

EVERY-DAY REASONING;

OR, THE

SCIENCE OF INDUCTIVE LOGIC.

BY

REV. GEO. P. HAYS, D.D.,

PRESIDENT OF WASHINGTON AND JEFFERSON COLLEGE.

26.5
5475



PHILADELPHIA:
CLAXTON, REMSEN & HAFFELFINGER,
624, 626 & 628 MARKET STREET.
1877.

77

BC 108
. H3



Entered, according to Act of Congress, in the year 1876, by
CLAXTON, REMSEN & HAFFELFINGER,
in the Office of the Librarian of Congress, at Washington.



A Dedicate this Volume

TO

MY CHERISHED FRIENDS,

THE YOUNG MEN WHO HAVE BEEN STUDENTS OF WASHINGTON
AND JEFFERSON COLLEGE DURING THE YEARS 1871-1877
(INCLUSIVE), AND ESPECIALLY TO THE GRADU-
ATING CLASSES DURING THAT PERIOD.

G. P. H.

P R E F A C E .

THIS work is offered to teachers as an aid in setting before their pupils the principles of Inductive Logic. As our reasoning is inductive rather than deductive in daily life, it is important that the young should know at least the methods and tests. No great claim to originality is made, as no effort was put forth to attain it. Everything within reach has been examined, in order to gain additional light; and much that was desirable was left out, in order to keep the book within such bounds that it could be easily mastered by average students in a single session. Some important matters, and some especially clear illustrations, have been repeated in different connections, in the belief that repetition aided the memory. The design in preparing the work was not merely to offer a text-book to schools, but also to provide a convenient manual for men and women in their professional and daily life, wherein they might find suggestions for making their experiments, reaching their conclusions, and testing the correctness of the same. Under the title EVERY-DAY REASONING, an outline of the thought has been very frequently delivered as a lecture; and the favorable reception accorded to the subject in that form has led to the hope that greater usefulness would be attained by its publication in this form. Of course, the difference of circumstance and aim will account for the difference of style.

CONTENTS.

	PAGE
PREFACE.....	v
INTRODUCTION	ix

PART FIRST.

TRUTH.

TRUTH vs. FALSEHOOD.....	13
MIXED TRUTH AND FALSEHOOD.....	16
THE IMPORTANCE OF TRUTH	17
NECESSARY AND CAUSED TRUTH.....	18
REASONING ON NECESSARY TRUTH.....	21
REASONING ON CAUSED TRUTH.....	22
CLASSIFICATION.....	23
CUMULATIVE REASONING.....	25

PART SECOND.

CAUSES.

NATURE'S OFFERING.....	29
NATURE'S LAWS.....	30
EFFICIENCY OF CAUSES.....	34
CAUSES DEFINED.....	39
DIFFICULTIES OF IDENTIFYING CAUSES.....	42
SELECTION OF FACTS.....	46

PART THIRD.

METHODS OF INDUCTION.

	PAGE
GENERAL STATEMENT.....	51
METHOD OF AGREEMENT.....	53
METHOD OF DIFFERENCE.....	58
METHOD OF RESIDUES.....	65
METHOD OF CONCOMITANT VARIATIONS.....	70
FOUR METHODS ILLUSTRATED.....	76
CLASSIFICATION BY THE FOUR METHODS.....	87
ANALYSIS.....	92
QUESTIONS OF INDUCTIVE LOGIC.....	96
FINAL CAUSES OR DESIGN.....	102

PART FOURTH.

STEPS IN INDUCTION.

STATING THE QUESTION.....	107
GATHERING THE FACTS.....	111
DETECTION OF LAW.....	115
VERIFICATION — EXPLANATION OF FACTS.....	120
RULE OF HARMONY.....	123
RULE OF SIMPLICITY.....	129
RULE OF CONCURRENCE.....	135
RULE OF SUFFICIENCY.....	141
RULE OF PREDICTION.....	148
THE INTERPRETATION OF DOCUMENTS.....	155
THE ART OF DEBATE.....	162
INDEX.....	169

INTRODUCTION.

THE irresistible reason for keeping arithmetic as a study in every common school is, that every person must keep all their accounts by it. If they are not able to perform its simpler operations correctly, they are not able to take care of their own rights. They are liable to be both intentionally and unintentionally cheated. In order, therefore, to fit them, in any sense, for their future lives, our children are taught these arithmetical rules. They are rightly enough compelled to learn the multiplication table, before they have any true idea of what it means, or any conception of the many uses they will afterwards have for it.

