Henry Smith Williams,
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A History of Science

(Vol. 1-5)

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BOOK I

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Should the story that is about to be unfolded be found to lack interest, the writers must stand convicted of unpardonable lack of art. Nothing but dulness in the telling could mar the story, for in itself it is the record of the growth of those ideas that have made our race and its civilization what they are; of ideas instinct with human interest, vital with meaning for our race; fundamental in their influence on human development; part and parcel of the mechanism of human thought on the one hand, and of practical civilization on the other. Such a phrase as "fundamental principles" may seem at first thought a hard saying, but the idea it implies is less repellent than the phrase itself, for the fundamental principles in question are so closely linked with the present interests of every one of us that they lie within the grasp of every average man and woman—nay, of every well-developed boy and girl. These principles are not merely the stepping-stones to culture, the prerequisites of knowledge—they are, in themselves, an essential part of the knowledge of every cultivated person.

It is our task, not merely to show what these principles are, but to point out how they have been discovered by our predecessors. We shall trace the growth of these ideas from their first vague beginnings. We shall see how vagueness of thought gave way to precision; how a general truth, once grasped and formulated, was found to be a stepping-stone to other truths. We shall see that there are no isolated facts,

no isolated principles, in nature; that each part of our story is linked by indissoluble bands with that which goes before, and with that which comes after. For the most part the discovery of this principle or that in a given sequence is no accident. Galileo and Keppler must precede Newton. Cuvier and Lyall must come before Darwin;—Which, after all, is no more than saying that in our Temple of Science, as in any other piece of architecture, the foundation must precede the superstructure.

We shall best understand our story of the growth of science if we think of each new principle as a stepping-stone which must fit into its own particular niche; and if we reflect that the entire structure of modern civilization would be different from what it is, and less perfect than it is, had not that particular stepping-stone been found and shaped and placed in position. Taken as a whole, our stepping-stones lead us up and up towards the alluring heights of an acropolis of knowledge, on which stands the Temple of Modern Science. The story of the building of this wonderful structure is in itself fascinating and beautiful.

I. PREHISTORIC SCIENCE

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To speak of a prehistoric science may seem like a contradiction of terms. The word prehistoric seems to imply barbarism, while science, clearly enough, seems the outgrowth of civilization; but rightly considered, there is no contradiction. For, on the one hand, man had ceased to be a barbarian long before the beginning of what we call the historical period; and, on the other hand, science, of a kind, is no less a precursor and a cause of civilization than it is a consequent. To get this clearly in mind, we must ask ourselves: What, then, is science? The word runs glibly enough upon the tongue of our every-day speech, but it is not often, perhaps, that they who use it habitually ask themselves just what it means. Yet the answer is not difficult. A little attention will show that science, as the word is commonly used, implies these things: first, the gathering of knowledge through observation; second, the classification of such knowledge, and through this classification, the elaboration of general ideas or principles. In the familiar definition of Herbert Spencer, science is organized knowledge.

Now it is patent enough, at first glance, that the veriest savage must have been an observer of the phenomena of nature. But it may not be so obvious that he must also have been a classifier of his observations—an organizer of knowledge. Yet the more we consider the case, the more clear it will become that the two methods are too closely

linked together to be dissevered. To observe outside phenomena is not more inherent in the nature of the mind than to draw inferences from these phenomena. A deer passing through the forest scents the ground and detects a certain odor. A sequence of ideas is generated in the mind of the deer. Nothing in the deer's experience can produce that odor but a wolf; therefore the scientific inference is drawn that wolves have passed that way. But it is a part of the deer's scientific knowledge, based on previous experience, individual and racial; that wolves are dangerous beasts, and so, combining direct observation in the present with the application of a general principle based on past experience, the deer reaches the very logical conclusion that it may wisely turn about and run in another direction. All this implies, essentially, a comprehension and use of scientific principles; and, strange as it seems to speak of a deer as possessing scientific knowledge, yet there is really no absurdity in the statement. The deer does possess scientific knowledge; knowledge differing in degree only, not in kind, from the knowledge of a Newton. Nor is the animal, within the range of its intelligence, less logical, less scientific in the application of that knowledge, than is the man. The animal that could not make accurate scientific observations of its surroundings, and deduce accurate scientific conclusions from them, would soon pay the penalty of its lack of logic.

