Rankine, and a dropping of the metaphysical reasoning which has recently become the fashion.

Wm. Kent

Montclair, N. J.,
April 26, 1910

SCIENTIFIC BOOKS

SCIENTIFIC RESULTS OF SHACKLETON'S SOUTH POLAR EXPEDITION

The Heart of the Antarctic: Being the Story of the British Antarctic Expedition, 1907–1909. By E. H. Shackleton, C.V.O. With an Introduction by Hugh Robert Mill, D.Sc. *An Account of the First Journey to the South Magnetic Pole.* By Professor T. W. Edgeworth David, F.R.S. 2 vols., ill., plates. Philadelphia, J. B. Lippincott Co. 1909. $10 net.

It rarely falls to the lot of any single explorer to conjointly arouse such popular interest and contribute such important scientific knowledge as has been done by Sir Ernest H. Shackleton through his Antarctic expedition of 1907–1909. It should be realized that the inception, financeering, organization and successful administration of the expedition are due to Shackleton, it being a private venture unaided, and it may be also said unhampered by governmental offices.

Shackleton played an active part in Scott's Antarctic expedition, 1901–1903—when he was one of the four men who made a world's record of the farthest south—from which he was later invalided on account of scurvy. His early experiences were fruitful factors in his recent successes, which were in a measure due to improved conditions of food, clothing, shelter, transportation and travel methods.

Sailing from New Zealand, January 1, 1908, Shackleton established his permanent station at Cape Royds, Ross Island, at the base of Mt. Erebus. The expedition returned in 1909 with its members in health and its work done with wonderful success. In addition to the meteorological work at Cape Royds, the famous volcano Erebus was ascended and studied, the south magnetic pole located and visited, while the southern party attained a point within 93 geographical miles of the south pole.

FARTHEST SOUTH.—Very brief reference will be made to this extraordinary journey in which Shackleton and three companions in 127 days traveled 1,755 miles, an average of 13.8 miles daily, the party in its earlier travel being aided by Manchurian ponies who were killed and eaten.

For nearly 400 miles the route lay nearly due south, over the Great Barrier which is practically on the sea-level. Mountains then barred a south course in about 83° S., when they discovered Beardmore glacier valley which enabled them to proceed with slight deviations. This glacier proved to be a difficult, dangerous pathway, its crevasses nearly costing their lives while pressure ridges and moraines made progress slow up the steep ascent—6,000 feet in 100 miles.

The glacial valley was between sandstone and slate mountains, in which were found fossils and coal to about 86° S., where the mountains vanished and there was visible only an immense, unbounded, ice-covered plateau. The ice rose steadily and was still rising to the south when through lack of food the party turned back on January 9, 1909, from a point in 88° 23′ S., 162° E., at an elevation exceeding 11,000 feet. For weeks the party never had the temperature above zero Fahrenheit.

This southern journey was made under such conditions of intense cold, constant danger and continued semi-starvation, as makes its simple record a most thrilling story for adventurous or sympathetic natures. While it does not differ in its material aspects from many polar journeys it had a spiritual side that must appeal strongly to every true scientist.

Geological specimens were collected from time to time on the outward march, the farthest within about 300 miles of the pole, and all gathered up on their return. Chilled by low temperatures, suffering from bruises and strains through glacier travel, with depleted strength, prostrated at times by dysentery, and once traveling 31 hours without solid food, the party not only dragged these specimens some 500 miles homeward without abandoning them but even refrain from mentioning this load, drawn at the risk of their lives, save to say "at the ice-edge [near home] taking on only . . . specimens."

A similar heroic spirit of scientific devotion was displayed by David Mawson and Mackay in locating the magnetic pole. It was only by desperate, repeated and prolonged efforts that they reached the surface of the continental ice-cap of South Victoria Land, where they pursued to success their magnetic work. It was not alone that they experienced most trying physical sufferings, but that they also faced the extreme hazard of their lives, knowing that with the advancing season the sea would open during their prolonged absence and leave them without food.

Such heroic examples in the field match well the sacrificing spirit of scientific research so often displayed within the environment of modern civilization.

MOUNT EREBUS.—The ascent and survey of this lofty active volcano were productive of interesting data. Rising to the height of 13,350 feet, its four superimposed craters have for centuries overlooked the great oceanic ice cap, contrasting aspects of eternal fire and enduring ice.