These same things are just as true of reasoning as of arithmetic. Everything we do is done for a reason. We do not need arithmetic for every conclusion to which we come. We cannot come to a conclusion without more or less of a reasoning process. The old adage, of children learning to dread the fire, is reached by the method of agreement. The child dreads this fire, because it agrees in appearance and otherwise with the fires by which it has heretofore been burned. This is exactly inductive reasoning. The same thing will be true of the child in all its after life. It will plan its business, and seek its pleasures, by reasons which are subject to, and may be tested by, the methods of inductive logic. Every merchant at his counter, every mechanic at his trade, every farmer in his fields, every housewife at her work, every cook at the stove, in arranging each step of their daily duties, will decide on what they will do, because they either wish to attain what they have been able

to accomplish in that way before, or they will try some new plan, because they want to avoid some evil, or danger, or apparently needless labor. If their reasoning is correct and their facts reliable, they may expect success; if they are mistaken as to the facts, or incorrect as to their inductions from them, they will almost certainly fail. Masses of men are bankrupt, because they bought at the wrong time and sold at the wrong time. Their intentions were honest, but their reasonings were fallacious; and no integrity of purpose will save a man, when he misses his facts, and reasons badly on such as he may have. When now life and its opportunities come to us but once, and a blunder, though sometimes it may be rectified in the future, irreparably loses for us the present occasion, of what supreme importance is it, that we should, as far as possible, save ourselves from mistakes! Every day we will do what we will do, because we think, by the course we adopt, we will attain our desired ends. If in that course of reasoning we are wrong, we will fail, and ought to. By as much, therefore, as the number of times we act on our own judgment exceeds the number of times we need to employ arithmetical computation, by so much is a knowledge of inductive logic of more practical use than arithmetic.

Geography is everywhere taught, and children's minds are burdened with the names of innumerable capes and rivers they will never see, and of whose existence, if they should be ignorant all their lives, they would perhaps lose but little. It is not creditable either to a child's parents or teachers, that it should be allowed to grow up unable to speak its mother tongue with considerable accuracy. Many people, however, who use bad grammar, and know but little geography, succeed finely in business, because they can reason correctly. Thus they make no mistakes in trade, and waste neither time nor money on foolish projects, with all their bad grammar.

The great difficulty, however, with inductive logic is, to make it so plain that its application to every-day life will be obvious. If it could be so simplified and adapted to common affairs, that its relation to daily business could be seen as directly as that of arithmetic or grammar, there would be no serious obstacle in securing for it a similar place. But even if no book fully meeting the case has yet been provided, it is worthy of consideration whether it is not better to study a poor book than none at all. By no possibility can any one escape the necessity of every-day reasoning; and the successes or failures that will come from their good or bad logic, will come upon their own heads, study or no study.

In this work, Part First is devoted to a discussion of the different kinds of truth and reasoning; Part Second treats of the materials furnished us on which to reason; Part Third explains the four methods and the questions inductive logic is adapted to answer; Part Fourth gives the steps to be followed and the five tests by which true conclusions may be known to be true, and false ones detected as false. Some practical matters are then added, not immediately connected with this subject, but belonging to its field rather more than to any other included among text-books. All readers, as well as all students, are strongly advised to commit to memory the names of the four methods and the five tests, and then so study them that their names will readily suggest their application.

EVERY-DAY REASONING.

PART FIRST.

TRUTH.



TRUTH vs. FALSEHOOD.

TRUTH is, what is, as it is. Otherwise defined, truth is the characteristics and relations of things, individually, collectively, and relatively. Truth thus includes not merely the conditions of things considered alone, but it is limited and confined by the relations of things among themselves. The opposite of truth is falsehood, which is an assertion that certain things, characteristics, or relations exist when they do not. By comparing and contrasting these two, a more exact knowledge of both will be obtained.

First Distinction.—Truth is in things. Falsehood is never in the things, but only in the conceptions of them, or the statement of those conceptions in words. There are thus three places where truth may be found, and only two for falsehood. Truth exists first in the things themselves. Then this truth may be correctly perceived by the mind. It may then be stated in words, as it is thus correctly perceived by the mind. For example, two and two are four. We see this and say so. The ship has three masts. We count them, and state the fact. The horse is a quadruped. We notice this when we see one, and so record it. But if we say two

and two are five; the ship is feathered; the horse chews the cud; these are not true. They have not, however, changed the relations of numbers, the character of the ship, or the nature of the horse. Things themselves never lie. Men may misunderstand them, and they may consciously or unconsciously state that which is not true concerning them; but the truth is not affected either by their misapprehension or misstatement. It remains the same, regardless of the impressions men take up concerning the matter. Truth, therefore, is in things themselves, and may be perceived by the mind, and then stated in words; but falsehood is only found in men's conception of things, or their statements in words.