What is true of man's precursors in the animal scale is, of course, true in a wider and fuller sense of man himself at the very lowest stage of his development. Ages before the time which the limitations of our knowledge force us to

speak of as the dawn of history, man had reached a high stage of development. As a social being, he had developed all the elements of a primitive civilization. If, for convenience of classification, we speak of his state as savage, or barbaric, we use terms which, after all, are relative, and which do not shut off our primitive ancestors from a tolerably close association with our own ideals. We know that, even in the Stone Age, man had learned how to domesticate animals and make them useful to him, and that he had also learned to cultivate the soil. Later on, doubtless by slow and painful stages, he attained those wonderful elements of knowledge that enabled him to smelt metals and to produce implements of bronze, and then of iron. Even in the Stone Age he was a mechanic of marvellous skill, as any one of to-day may satisfy himself by attempting to duplicate such an implement as a chipped arrow-head. And a barbarian who could fashion an axe or a knife of bronze had certainly gone far in his knowledge of scientific principles and their practical application. The practical application was, doubtless, the only thought that our primitive ancestor had in mind; quite probably the question as to principles that might be involved troubled him not at all. Yet, in spite of himself, he knew certain rudimentary principles of science, even though he did not formulate them.

Let us inquire what some of these principles are. Such an inquiry will, as it were, clear the ground for our structure of science. It will show the plane of knowledge on which historical investigation begins. Incidentally, perhaps, it will reveal to us unsuspected affinities between ourselves and

our remote ancestor. Without attempting anything like a full analysis, we may note in passing, not merely what primitive man knew, but what he did not know; that at least a vague notion may be gained of the field for scientific research that lay open for historic man to cultivate.

It must be understood that the knowledge of primitive man, as we are about to outline it, is inferential. We cannot trace the development of these principles, much less can we say who discovered them. Some of them, as already suggested, are man's heritage from non-human ancestors. Others can only have been grasped by him after he had reached a relatively high stage of human development. But all the principles here listed must surely have been parts of our primitive ancestor's knowledge before those earliest days of Egyptian and Babylonian civilization, the records of which constitute our first introduction to the so-called historical period. Taken somewhat in the order of their probable discovery, the scientific ideas of primitive man may be roughly listed as follows:

1. Primitive man must have conceived that the earth is flat and of limitless extent. By this it is not meant to imply that he had a distinct conception of infinity, but, for that matter, it cannot be said that any one to-day has a conception of infinity that could be called definite. But, reasoning from experience and the reports of travellers, there was nothing to suggest to early man the limit of the earth. He did, indeed, find in his wanderings, that changed climatic conditions barred him from farther progress; but beyond the farthest reaches of his migrations, the seemingly flat land-surfaces and water-surfaces stretched

away unbroken and, to all appearances, without end. It would require a reach of the philosophical imagination to conceive a limit to the earth, and while such imaginings may have been current in the prehistoric period, we can have no proof of them, and we may well postpone consideration of man's early dreamings as to the shape of the earth until we enter the historical epoch where we stand on firm ground.

2. Primitive man must, from a very early period, have observed that the sun gives heat and light, and that the moon and stars seem to give light only and no heat. It required but a slight extension of this observation to note that the changing phases of the seasons were associated with the seeming approach and recession of the sun. This observation, however, could not have been made until man had migrated from the tropical regions, and had reached a stage of mechanical development enabling him to live in subtropical or temperate zones. Even then it is conceivable that a long period must have elapsed before a direct causal relation was felt to exist between the shifting of the sun and the shifting of the seasons; because, as every one knows, the periods of greatest heat in summer and greatest cold in winter usually come some weeks after the time of the solstices. Yet, the fact that these extremes of temperature are associated in some way with the change of the sun's place in the heavens must, in time, have impressed itself upon even a rudimentary intelligence. It is hardly necessary to add that this is not meant to imply any definite knowledge of the real meaning of, the seeming oscillations of the sun. We shall see that, even at a relatively late

period, the vaguest notions were still in vogue as to the cause of the sun's changes of position.