When discovered by Ross in 1841 the crater was discharging molten lava which flowed down in streams.

Professor T. W. E. David gives an interesting account of the mountain. Of its three inactive craters the oldest rises to 6,500 feet with a diameter of six miles, while the second is two miles across at an elevation of 11,350 feet. The outline of the third, at 12.200 feet, was almost obliterated by the material of the modern active cone and crater which rose about 800 feet above the former.

The active crater of Erebus, three times as deep as that of Vesuvius, is about 900 feet deep, and one half a mile in diameter.

> Molten lava still wells up into the crater. . . . Fresh volcanic bombs on comparatively new snow are evidence that Erebus has recently been projecting lava to great heights.
>
> A most striking feature was the long row of steam jets about 300 feet below the inside rim of the crater.
>
> The ice fumaroles (some 50 were seen) are especially remarkable. These unique ice-mounds

have resulted from the condensation of vapor around the orifices of the fumaroles.

It will be obvious that Erebus is very interesting geologically on account of its unique fumaroles, its remarkable feldspar crystals and rare lavas, and as a gigantic tide gauge to record the flood level of the greatest recent glaciation of Antarctica.

Accounts of several eruptions are given in which the ejected steam rose from 6,000 to 10,000 or more feet above the crater.

Biology.—As might be expected, far the greater portion of biological data pertain to bird life, especially to the penguins, whose habits and methods are treated with interesting fulness.

Save rare specimens of the lowest forms of lichens, mosses and algæ, vegetation was entirely lacking. Doubtless the most important observations were those relating to microscopic fresh-water animals, of which Murray says:

On some of the moraines the growth of mosses and lichens was, comparatively speaking, luxuriant. A dried-up pool, close by the penguin rookery, . . . was covered by green filamentous algæ. Around smaller lakes was seen a dingy green or brown plant resembling some of the foliaceous lichens in form.

The plant-life consisted of various spheres and threads of blue-green algæ. The animals were more abundant . . . the rotifers and water-bears most important in point of numbers. [There were] thread-worms; . . . protozoa, each of a single cell . . . active infusoria . . . and the slow-moving rhizopods. . . . Skins of animals higher in the scale, . . . mites related to the cheese mite, small shrimps (crustacea) . . . were occasionally found.

A temperature of $-40°$ F. did not kill the rotifers. They were alternately frozen and thawed weekly for a long period and took no harm. They were dried and frozen, thawed and moistened and still they lived. They were dried, the bottle in which they were immersed in boiling water and still a great many survived.

Such is the vitality of these little animals (rotifers and water-bears) that they can endure being taken from ice at a minus temperature, thawed, dried and subjected to a temperature not far short of the boiling point, all within a few hours. . . . These are animals comparatively high in the scale. The rotifers are worms, and the water-bears are cousins to the insects and spiders.

Of the twelve kinds of creeping rotifers two were viviparous, one belonging to a genus (*Adineta*) of which no other known member is viviparous.

Dredging in depths less than 100 fathoms "the bottom appeared to be carpeted with a dense growth of living things."

Scant space is given to marine biology, perhaps as of little popular interest. There were obtained sponges, sea-weeds, anemones, tunicates, big-headed fishes (*Nototheia*), carnivorous whelks (*Neobuccinum*), tube-dwelling worms, crustacea, corals, sea-butterflies, diatirus, sea-spiders, etc.

Of the phosphorescence displayed by some of the worms from the bottom and by the copepods of the open sea, Murray says:

The phosphorescence is displayed by cold-blooded animals, living in a temperature always some degrees below the freezing-point of fresh water, and it is shown equally throughout the winter.

Geology.—Professor T. W. E. David and Mr. R. E. Priestley discuss the geological data in connection with those of preceding Antarctic expeditions. In the Victoria Land region previous researches, especially those by H. T. Ferrar, disclose:

An ancient complex of gneisses and gneissic granites, with mica-schists, calc-schists and quartzites, and that these rocks are capped for a great distance by a formation almost horizontally bedded, called the *Beacon sandstone*.