Second Distinction.—Truth is true without regard to man's action, and so is true before its discovery by the human mind. Our perception of it affected us, but it did not affect it. It was just as true before, as after, men came to the knowledge of it. Gravitation was just the same before the discovery of its laws by Newton, that it has been since. It acted just as powerfully, and in just the same way. The stones fell, and stars moved, and bodies weighed, just as they did afterwards. After we discover truth, we are enabled to avail ourselves of it in the accomplishment of our purposes; but the truth was there before. Steam was as ready to do its work before the days of Watt as since, only we could not use it. The development of geometry in no way affected the relations of lines or angles. Falsehood, on the other hand, never exists until after men have acted. As it exists only in our conceptions or our statements, of course it could only come into being by the action of our minds. It was a great error to say that two pounds of lead would fall to the ground twice as fast as one pound; but such a thought never had any existence until some mistaken philosopher made the assertion. The indications were all the other way, until Ananias and Sapphira asserted that what they gave

the apostles was the whole price for which they sold their land. It is thus left for the action of finite mind to bring all falsehood into being.

Third Distinction.—Truth is always consistent with itself, so that each separate truth is consistent with every other truth. There is no such self-consistency and harmony in error. Falsehoods are not only at war with truth, but they wrangle and fight with each other. Every proposition of geometry is consistent with every other proposition. Every law of nature harmonizes with every other law. Truths are not only consistent when occurring at the same time, but they are the same in all time. When we have met with them once, we always find them returning the same. Even when they seem to contradict, we are sure that further inquiry will reveal the secret of the apparent contradiction, and show that, instead of being a real contradiction, it is only a further proof of their fundamental harmony. Falsehoods and errors, however, cannot be reconciled. Their contradictions are obstinate and without remedy. They are Ishmaelites. Each one is against every other, and all the others against it. The reason of this is plain. They come from finite mind, not from nature; thus there is no uniform cause underlying their existence. They spring up out of men's mistaken notions, or their misleading words. If there is, therefore, consistency and harmony,—as there is sometimes among a few of them,—it is not the result of nature, but of design. Hence the proverb, that “liars should have good memories.” Lacking this, they contradict themselves, and so disclose their falsehoods. History scarcely offers an instance of a fraud that could not be detected by its contradictions, while almost every page is marked by truths whose discovery was more or less due to search suggested by apparent inconsistencies, which were resolved by the new discoveries.

MIXED TRUTH AND FALSEHOOD.

Truth and falsehood, or error, although thus radically different, are not so opposed that they may not be mingled together. The truth in things is indeed unmixed with error, but a large part of men's observations have somewhat of truth, and somewhat of error in them; and it is often very difficult so to state even true views, that no mixture of error shall be allowed to be hidden under our words. A witness is testifying as to what he saw of a quarrel, and affirms that he saw the prisoner strike the wounded man with a weapon. The truth was, he saw the prisoner in the melee with a knife in his hand, brandishing it over his head, and inferred that he inflicted the wound. The wound, however, was made with a dagger, sharp-pointed, but with no side edges; and as there was but one wound, it was clear that the knife was not used at all. Both his observations and his statements had a mixture of truth and error. Many times the most difficult and delicate task is to separate this truth from falsehood, and much discipline is needful to enable us to recognize just what we do see, and limit our statements to the things thus actually seen. All falsehoods are by no means intentional, but they are just as misleading as if they were. An intention to state the truth no more makes an error true, than an intention to see correctly will remedy defective vision. An honest error may be just as fatal as a premeditated lie. A minister gave his wife poison when he intended to give her medicine. The fact that it was given in love could not save her life. No purpose, however pure, can transform error into truth. We must, therefore, inquire into the ability as well as the integrity of those who furnish us our facts, before we decide on their credibility. We cannot for ourselves verify all the facts on which we must reason, and so must take much furnished by others; and great care and ability will be required to separate the wheat of truth from the chaff of error with which it is mingled.

THE IMPORTANCE OF TRUTH.

It is impossible to rate at too high a value this knowledge of the truth. The successes and failures, the encouragements and disappointments of life, are mainly attributable to want of correct information, and inability to draw correct conclusions from the information we have. If we proceed on false grounds, we are not to hope that nature will change, to relieve our defects. Having received the endowments of mind for the very purpose of discovering the true, and separating it from the false, a neglect to use these intellectual gifts properly is a crime that deserves the failures and mistakes by which, in the course of nature, it is punished. The experience of all ages has taught the wisest of mankind to esteem the truth very highly. No patience or perseverance is considered in any measure unrequited, if thereby any grain of truth is added to human knowledge. The very first prerequisite to entering on investigation, therefore, is a singleness of mind that will accept any truth that may reveal itself, however it may contradict some previous notions. There is required a like readiness to discard any error, however it may have been cherished, the moment its character is detected. No error is valuable. All truth is priceless, and no man has any claim to be called a true thinker, who rebels against giving up any error at the demands of the truth. The truth always issues in the right, and error, however prosperous for a time, can only come to ultimate grief. Nature, and the God of nature, will at last be found supreme, and their truth vindicated. In all ages, scholars and philosophers have exhausted their power of language in laudation of truth, and the Son of God, as if to emphasize its importance, called himself "the way, the truth, and the life." Truth is our only guide to safety, and if, adopting error, we escape folly and peril, it is by accident.