That the sun, moon, and stars move across the heavens must obviously have been among the earliest scientific observations. It must not be inferred, however, that this observation implied a necessary conception of the complete revolution of these bodies about the earth. It is unnecessary to speculate here as to how the primitive intelligence conceived the transfer of the sun from the western to the eastern horizon, to be effected each night, for we shall have occasion to examine some historical speculations regarding this phenomenon. We may assume, however, that the idea of the transfer of the heavenly bodies beneath the earth (whatever the conception as to the form of that body) must early have presented itself.

It required a relatively high development of the observing faculties, yet a development which man must have attained ages before the historical period, to note that the moon has a secondary motion, which leads it to shift its relative position in the heavens, as regards the stars; that the stars themselves, on the other hand, keep a fixed relation as regards one another, with the notable exception of two or three of the most brilliant members of the galaxy, the latter being the bodies which came to be known finally as planets, or wandering stars. The wandering propensities of such brilliant bodies as Jupiter and Venus cannot well have escaped detection. We may safely assume, however, that these anomalous motions of the moon and planets found no explanation that could be called scientific until a relatively late period.

3. Turning from the heavens to the earth, and ignoring such primitive observations as that of the distinction between land and water, we may note that there was one great scientific law which must have forced itself upon the attention of primitive man. This is the law of universal terrestrial gravitation. The word gravitation suggests the name of Newton, and it may excite surprise to hear a knowledge of gravitation ascribed to men who preceded that philosopher by, say, twenty-five or fifty thousand years. Yet the slightest consideration of the facts will make it clear that the great central law that all heavy bodies fall directly towards the earth, cannot have escaped the attention of the most primitive intelligence. The arboreal habits of our primitive ancestors gave opportunities for constant observation of the practicalities of this law. And, so soon as man had developed the mental capacity to formulate ideas, one of the earliest ideas must have been the conception, however vaguely phrased in words, that all unsupported bodies fall towards the earth. The same phenomenon being observed to operate on water-surfaces, and no alteration being observed in its operation in different portions of man's habitat, the most primitive wanderer must have come to have full faith in the universal action of the observed law of gravitation. Indeed, it is inconceivable that he can have imagined a place on the earth where this law does not operate. On the other hand, of course, he never grasped the conception of the operation of this law beyond the close proximity of the earth. To extend the reach of gravitation out to the moon and to the stars, including within its compass every particle of matter in the universe, was the work of

Newton, as we shall see in due course. Meantime we shall better understand that work if we recall that the mere local fact of terrestrial gravitation has been the familiar knowledge of all generations of men. It may further help to connect us in sympathy with our primeval ancestor if we recall that in the attempt to explain this fact of terrestrial gravitation Newton made no advance, and we of to-day are scarcely more enlightened than the man of the Stone Age. Like the man of the Stone Age, we know that an arrow shot into the sky falls back to the earth. We can calculate, as he could not do, the arc it will describe and the exact speed of its fall; but as to why it returns to earth at all, the greatest philosopher of to-day is almost as much in the dark as was the first primitive bowman that ever made the experiment.

Other physical facts going to make up an elementary science of mechanics, that were demonstratively known to prehistoric man, were such as these: the rigidity of solids and the mobility of liquids; the fact that changes of temperature transform solids to liquids and vice versa—that heat, for example, melts copper and even iron, and that cold congeals water; and the fact that friction, as illustrated in the rubbing together of two sticks, may produce heat enough to cause a fire. The rationale of this last experiment did not receive an explanation until about the beginning of the nineteenth century of our own era. But the experimental fact was so well known to prehistoric man that he employed this method, as various savage tribes employ it to this day, for the altogether practical purpose of making a fire; just as he employed his practical knowledge of the mutability of solids and liquids in smelting ores, in alloying copper with

tin to make bronze, and in casting this alloy in molds to make various implements and weapons. Here, then, were the germs of an elementary science of physics. Meanwhile such observations as that of the solution of salt in water may be considered as giving a first lesson in chemistry, but beyond such altogether rudimentary conceptions chemical knowledge could not have gone—unless, indeed, the practical observation of the effects of fire be included; nor can this well be overlooked, since scarcely another single line of practical observation had a more direct influence in promoting the progress of man towards the heights of civilization.