Amongst volcanic rocks are comprised horneblende-basalts, olivine basalts, dolomites, basalt tuffs, kenytes, phonolitic trachytes and phonolites. Amongst the foundation rocks of South Victoria Land Prior records crystalline limestones with chondrodites, gneiss, granites, diorites, camptonites, kewantites and banakite.

David says:

The oldest rocks seen by us . . . consist of banded gneiss, gneissic granite, grano-diorite and diorite rich in sphene. In some spots masses of very coarse white crystalline marble are interspersed in the gneiss. . . .

The next oldest sedimentary rocks appear to be the greenish grey slates brought by the Southern Party from the surface of Beardmore glacier . . .

in approximately 84° S., . . . fragments blown on to the ice from . . . mountains further west.

The most important geological inferences put forward are:

The Beacon sandstone formation, which extends for at least 1,100 miles from north to south in Antarctica, contains coniferous wood associated with coal seams. [In 85° S. 7 coal seams aggregating 25 feet in thickness were found in one sandstone cliff, associated with coniferous wood.] It is probably of Paleozoic age.

Limestones, pisolitic in places, in 85° 95′ S., and 7,000 ft. above sea-level, contain obscure casts of radiolaria, which appear to be of older Paleozoic age.

The succession of lavas at Erebus appears to have been first trachytes, then kenytes, then olivine basalts. Erebus is, however, still erupting kenyte.

Peat deposits, formed of fungus, are now forming on the bottoms of some glacial lakes near 78° S.

Raised beaches of recent origin extend at Ross Island to a height of 160 ft. above sea-level.

SOUTH MAGNETIC POLE.—Of great popular interest, as well as of especial scientific importance, was the definite location of the south magnetic pole, a most valuable work done by Professors E. David, D. Mawson and Mr. A. Mackay. It involved an outward journey of unusual difficulties, which occupied three months and eleven days. Two months of arduous labor, constant suffering and repeated failures were experienced before the party succeeded in attaining the surface of the continental ice-cap of South Victoria Land, whereon the pole is situated, 260 miles inland. They were quite at the limit of their provision supply, as well as of their physical strength, when they reached on the ice-cap the pole, on January 16, 1909, in 72° 25′ S., 155° 16′ E., at an elevation exceeding 7,000 feet. Their necessarily prolonged journey nearly involved the lives of the party as the open sea cut them off on their return, but they were picked up fortunately by the *Nimrod.*

Professor Douglas Mawson, who made the observations, says:

In the interval between 1841, when [the south magnetic pole was approximately located from his ship by Sir James Clark Ross] . . . and 1902, when the *Discovery* expedition again located the magnetic pole, it had moved about 200 geographical miles to the eastward.

Observations of magnetic declination and dip taken at intervals . . . indicate that the magnetic pole has [since 1902] moved in a northerly and westerly direction.

The determination of the *exact center* of the magnetic polar area could not be made on the spot, as it would involve a large number of readings taken at positions surrounding the pole. Such observations [were impossible] under conditions of such low temperatures [about zero] and prevalent high winds.

AURORA AUSTRALIS.—Auroras were frequently observed, but rarely in the direction of the magnetic pole. Mawson says:

When at their greatest brilliancy the displays were powerful enough to throw shadows [confirming similar observation by the Lady Franklin Bay expedition in Grunell Land], but were yet insufficiently strong to allow of their being photographed. We obtained impressions, of little value, on photographic plates after about ten minutes' exposure.

TIDAL OBSERVATIONS.—By ingenious devices the tide was automatically registered, on a barograph drum, for about three months. The usual tidal movements were marked by oscillations, chiefly during blizzards, considered to be in the nature of *seiche* waves.

The tide record was a simple undulating curve with one maximum per day, attaining the greatest amplitude at full and new moon, and diminishing almost to nothing at the quarters.

When the record was analyzed it was resolved into two undulations, the larger one having the period equal to the lunar day, the smaller one having a period of half a day.

The tidal range is not given in the narrative, but from the reproduced record, without scale, it would appear to range from about 8 inches in the neaps to about 35 inches in the springs.

METEOROLOGY.—Tabulated meteorological data are wanting as is frequently the case in popular accounts of polar expeditions. It is, however, evident that the bi-hourly meteorological observations of Shackleton's party, conjoined with those of his predecessors in this region, will be a valuable contribution to Antarctic climatology and meteorology, when discussed and published in detail.