NECESSARY AND CAUSED TRUTH.

Truth may be divided into two departments, according to the character of the subjects with which it has to do. One of these divisions is called necessary truth, and the other caused truth. The essential difference is indicated by the names necessary and caused. The relations of space and number are illustrations of necessary truth. The angles made by two intersecting straight lines in the same plane are not equal to four right angles, because any will make them so. It could not be otherwise. Two and two are four, always and everywhere. It is not so with some other things. Thus, the builders might have made a ship with four or five masts, if they had so pleased. The Creator might have made the horse to chew the cud, as well as the cow and the sheep. These last are, therefore, not necessary truths, but caused truths. This leads us to notice a second distinction between these two kinds of truths, namely, that caused truth depends on some will, while necessary truth does not. No volition could make two and two ten, or construct six right angles by any number of straight lines, intersecting each other at the same point in the same plane. Volition can have no influence on necessary truth; it exists as it is, by its own necessity. On the other hand, all caused truth exists as the result of volition; otherwise it would not exist at all. If the builders had not done their work, there would have been no ship; if the Creator had so pleased, the world might have been made, and never a horse appeared on it; or the horses that were on it might all have had horns. What was, and how it was to be, depended on his determination. How long it shall be true also depends on will. I have built my house, but it depended on my will when I should build it, and it depends on my will how long it will last. I may, if I please, tear it down to-morrow. It exists, like all caused truth, as we might say, by sufferance.

It was produced by causes, and causes can destroy it. The house will last so long as it is not taken down, or destroyed by fire, or tempest, or decay. So geology tells us of animals, not now extant, and other convulsions may so change the face of the earth as to destroy some kinds of animals altogether, and it may be occupied by others, as different from any now as the elephant is different from the megatherium. Caused truth is thus comparatively temporary. Its existence and present modifications are of recent origin, and will not, in any event, remain long unchanged: It is otherwise with necessary truth; it is unchangeable. As it exists of necessity, it must, of course, be eternal. Two and two have always been four, and always will be. No cause made this so, and no cause can change it, so that two and two would be anything else than four. It is identical and invariable. We have thus three points of distinction between necessary and caused truth. The first is that from which each division takes its name. One is necessary, and the other is caused. Again, caused truth depends on volition, while the other does not. So, thirdly, necessary truth is eternal, while caused truth is temporary.

With these three points of difference, there is one point wherein there is no difference. Both are equally true. Because a thing which is true now was not true last year, and may not be true next, does not in any way invalidate its present verity. Caused truth, while it is true, is just as true as any necessary truth can be. It is no more certain that two and two are four, than that Napoleon was defeated at Waterloo, or that Washington was the first President of the United States. This is important, in view of the fact that often words and phrases are used to designate caused truth, which seem to carry under them an implication of some uncertainty. Thus the adjectives experiential, contingent, and probable, are used in speaking of it, or of the evidence by which it is proved; and these are set over against, and con-

trusted with, such words as self-evident, axiomatic, and demonstrative, as applied to necessary truth, and reasoning on it. This use of terms is apt to mislead us. The name caused truth is better, for the reason that after the causes have once produced their effect, the existence of that effect is just as certain as any truth is, and may be unhesitatingly relied on, so long as it lasts. With reference to very much of this caused truth, such as the events of history, it has passed out of the reach of change, and can, therefore, be no more doubtful. No future event can destroy the fact of Napoleon's overthrow, or substitute another name for Washington's as the first President. The channel of the Mississippi may be changed by the water wearing for itself new courses, and the great cities of to-day may become ruins, as many of the great cities of the past are now in decay. Some forms of caused truths are thus liable to change. The element of time must, therefore, be carefully noted; for while a truth may not continue to be true as a constantly present truth, yet if it ever has been true, no change can destroy the fact that it was true at that time. Attention is, therefore, to be given to this point in every statement, whether it makes its assertion as a present and continuing fact, or as a fact at a definite time in the past. If it is true, nothing can be more true. There may be, as we shall see, a difference in our assurance of its truth; but even in this respect, concerning a large part of caused truth, the assurance and certainty are just as absolute and positive as they can be in regard to any necessary truth. There may be great uncertainty as to the authorship of the letters of Junius. We may assert, with pretty strong confidence, that Shakespeare wrote the plays which go by his name, although many stoutly deny it. But who doubts his own existence, or the erection of the Egyptian pyramids, or that eagles can fly? The truth, therefore, of caused truth, is as true as any truth. Our uncertainty of it does not affect it.