4. In the field of what we now speak of as biological knowledge, primitive man had obviously the widest opportunity for practical observation. We can hardly doubt that man attained, at an early day, to that conception of identity and of difference which Plato places at the head of his metaphysical system. We shall urge presently that it is precisely such general ideas as these that were man's earliest inductions from observation, and hence that came to seem the most universal and "innate" ideas of his mentality. It is quite inconceivable, for example, that even the most rudimentary intelligence that could be called human could fail to discriminate between living things and, let us say, the rocks of the earth. The most primitive intelligence, then, must have made a tacit classification of the natural objects about it into the grand divisions of animate and inanimate nature. Doubtless the nascent scientist may have imagined life animating many bodies that we should call inanimate—such as the sun, wandering

planets, the winds, and lightning; and, on the other hand, he may quite likely have relegated such objects as trees to the ranks of the non-living; but that he recognized a fundamental distinction between, let us say, a wolf and a granite bowlder we cannot well doubt. A step beyond this—a step, however, that may have required centuries or millenniums in the taking—must have carried man to a plane of intelligence from which a primitive Aristotle or Linnaeus was enabled to note differences and resemblances connoting such groups of things as fishes, birds, and furry beasts. This conception, to be sure, is an abstraction of a relatively high order. We know that there are savage races to-day whose language contains no word for such an abstraction as bird or tree. We are bound to believe, then, that there were long ages of human progress during which the highest man had attained no such stage of abstraction; but, on the other hand, it is equally little in question that this degree of mental development had been attained long before the opening of our historical period. The primeval man, then, whose scientific knowledge we are attempting to predicate, had become, through his conception of fishes, birds, and hairy animals as separate classes, a scientific zoologist of relatively high attainments.

In the practical field of medical knowledge, a certain stage of development must have been reached at a very early day. Even animals pick and choose among the vegetables about them, and at times seek out certain herbs quite different from their ordinary food, practising a sort of instinctive therapeutics. The cat's fondness for catnip is a case in point. The most primitive man, then, must have

inherited a racial or instinctive knowledge of the medicinal effects of certain herbs; in particular he must have had such elementary knowledge of toxicology as would enable him to avoid eating certain poisonous berries. Perhaps, indeed, we are placing the effect before the cause to some extent; for, after all, the animal system possesses marvellous powers of adaption, and there is perhaps hardly any poisonous vegetable which man might not have learned to eat without deleterious effect, provided the experiment were made gradually. To a certain extent, then, the observed poisonous effects of numerous plants upon the human system are to be explained by the fact that our ancestors have avoided this particular vegetable. Certain fruits and berries might have come to have been a part of man's diet, had they grown in the regions he inhabited at an early day, which now are poisonous to his system. This thought, however, carries us too far afield. For practical purposes, it suffices that certain roots, leaves, and fruits possess principles that are poisonous to the human system, and that unless man had learned in some way to avoid these, our race must have come to disaster. In point of fact, he did learn to avoid them; and such evidence implied, as has been said, an elementary knowledge of toxicology.

Coupled with this knowledge of things dangerous to the human system, there must have grown up, at a very early day, a belief in the remedial character of various vegetables as agents to combat disease. Here, of course, was a rudimentary therapeutics, a crude principle of an empirical art of medicine. As just suggested, the lower order of animals have an instinctive knowledge that enables them to

seek out remedial herbs (though we probably exaggerate the extent of this instinctive knowledge); and if this be true, man must have inherited from his prehuman ancestors this instinct along with the others. That he extended this knowledge through observation and practice, and came early to make extensive use of drugs in the treatment of disease, is placed beyond cavil through the observation of the various existing barbaric tribes, nearly all of whom practice elaborate systems of therapeutics. We shall have occasion to see that even within historic times the particular therapeutic measures employed were often crude, and, as we are accustomed to say, unscientific; but even the crudest of them are really based upon scientific principles, inasmuch as their application implies the deduction of principles of action from previous observations. Certain drugs are applied to appease certain symptoms of disease because in the belief of the medicine-man such drugs have proved beneficial in previous similar cases.