Barometrical observations are lacking, but the comments of Murray are especially interesting, and worthy of close scrutiny, that the usually close relations between the wind and barometric changes were absent, though there was an evident connection between the wind and changes of temperature. He adds that violent blizzards were frequently experienced while the barometric pressure was steady or changing slightly, while rapid barometric changes were often noted during fine and relatively calm weather.

Judging from the reproduced barometric chart for May and June, 1908, the normal variations are small, as they only ranged from a maximum of 29.44 on May 7 to a minimum of 28.30 on June 17.

Temperature Observations.—As they are always of unusual interest in polar work, it is unfortunate that the greater number of observations were of temperatures below zero Fahrenheit. As the expedition had no mercurial thermometers scaled below zero, such observations were necessarily made from spirit thermometers, which usually tend to unduly low records, owing in part to the instrumental inaccuracies and in part to frequent derangements and untrained manipulation of the thermometers.

As to the exceedingly low temperatures of the great south polar plateau, with its elevation of more than eleven thousand feet, it should be borne in mind that they were in large measure due, to the extent of about fifty degrees, to the normal cold of elevation; they are therefore not strictly comparable with the temperatures at Cape Royds.

The annual mean temperature of Cape Royds, approximating zero Fahrenheit, although unusually low, is yet four degrees higher than that experienced by the Lady Franklin Bay expedition at Fort Conger, 81° 44′ N., 1881–1884. The monthly means at Cape Royds are approximately as follows: January, 25° F.; February, 13°; March, 4°; April, —12°; May, —11°; June, —13°; July, —16°; August, —16°; September, —12°; October, —4°; November, 14°, and December, 26°. While the three coldest months (June to August) are comparatively warm with their aggregate mean of —15°, the three warmest months (November to January) are extremely cold with their mean of 22°. It is not surprising that only the very hardiest forms of vegetable life are able to survive such an unfavorable land environment.

With reference to violent temperature interruptions, there are reproduced combined temperature and wind records for May and June, 1908. These charts show regular and intimate relations between wind and temperature changes. In every case, seven in all, of high winds rapid and great increments of temperature systematically followed. This intimate relation, Professor David states, obtains only in the winter season, practically disappearing during the summer months.

It appears that the high winds, sixty to seventy miles an hour, always came as part of the southerly blizzards, concerning which it is said:

> The temperature invariably increased considerably from the beginning of a blizzard towards its end. This rise was very marked (from) perhaps — 30° F. . . . after 24 or 30 hours . . . to plus 15° F.

While Professor David suggests as possibly one of the important causes of this rise in temperature the usual Föhn compression, the reviewer considers it as practically the whole cause.

When abnormal barometric gradients near the south-polar plateau set up atmospheric movements with even a slight northern tendency, the intensely cold air of the polar plateau naturally follows the path of least resistance. This is through the valley of Beardmore glacier, with its downward gradient of 6,000 feet in sixty miles. The descent of such air-masses from an elevation of 11,000 feet to the sea-level must proceed with increasing velocity for the wind, while the rise in temperature must approximate sixty degrees from compression, independent of the latent heat set free by the accompanying snow-fall.

Winds, Surface and High-level.—Surface winds at Cape Royds were either north from the sea or southerly from the plateau. On the southern journey south-southeast winds predominated, occasionally veering a few points. The direction was thus largely due to topographical conditions. At the farthest, 88° 23′ S., the many sastrugi trended from the south-southeast, and all blizzards were from that direction.

The record of the higher winds is most important. As Cape Royds is practically at the base of volcanic Mt. Erebus, the constant volcanic steam-cloud served as a gigantic wind-vane which was usually in full view. It developed that there were three normal wind-currents—the *surface* up to about 6,000 feet, the *middle-level* thence to about 15,000 feet, and the *high-level* above all. The direction of the *middle-level* was definitely shown by the many strongly marked sastrugi, from 11,000 to 12,000 feet, to blow from the west-southwest. Occasional eruptions sent steam-clouds upward from the crater of Erebus to a height of twenty thousand feet, and these cloud-streamers displayed clearly and persistently *high-level* current from the northwest. Interruptions and reversals of the various upper currents were noted in connection with violent blizzards. The detailed observations should throw much light on the atmospheric circulation of the southern hemisphere.