It may affect us; but to doubt that which is sufficiently proved is utterly unreasonable.

REASONING ON NECESSARY TRUTH.

In reasoning on necessary truth, we begin with axioms, whose truth we see by direct inspection. This direct perception is also called intuition, and is a power with which the human mind is endowed to perceive certain truths, not merely as true to the extent of its experience or observation, but as true in all time and in all space. As examples, we have such axioms as, that the whole is greater than any part; things equal to the same thing are equal to each other. Such truths the mind perceives to be true on its first occasion of experience, as universal truths; yet all such truths must show themselves true in every case of experience or observation. They cannot, as some say, override our experience; but they must vindicate themselves in all experience. Every case must be an illustration of their truth. This is what is meant by their being universal truths. Of course, if they are necessary, they must be universal.

Beginning, then, with these axioms, or self-evident truths, we proceed by logical steps, all of which are easily reducible to the form of the syllogism, to reach other necessary truths, which are no less true than the first, but whose truth is not equally obvious at first sight. We say that multiplying by five hundredths is the same as dividing by twenty. We may not perceive this at once, but we can easily discover that they are in effect the same. It may not be obvious at once, that if I have a table eight feet long and four feet wide, it contains thirty-two square feet; but by examination, I can see that there must be four rows of eight square feet, and thus thirty-two square feet in all. From that instance, I know that the same is true of every surface. In

all such cases, we proceed from that which is seen to be true by intuition to that which is seen, by this process of reasoning, to be just as certain as the first conceded truths. This kind of reasoning is aptly called demonstrative, and the whole process a demonstration. It carries with it the highest degree of certainty.

REASONING ON CAUSED TRUTH.

When we come to reason on caused truth, we are not able to proceed by such easy steps, since we have no self-evident truths with which to start out. We must begin with propositions, whose truth is itself a subject of inquiry. As we have said, necessary truth, being independent of all volition, and having but one way in which it can be, this may be learned beforehand, as that all right angles are equal. Caused truth, however, was made true by the adoption by some will of one out of the, perhaps, infinite variety of possibilities, and; therefore, it cannot be known beforehand. It can be learned only by experience. You cannot tell beforehand how many acres a farmer will sow in wheat. You can tell just how many degrees there will be in any circle he may draw. You know with certainty that, however many fields he may divide his farm into, the sum of all the fields will be equal to the whole farm. These latter are illustrations of necessary truth. In caused truth, no such self-evident truths furnish a starting-point. We see that the sheep and cow both chew the cud, and both have cloven feet; but we cannot thence say that all cloven-footed animals chew the cud, as we could in regard to the sum of the farmer's fields being equal to the whole farm. We can see no necessity for cloven-footed animals chewing the cud. Indeed, if we look further, we find that the hog, although cloven-footed, does not chew the cud. It is thus evident that observation is our only resource, and that it is a work requiring very great care and caution. To no error are

inexperienced persons more liable, than this of leaping at unfounded conclusions. With such false premises, it would be strange if our reasoning did not lead us to false conclusions. That it does so lead, is evident from the blunders men are constantly making. It will not do, however, in recoiling from such mistakes, to adopt the equally unfounded conclusion that all reasoning is hopeless. It is a well-established fact that qualities are found in clusters, so that one is a sign of the others. It is on this basis that we proceed in classification.

CLASSIFICATION.

By classification is meant the division of objects into groups which are more or less alike. No two things are exactly alike in every particular; but while there are sufficient differences to distinguish even the most similar, yet there are also very great resemblances. It seems to be a natural operation of mind to simplify its labors by omitting all particulars not important to its immediate aims, and so hold more firmly those that are of this present importance. These last become more obvious by being kept solely in view. Of the things thus under consideration, there are those which may be considered as a unit, in that they all agree in some one particular. The others agree in the absence of this one particular. This is the simplest form of classification, where all the things considered are divided into these two classes, namely, those which have, and those which have not, a given quality.

Observation of nature, however, shows that it is possible to carry this operation much further, because things are found which agree not merely in one quality, but in many others also. Thus, the distinction between animal and vegetable life is one that includes a great many points of difference. So eagles and robins, although both birds, differ in a great many other respects beside the beak and the claws.