All this, however, implies an appreciation of the fact that man is subject to "natural" diseases, and that if these diseases are not combated, death may result. But it should be understood that the earliest man probably had no such conception as this. Throughout all the ages of early development, what we call "natural" disease and "natural" death meant the onslaught of a tangible enemy. A study of this question leads us to some very curious inferences. The more we look into the matter the more the thought forces itself home to us that the idea of natural death, as we now conceive it, came to primitive man as a relatively late scientific induction. This thought seems almost startling, so

axiomatic has the conception "man is mortal" come to appear. Yet a study of the ideas of existing savages, combined with our knowledge of the point of view from which historical peoples regard disease, make it more probable that the primitive conception of human life did not include the idea of necessary death. We are told that the Australian savage who falls from a tree and breaks his neck is not regarded as having met a natural death, but as having been the victim of the magical practices of the "medicine-man" of some neighboring tribe. Similarly, we shall find that the Egyptian and the Babylonian of the early historical period conceived illness as being almost invariably the result of the machinations of an enemy. One need but recall the superstitious observances of the Middle Ages, and the yet more recent belief in witchcraft, to realize how generally disease has been personified as a malicious agent invoked by an unfriendly mind. Indeed, the phraseology of our present-day speech is still reminiscent of this; as when, for example, we speak of an "attack of fever," and the like.

When, following out this idea, we picture to ourselves the conditions under which primitive man lived, it will be evident at once how relatively infrequent must have been his observation of what we usually term natural death. His world was a world of strife; he lived by the chase; he saw animals kill one another; he witnessed the death of his own fellows at the hands of enemies. Naturally enough, then, when a member of his family was "struck down" by invisible agents, he ascribed this death also to violence, even though the offensive agent was concealed. Moreover, having very little idea of the lapse of time—being quite unaccustomed,

that is, to reckon events from any fixed era—primitive man cannot have gained at once a clear conception of age as applied to his fellows. Until a relatively late stage of development made tribal life possible, it cannot have been usual for man to have knowledge of his grandparents; as a rule he did not know his own parents after he had passed the adolescent stage and had been turned out upon the world to care for himself. If, then, certain of his fellow-beings showed those evidences of infirmity which we ascribe to age, it did not necessarily follow that he saw any association between such infirmities and the length of time which those persons had lived. The very fact that some barbaric nations retain the custom of killing the aged and infirm, in itself suggests the possibility that this custom arose before a clear conception had been attained that such drags upon the community would be removed presently in the natural order of things. To a person who had no clear conception of the lapse of time and no preconception as to the limited period of man's life, the infirmities of age might very naturally be ascribed to the repeated attacks of those inimical powers which were understood sooner or later to carry off most members of the race. And coupled with this thought would go the conception that inasmuch as some people through luck had escaped the vengeance of all their enemies for long periods, these same individuals might continue to escape for indefinite periods of the future. There were no written records to tell primeval man of events of long ago. He lived in the present, and his sweep of ideas scarcely carried him back beyond the limits of his individual memory. But memory is observed to be fallacious. It must

early have been noted that some people recalled events which other participants in them had quite forgotten, and it may readily enough have been inferred that those members of the tribe who spoke of events which others could not recall were merely the ones who were gifted with the best memories. If these reached a period when their memories became vague, it did not follow that their recollections had carried them back to the beginnings of their lives. Indeed, it is contrary to all experience to believe that any man remembers all the things he has once known, and the observed fallaciousness and evanescence of memory would thus tend to substantiate rather than to controvert the idea that various members of a tribe had been alive for an indefinite period.

Without further elaborating the argument, it seems a justifiable inference that the first conception primitive man would have of his own life would not include the thought of natural death, but would, conversely, connote the vague conception of endless life. Our own ancestors, a few generations removed, had not got rid of this conception, as the perpetual quest of the spring of eternal youth amply testifies. A naturalist of our own day has suggested that perhaps birds never die except by violence. The thought, then, that man has a term of years beyond which "in the nature of things," as the saying goes, he may not live, would have dawned but gradually upon the developing intelligence of successive generations of men; and we cannot feel sure that he would fully have grasped the conception of a "natural" termination of human life until he had shaken himself free from the idea that disease is always the result