Precipitation.—This was entirely in the form of snow, which usually falls during blizzards. The annual amount at Cape Royds equalled about 9.5 inches of rain. The buried depot on the Great Barrier showed in six years and four months about 45 inches of melted water, or more than seven inches annually of rain.

ICE-CAPS AND GLACIERS.—Shackleton's journey furnished much information on the physical conditions attendant on the great Ice Age, of which the only surviving examples of note are Greenland and the continent of Antarctica—the latter of enormously greater extent and importance.

While existing data justify the belief that the ice-cap of Antarctica covers an area fifty per cent. greater than the continent of Europe, we now have positive evidence of an unbroken expanse of inland ice extending north and south more than 1,100 statute miles in a right line, from 72° 25′ S., the magnetic pole of Mawson, to 88° 23′ S., the farthest of Shackleton, and covering an arc east and west of fifty-five degrees of longitude south of the 78th parallel of latitude.

Erratic blocks and other proofs indicate that the thickness of the northern edge of the continental ice-cap near South Victoria Land exceeded by some two thousand feet that of the present wonderful inland ice.

Of the ice of the south-polar plateau at an elevation of 9,600 feet, Shackleton writes:

> I do not think that the land lies very far below the ice-sheet, for the crevasses on the ridges suggest that the sheet is moving over land at no great depths. The descent, towards the glacier proper, is by a series of terraces.

Everywhere were evident signs of waning glaciation. Erratic granitic blocks of enormous size were found on the flanks of Mt. Erebus, while in 85° S., on the summit of Mt. Hope, 3,350 feet above the sea and 2,000 feet above the surface of the adjacent glacier, was strewn with erratic blocks.

Murray believes that during the period of recent maximum glaciation the ice-cap had a thickness of four thousand feet in parts of McMurdo Sound, now ice-free.

It is thus evident that in the period of maximum glaciation there existed very extensive oceanic ice-caps, which projected seaward far beyond the continental shelf. Even in late years these ice-caps were sufficiently projected to furnish tabular icebergs or snowbergs of enormous thickness and vast extent, though they appear to have been more numerous from fifty to eighty years since than to-day. The present detachments are yet enormous, and Shackleton's southern party heard the noise and felt the ice-vibrations attendant on the breaking-away of the sea-front of the barrier while fifty miles distant.

Three examples of oceanic ice-caps, or barriers, yet remain: Drygalski Barrier, 200 feet elevation, fifty miles by twelve in surface, which projects 30 miles seaward with three fourths afloat; Nordenskiöld Barrier, of fifty feet elevation, twenty by five miles in surface, entirely detached from the inland ice and afloat. Finally, the Great Barrier, of yet unknown extent, discovered by Sir J. C. Ross in 1841.

Shackleton's discoveries add very materially to the known area of the wonderful Great Barrier. The northern front of this oceanic ice-cap, which formerly extended at least one sixth around the globe on the 76th parallel, now covers forty-two degrees of longitude near the 78th parallel, a sea-frontage of about 470 statute miles. Its known projection seaward exceeds 400 statute miles, as its landward origin was determined by Shackleton to be south of 83° 30′ S., while its surface is in 77° 45′ S. He estimates its average elevation at 150 feet, and it seems most probable that the Barrier is afloat through the greater part, if not all, of its known extent. It is doubtless an under-estimate to place the superficial area of the Great Barrier at 200,000 square miles.

Formed as are all ice-caps of névé, the Great Barrier is peculiar in that it has not been subjected to great vertical pressures, and consequently has a low specific gravity, as is proved inferentially from a detached tabular snowberg which grounded in water about half its depth or thickness.

While the Great Barrier is fed only to a very slight degree by the inflowing glaciers, yet its movement seaward is doubtless due to some degree to the impulse given by enormous pressures from the great incoming glaciers of adjacent lands, especially from the mountains of South Victoria Land. For instance there must be a pressure of incalculable but vastly enormous power from Beardmore glacier, which has a surface area of over five thousand square miles, an average thickness of possibly a thousand feet, and necessarily a great velocity of movement due to its average fall of sixty feet to a mile throughout its length of one hundred miles. Some idea of this force may be gathered from the fact that it "raises pressure ridges on the Barrier for twenty miles out from its junction therewith."