The camel differs from all other animals used by man for travel or burden in a great many points, in which they are all alike among themselves. We thus find that there are groupings extant in the things themselves. Men may make divisions and classifications regardless of these natural clusters, but such are justly called arbitrary classifications. When we follow the groupings of nature, our classification is scientific. Perhaps nothing could more certainly manifest the deep conviction of the human mind that there are these groupings of nature, than the readiness with which we appreciate the ludicrousness of a fanciful classification. In "Gulliver's Travels," we are treated to a description of a race of Liliputians, who were divided into two fierce parties over the question whether, when an egg was eaten, it should be broken at the big end or the little end. Both the Big-endians and the Little-endians asserted that there was a difference in the flavor and fitness in this practice. If, now, nature has no classifications, and the distinction between a bird and a fish has no more meaning and reality in nature than this given by Swift, then there can be nothing absurd in Gulliver's histories. The truth is, men make only arbitrary classifications. In so far as their classifications are scientific, they are only reading the classifications God has made in nature. When we are able to read the constitution of the world aright, we find all things already in their own place, classified ready to our hand. It is here, just as it is in a book. The book may be written in a language we cannot understand. It contains the thoughts of its author, but they are as yet concealed from us. When we are able to read the language, we receive and think again the author's thoughts. The task for man is, to learn to read aright the truths of nature. When we are able to do this, we think again the thoughts of God, and that is the perfection of science. The task we have in hand is to understand the correct methods for this study of nature.

CUMULATIVE REASONING.

We have seen that, in reasoning on necessary truth, we begin with self-evident or intuitive truths, and thence proceed by demonstrative reasoning to reach other truths just as necessary, but not, at first sight, so obvious. How, now, are we to attain certainty in regard to caused truth? When can we know that we read aright nature's classifications, and correctly understand her laws? This is done by an accumulation of facts and observations which, though at times of seemingly small importance at first, may yet, by enlarged experience, so increase in number and clearness as to produce the most absolute certainty. At other times, the meaning of the facts is so obvious at once, that we have no doubt, and all subsequent experience only serves to confirm these our first conclusions. When Copernicus first suggested that the earth revolved around the sun, it was a mere hypothesis, which everybody's eyes seemed to contradict; but it is now proved by so many facts, that it cannot be doubted by any one acquainted with the evidence.

One single fact makes the truth so indicated possible. Some things are possible; others are impossible. For the same thing to be in two places at the same time, is impossible. It is possible for a man to live a day without food. We are certain that fish can swim. At present, it seems impossible for man to live without air; but if one man should do so, that one case would prove its possibility. Added instances would each increase the testimony in its favor. One message by the ocean cable proved such a telegraph possible. Whether it would work long and well enough to pay, needed other facts to prove it. That point is now settled also. Between, therefore, the mere possibility proved by one fact, and the positive certainty which is reached by a sufficient number of facts, there is every shade and gradation of proof. A sufficient accumulation of facts and observations all point-

ing in the one direction, will ultimately bring certainty on any question. A feather will not balance a pound, but the fact that the feather weighs something, proves that if enough of them are gathered they will weigh a pound. One feather will balance part of the pound, and two feathers will balance more, and if enough are accumulated, they are sure at length to lift the other end of the scales; and if this process is continued, you can pin the feather end to the floor as firmly as by a ton of lead. The term Cumulative Reasoning, or evidence, rests on the same principle of increasing weight, until all doubt may be overcome, and we rest in certainty.

It may be proper here to give the leading points of difference between Demonstrative Reasoning, as applied to necessary truth, and Cumulative Reasoning, as applied to caused truth.

1. The fundamental difference, of course, is that, in reasoning in regard to necessary truth, you start with axioms and things self-evident; while in the other, you are dependent in whole or in part on experience. In the first, therefore, no experience is needed, and each item of experience is of universal application. There is no limit to the progress that might be made; and, if the argument is correct, the conclusion is certain without trial. In the other, however, we begin with trials, and we must test every step which we take by repeated trials. However logical the argument, it is to be tested as if we were to begin anew just at that point of progress. This insisting on constant and unvarying experimentation was perhaps Bacon's greatest service to science.

2. In demonstrative reasoning, there is not ordinarily any conflicting evidence. All the evidence is on one side. In cumulative reasoning, however, there is very generally a balancing of arguments, that seem to contradict each other. No argument was ever yet produced to make it appear pos-

sible that two straight lines could enclose a space, or that two and ten were anything else than twelve. But how many arguments appear on each side of the question, as to the habitability of the heavenly bodies. The debates of scholars and statesmen are but the marshalling of these antagonistic arguments on the various questions in controversy. In the way of practical genius, nothing is of greater value than that power of determining correctly among these warring probabilities. This is the true secret of business tact and public leadership.