of the magic practice of an enemy. Our observation of historical man in antiquity makes it somewhat doubtful whether this conception had been attained before the close of the prehistoric period. If it had, this conception of the mortality of man was one of the most striking scientific inductions to which prehistoric man attained. Incidentally, it may be noted that the conception of eternal life for the human body being a more primitive idea than the conception of natural death, the idea of the immortality of the spirit would be the most natural of conceptions. The immortal spirit, indeed, would be but a correlative of the immortal body, and the idea which we shall see prevalent among the Egyptians that the soul persists only as long as the body is intact—the idea upon which the practice of mummifying the dead depended—finds a ready explanation. But this phase of the subject carries us somewhat afield. For our present purpose it suffices to have pointed out that the conception of man's mortality—a conception which now seems of all others the most natural and "innate"—was in all probability a relatively late scientific induction of our primitive ancestors.

5. Turning from the consideration of the body to its mental complement, we are forced to admit that here, also, our primitive man must have made certain elementary observations that underlie such sciences as psychology, mathematics, and political economy. The elementary emotions associated with hunger and with satiety, with love and with hatred, must have forced themselves upon the earliest intelligence that reached the plane of conscious self-observation. The capacity to count, at least to the number

four or five, is within the range of even animal intelligence. Certain savages have gone scarcely farther than this; but our primeval ancestor, who was forging on towards civilization, had learned to count his fingers and toes, and to number objects about him by fives and tens in consequence, before he passed beyond the plane of numerous existing barbarians. How much beyond this he had gone we need not attempt to inquire; but the relatively high development of mathematics in the early historical period suggests that primeval man had attained a not inconsiderable knowledge of numbers. The humdrum vocation of looking after a numerous progeny must have taught the mother the rudiments of addition and subtraction; and the elements of multiplication and division are implied in the capacity to carry on even the rudest form of barter, such as the various tribes must have practised from an early day.

As to political ideas, even the crudest tribal life was based on certain conceptions of ownership, at least of tribal ownership, and the application of the principle of likeness and difference to which we have already referred. Each tribe, of course, differed in some regard from other tribes, and the recognition of these differences implied in itself a political classification. A certain tribe took possession of a particular hunting-ground, which became, for the time being, its home, and over which it came to exercise certain rights. An invasion of this territory by another tribe might lead to war, and the banding together of the members of the tribe to repel the invader implied both a recognition of communal unity and a species of prejudice in favor of that

community that constituted a primitive patriotism. But this unity of action in opposing another tribe would not prevent a certain rivalry of interest between the members of the same tribe, which would show itself more and more prominently as the tribe increased in size. The association of two or more persons implies, always, the ascendency of some and the subordination of others. Leadership and subordination are necessary correlatives of difference of physical and mental endowment, and rivalry between leaders would inevitably lead to the formation of primitive political parties. With the ultimate success and ascendency of one leader, who secures either absolute power or power modified in accordance with the advice of subordinate leaders, we have the germs of an elaborate political system —an embryo science of government.

Meanwhile, the very existence of such a community implies the recognition on the part of its members of certain individual rights, the recognition of which is essential to communal harmony. The right of individual ownership of the various articles and implements of every-day life must be recognized, or all harmony would be at an end. Certain rules of justice—primitive laws—must, by common consent, give protection to the weakest members of the community. Here are the rudiments of a system of ethics. It may seem anomalous to speak of this primitive morality, this early recognition of the principles of right and wrong, as having any relation to science. Yet, rightly considered, there is no incongruity in such a citation. There cannot well be a doubt that the adoption of those broad principles of right and wrong which underlie the entire structure of modern

civilization was due to scientific induction—in other words, to the belief, based on observation and experience, that the principles implied were essential to communal progress. He who has scanned the pageant of history knows how often these principles seem to be absent in the intercourse of men and nations. Yet the ideal is always there as a standard by which all deeds are judged.

It would appear, then, that the entire superstructure of later science had its foundation in the knowledge and practice of prehistoric man. The civilization of the historical period could not have advanced as it has had there not been countless generations of culture back of it. The new principles of science could not have been evolved had there not been great basal principles which ages of unconscious experiment had impressed upon the mind of our race. Due meed of praise must be given, then, to our primitive ancestor for his scientific accomplishments; but justice demands that we should look a little farther and consider the reverse side of the picture. We have had to do, thus far, chiefly with the positive side of accomplishment. We have pointed out what our primitive ancestor knew, intimating, perhaps, the limitations of his knowledge; but we have had little to say of one all-important feature of his scientific theorizing. The feature in question is based on the highly scientific desire and propensity to find explanations for the phenomena of nature. Without such desire no progress could be made. It is, as we have seen, the generalizing from experience that constitutes real scientific progress; and yet, just as most other good things can be overdone, this scientific propensity may be carried to a disastrous excess.