The rate of superficial increase of the Barrier from local snowfall, and its rate of seaward movement are approximately known through a depot of provisions made on the ice in 1902 and uncovered six years and four months later. There had been an increase of 98 inches of snow, an average of 15 inches of unmelted snow annually, and an average annual movement seaward of "a little over 500 yards a year," about three tenths of a mile.

It would appear that the portion of the barrier farthest from the sea (over 400 miles) might be twelve hundred years in reaching the open ocean, and could then have acquired a thickness of 1,500 feet, provided it was wasted with normal rapidity. Ross in 1841 and Shackleton in 1908 observed portions of the sea-front where the cliffs rose 250 feet above the open ocean.

It is apparent that the sea-face of the barrier is steadily and rapidly disintegrating, as it has receded more than thirty miles since 1841.

The suggestion that "a great deal of (the inflowing glacier ice) may be thawed off from below by the sea-water" can not be accepted as undoubtedly the ocean has a uniform temperature of about 28°. Repeated observations for about three years by the Lady Franklin Bay expedition in the Arctic regions proved that the immersed portions of ice-floes of the northern seas, being fresh-water ice of land origin, are preserved indefinitely.

Glaciers.—Space fails in which to consider at length the many interesting observations on Antarctic glaciers visited and discovered. The two floating piedmont glaciers, Nordenskiöld and Drygalski barriers, have been elsewhere mentioned. The former is believed to be "moving actively from inland seawards," and there were 660 fathoms of water along its fifty-foot sea-face eighteen miles from shore.

The largest known ice-river of the world is the Beardmore Glacier, situated between 83° 33′ and 85° S., discovered and traversed by Shackleton and his Southern party. It is equally wonderful in its extent, its environment and its rapid movement.

One hundred miles in length and fifty in width, its surface area approximates 5,000 square miles. Through a glacial valley shut in between lofty sandstone mountains, the glacier falls 6,000 feet in its course of 100 miles, and is the only visible outflow from a vast unknown expanse of the south-polar ice-cap. Confined to a certain extent by lofty mountains and forced into a tortuous route, it is scarred by countless ridges and broken by thousands of crevasses. Receiving at its head enormous masses of névé it transforms them by the well-known processes of compression and expansion, of melting and regelation into glacial ice of the hardest, densest quality, and in most varied forms.

Of the surface conditions Shackleton records:

Sharp blue-edged ice, full of chasms and crevasses, rising to hills and descending to gullies. . . . One crevasse (where Marshall fell through and was saved by his harness) open from the top, with no bottom to be seen . . . a drop of at least 1,000 feet. . . . In another, the last pony dropped out of sight, the broken swingle-tree saving Wild. . . . We marched 9 miles over a surface where many times a slip meant death. . . . Followed the bed of an ancient moraine, full of holes through which boulders have melted down.

[Of the country] the wonderful scenery, the marvelous rocks. . . . A wonderful view of the mountains, with new peaks. . . . [In 84° 10′ S.] The main rocks of the mountain under which we are camped . . . the erratics of marble conglomerate and breccia are beautiful, showing wonderful colors, . . . a wonderful sight as [the mountain] towers above us with the snow clinging to its sides. . . . [In 84° 54′ S.] Rock mainly sandstone with six seams of coal.

Fitting surroundings these for such an ice-river—issuing from the highest plateau of the world.

To crown the scientific observation is the very brief medical report which records that there was no case of scurvy or other sickness, apart from temporary sufferings of the half-starved southern party on its return.

PHYSIOGRAPHY.—From a broad standpoint the southward extension of South Victoria Land, the discovery of eight mountain ranges and scores of peaks, the reaching of the vast ice-clad plateau and the locating of the south geographic pole on tableland approximately 12,000 feet in elevation, may be considered as the most important of the scientific labors of the expedition.

The southern journey disclosed the continuity of Antarctica for about 1,250 miles due north and south, from Cape North to Shackleton's farthest. It thus establishes beyond peradventure the actual existence of a southern continent as announced by Wilkes in 1840, and as conjecturally charted by Sir John Murray in about 1875.

Moreover, the many ranges of lofty mountains, with the extent and great elevation of the wonderful south-polar tableland, clearly classify Antarctica as the most remarkable of continents not only in its conditions of glaciation but also in its surpassing elevation. Well-considered calculation places, with a possible error of ± 200 meters, the mean elevation of Antarctica at 2,000 meters, more than twice the average elevation of Asia.