3. In view of these two, the third difference is obvious, namely, that while cumulative evidence admits of degrees, demonstrative evidence does not. This last is certain, one way or the other. If a proposition is legitimately demonstrated, nothing can make it more certain. Every conclusion reached by it is equally true. It is quite otherwise in cumulative reasoning. Here, indeed, we may, and often do, rise to absolute certainty; but in the majority of cases there are doubts. The rise in the price of grain next year may be very probable, and all through the passing season the likelihood of this may be increasing, until no thoughtful man would sell his crop at a low figure. After all, however, it may be a mistake. The perplexity lies in this uncertainty, and this leads to the next distinction.

4. Responsibility is connected with the one, and is not with the other. No praise is due to him who believes that things equal to the same thing are equal to each other. No man can avoid believing that two and two are four. In cumulative evidence, however, a man may or may not listen to it. Men often do shut their eyes to the plainest proofs, and the follies they then commit are sins. It is a duty binding on all to consider these proofs well, and, in this light, adopt the part of wisdom. Men may demand the irresistible force of demonstration on all subjects, but it will not be given, and cannot be gained in any field to which it

does not belong. It belongs to necessary truth, and not to caused; and those who object to action in the department of caused truth, because they cannot get the kind of proof obtainable in regard to necessary truth, are as silly and wicked as those who would refuse medicines to cure malarial disease, because they could not, by a mathematical computation, figure out, from the character of the disease, the weight of the dose. In its sphere, cumulative reasoning is all we have or can have, and on all the practical questions of life it is sufficient for our wants.

PART SECOND.

CAUSES.



NATURE'S OFFERING.

IN the world around us, we find a multitude of things inviting our inspection. The most casual glance will show us that these things are constantly acting and reacting on each other. The same thing is, at the same time, both acting on other things and being acted on by them. We have thus two things furnished for our investigation,—the things themselves, and their mutual action and interaction on each other. There is much discussion as to whether we know anything about objects except their qualities. Without indulging in metaphysical speculation, it will perhaps lead us, with more clearness and ease in our present progress, to define a quality as any power a thing has to produce an effect. Thus, we say sugar is sweet, because, when we put it to our tongue, it produces a certain taste there. We say vinegar is acid, because, when soda is put into it, certain chemical changes go on. We call powder explosive, since, when fire is applied, it is suddenly converted into an elastic gas. So minerals are heavy, when they press strongly towards the earth. Animals are fleet, when they can move rapidly. When, then, we are inquiring into the qualities of things, we are asking what effects they are able to produce, either on our senses or on each other. Color is an effect on our sense of sight. Hardness is power to resist pressure. We know but little of electricity, except by what it can do. In the last analysis, the same is probably true of other things.

Let it not be supposed that by this the limits of our knowledge are contracted. If we properly enlarge our notions of cause and effect, we will find that what we have just said is only another way of stating what everybody believes. The convenience of this statement here is, that it makes it our first business in inductive logic to learn how to eliminate and identify causes. After that is done, we will be better prepared for the more difficult subject of classification. Usually, this last subject is put first, and its natural difficulty is increased by the want of preparation to understand the basis on which the classification proceeds. If we classify objects according to the effects they are able to produce, our path is plain. We will first find out what effects are attributable to each object, or what its power is as a cause, and then we will know where to place it. Those that produce the same effects will be in the same class. We thus inquire into causes, in order to classify the agents. We investigate one thing nature gives, the interaction of things; in order to find out in what groups she has placed her other offering, the things themselves.

This leads directly to THE FIRST GREAT QUESTIONS of science in the department of Caused Truth — WHAT, HOW, and WHY. The What inquires for the facts. The How inquires into causes and laws. The Why inquires into the end sought to be attained, which is sometimes called final cause. The first two belong to material things as well as immaterial; but the last requires an intellectual answer, and a reply to it is only possible when we are considering that which is the work of mind, and done with a purpose. This point will come up again.

NATURE'S LAWS.

The simplest definition of a law of nature, perhaps, is this: Such a statement of our past observations, in relation

to a given matter, as we believe will be found to hold good in all future experience. If we merely tell what has occurred, that is only history; but when we step beyond that, and try to state the law of the events, we mean that such has been the frequency with which the concurrence of certain agents has been followed by certain results, that we expect those results to follow that concurrence in the future. A superstitious man says Friday is an unlucky day; because he thinks he has noticed that the undertakings he has begun on that day have failed so often, he may expect such to fail in the future. The physician says the child will not have the measles again, because medical men have noticed that people usually have that disease but once, and the same may be expected in this case. Newton's law of gravitation is, that the force of gravitation diminishes as the square of the distance increases. It always has been so, and we have not a doubt it will be so in the future. The difference, then, is plain. When we state the result of our observations, we take the first step towards enunciating a law. When we go on and assert it as a general truth beyond present experience, we take the other step.