Primeval man did not escape this danger. He observed, he reasoned, he found explanations; but he did not always discriminate as to the logicality of his reasonings. He failed to recognize the limitations of his knowledge. The observed uniformity in the sequence of certain events impressed on his mind the idea of cause and effect. Proximate causes known, he sought remoter causes; childlike, his inquiring mind was always asking, Why? and, childlike, he demanded an explicit answer. If the forces of nature seemed to combat him, if wind and rain opposed his progress and thunder and lightning seemed to menace his existence, he was led irrevocably to think of those human foes who warred with him, and to see, back of the warfare of the elements, an inscrutable malevolent intelligence which took this method to express its displeasure. But every other line of scientific observation leads equally, following back a sequence of events, to seemingly causeless beginnings. Modern science can explain the lightning, as it can explain a great number of the mysteries which the primeval intelligence could not penetrate. But the primordial man could not wait for the revelations of scientific investigation: he must vault at once to a final solution of all scientific problems. He found his solution by peopling the world with invisible forces, anthropomorphic in their conception, like himself in their thought and action, differing only in the limitations of their powers. His own dream existence gave him seeming proof of the existence of an alter ego, a spiritual portion of himself that could dissever itself from his body and wander at will; his scientific inductions seemed to tell him of a world of invisible beings, capable of influencing him for good or ill.

From the scientific exercise of his faculties he evolved the all-encompassing generalizations of invisible and all-powerful causes back of the phenomena of nature. These generalizations, early developed and seemingly supported by the observations of countless generations, came to be among the most firmly established scientific inductions of our primeval ancestor. They obtained a hold upon the mentality of our race that led subsequent generations to think of them, sometimes to speak of them, as "innate" ideas. The observations upon which they were based are now, for the most part, susceptible of other interpretations; but the old interpretations have precedent and prejudice back of them, and they represent ideas that are more difficult than almost any others to eradicate. Always, and everywhere, superstitions based upon unwarranted early scientific deductions have been the most implacable foes to the progress of science. Men have built systems of philosophy around their conception of anthropomorphic deities; they have linked to these systems of philosophy the allied conception of the immutability of man's spirit, and they have asked that scientific progress should stop short at the brink of these systems of philosophy and accept their dictates as final. Yet there is not to-day in existence, and there never has been, one jot of scientific evidence for the existence of these intangible anthropomorphic powers back of nature that is not susceptible of scientific challenge and of more logical interpretation. In despite of which the superstitious beliefs are still as firmly fixed in the minds of a large majority of our race as they were in the mind of our prehistoric ancestor. The fact of this baleful heritage must

not be forgotten in estimating the debt of gratitude which historic man owes to his barbaric predecessor.

II. EGYPTIAN SCIENCE

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In the previous chapter we have purposely refrained from referring to any particular tribe or race of historical man. Now, however, we are at the beginnings of national existence, and we have to consider the accomplishments of an individual race; or rather, perhaps, of two or more races that occupied successively the same geographical territory. But even now our studies must for a time remain very general; we shall see little or nothing of the deeds of individual scientists in the course of our study of Egyptian culture. We are still, it must be understood, at the beginnings of history; indeed, we must first bridge over the gap from the prehistoric before we may find ourselves fairly on the line of march of historical science.

At the very outset we may well ask what constitutes the distinction between prehistoric and historic epochs—a distinction which has been constantly implied in much that we have said. The reply savors somewhat of vagueness. It is a distinction having to do, not so much with facts of human progress as with our interpretation of these facts. When we speak of the dawn of history we must not be understood to imply that, at the period in question, there was any sudden change in the intellectual status of the human race or in the status of any individual tribe or nation of men. What we mean is that modern knowledge has penetrated the mists of the past for the period we term historical with something more of clearness and precision than it has been able to