Not only is it of scientific interest that the great, almost landless Arctic Ocean is opposite the enormous uplifted mountainous Antarctica, but the mass and location of this vast southern continent, one and a half times greater in surface than Europe, should serve to solve or elucidate vexed problems of latitude-variations and pole-shiftings. If not a practical factor for the far future these conditions may well have been so during past ages, when a milder climate, abundant animal life, luxuriant vegetation and forestal growths obtained in the vicinity of the present north and south geographical poles.

REGION OF WILKES LAND.—Of geographic importance is Shackleton's discovery on his return voyage of an extension of the north coast of South Victoria Land some 45 miles to the westward. This ice-bound mountainous coast connects in all probability with the land of Wilkes, whose priority of discovery has been lately put beyond question by Admiral Pillsbury, U.S.N.

GENERAL RESULTS.—Briefly summarized the most important scientific results of Shackleton's expedition are:

1. Culminating data establishing the existence of an Antarctic continent.

2. The definite location of the south magnetic pole.

3. The existence of a continental mass twice greater in elevation than any other continent.

4. Geological data showing the structure of Antarctica.

5. Evidences of a former mild climate and extensive vegetation in the vicinity of the pole.

6. Meteorological data elucidating the atmospheric circulation of the southern hemisphere.

7. The highest tableland of the world, with the location of the south geographic pole on an unbroken ice-cap.

It thus appears that Shackleton has solved the difficult problem of equally satisfying by his expedition the demands of science and the expectations of the public.

A. W. GREELY

U. S. ARMY

SPECIAL ARTICLES

PREDICTION OF RELATIONSHIPS AMONG SOME PARASITIC FUNGI

A FLOWERING plant which would produce two separate and dissimilar sorts of fruit would indeed be a curiosity, and yet there are some of the common parasitic fungi which exhibit two, three and even four kinds of fruiting bodies or spores. In addition to the variability displayed by many species of fungi in the production of different sorts of spores, a large number of the rust-fungi present a still greater complexity of existence by having the life-cycle divided into two distinct alternating phases, which inhabit wholly different and unlike host plants, such as a sedge and a composite, or a broad-leaved deciduous tree and an evergreen.

In these species which are known to change hosts and on that account are termed heterœcious, the one phase consists usually of æcia, accompanied by one other spore-structure, the pycnium, and the other phase of telia, either alone, or accompanied by uredinia.

The combination in one species of these pleomorphic and heterœcious characters may make the working out of the life-history a very difficult problem. The connection or relation between two alternating phases is best shown by means of cultures. A culture in which a spore from one phase on one host is sown upon another host, and subsequently gives rise to a spore-form of the alternating phase, is the only conclusive evidence that the two phases are related and merely represent different forms of the same parasite. Cultures, therefore, must play an important rôle in the study and investigation of the rust-fungi, especially of those forms which are not only pleomorphic but also heterœcious.

In order that the culture work may be carried on in an expeditious manner, entailing as small an amount of unprofitable labor as possible, it is essential that the experimenter should be guided by some ideas of probable relationships between alternating phases. It often happens that there is nothing in the form or habit of either fungus or host which will give the slightest hint regarding the alternate host. In such instances a notion of relations can be gained only by field observations. The finding of spore-structures of two alternating phases in close proximity in the field is usually the only obtainable factor indicative of a connection between them. This is the case with many of the species of the genera *Puccinia* and *Uromyces*, the common rusts of grasses and sedges. The association of telial and æcial stages is, to be sure, not proof of their affinity, but only a bit of prima facie evidence. The closeness of the association, the abundance of the infection, and the occurrence of stages of other species must all be taken into account. A great deal has already been written[1] emphasizing the value of these observations of association in the field and it seems unnecessary to make further explanation here, suffice it to say that this method of gaining clues to relationships is largely a deductive one. From the fact that related alternating phases are often found associated together, we infer that other associated phases may be related. Association, in

[1] See "Clues to Relationship among Heterœcious Rusts," *Bot. Gaz.*, **33**: 62–66, 1902, and "A Search for Rusts in Colorado," *Plant World*, **11**: 69–77, 1908.