In nature, however, there are none of these, which we may, for the present, call tentative laws. Viewed as from nature's side, laws are merely the methods in which things act. In the things there is no choice, but they act according to these laws under which they are made. Even mind has its laws of thought and emotion. The will has its laws of freedom and responsibility, from which no volition of its own can set it free. All these laws, therefore, viewed from nature's side, are of the same character—absolute, and always operative. Their action is only to be controlled by bringing other like laws of greater efficiency to counteract their energy. Bodies tend to fall to the ground, but we may prevent this by placing under them a support strong enough to bear their weight. It is a law of mind to think, and we can

only keep out evil thoughts by occupying the mind with better thoughts.

While, however, all nature's laws are thus equal and uniform in their action, we do not, by any means, always know what these laws are, or what the action of different agents will be. On our side, therefore, there is the greatest difference among these laws. The difference depends on the varying degrees of our knowledge. Some are mere suggestions of laws, by the fact that certain things are seen to occur together. These, for want of a better name, we call empirical laws.

Empirical means blindly following observations without regard to causes or reasons. As applied to nature's laws, it refers to those cases where the relation of cause and effect is not considered, and all that is considered is, that certain things have frequently occurred together. It especially includes those rules where there is nothing but mere concurrence known to be present, and where there is no attempt to assign a cause. Thus, all these rules for building fences by the signs of the moon, and the predictions of the weather founded on the character of certain days, and that children have whooping-cough but once, are illustrations of empirical laws. Their whole basis is observation, more or less frequent. In some cases they rise to a very high degree of probability, but in other cases they show in themselves that they have very little foundation. These last are wholly unreliable, and have, perhaps, as many exceptions as fulfilments, while the former are fulfilled with very few exceptions. The distinguishing feature, therefore, of these empirical laws is, their dependence on mere frequency of observation, without any known reason for their existence as laws.

The other class of laws we may denominate established laws. These are laws of nature, where we not only know the law, but also the reason for it. It is established by the discovery in nature of the cause by which its fulfilment is

secured. We have, therefore, in these, both the facts and their philosophy; so that the law is a general statement, including under it a large class of facts. As an illustration, we say it is a law of nature that the frost is not so severe in cloudy nights as in clear, because the clouds shut in the earth's heat and prevent its rapid radiation, just as a man is warmer with a large quantity of covering on his bed, than if he had none. The law that the frost was most severe in clear nights, was known long before the reason of it was detected. At that time it was an empirical law. It became an established law by the detection of its reason. So it is an established law that cropping is more exhausting to land than pasturing, because the animals drop their manure on the field from which they took their food, and so but little of its fertility is taken away, while the removal of both the straw and the grain will rapidly diminish its productive power. A very admirable illustration of an empirical law that has passed into the class of established laws, is the fact of the periodicity of the moon's eclipses. By mere observation, astronomers had found that these eclipses followed each other in a regular succession at fixed intervals. By this means it was possible to foretell the time of the occurrence of these eclipses. As yet, however, no satisfactory explanation of the eclipse itself was offered, much less any explanation of the reason of their regular recurrence. When, however, the true theory of the motions of the heavenly bodies was discovered, and the laws of those motions ascertained, it was found that they required just these several eclipses, and just in the order laid down in their periodical tables. These empirical laws have thus a constant tendency to become established laws, or else to be disproved. In other words, the human mind has a natural curiosity to seek for the reason of all that it observes, and thus either establish and explain these empirical laws generalized from its observations, or overthrow them altogether. Very many of the

scientific problems of to-day are the solutions of empirical laws, such as the inequalities of the tides at different places in the same latitude, the averages of crimes in large communities in different years, the improvements in animals and vegetables by cross-breeding, and such like. The success that has attended past efforts to resolve these perplexities, gives strong confidence to future labor.

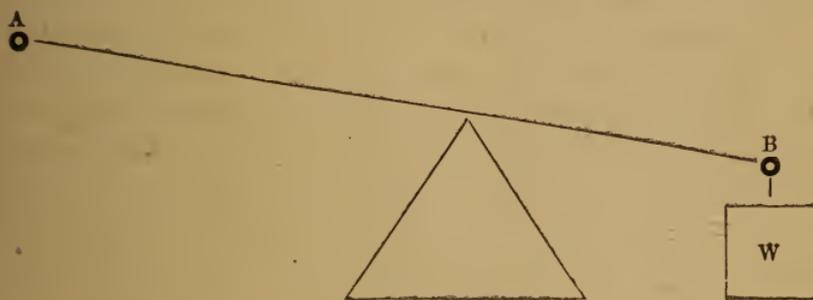
We have, then, these peculiarities as marks of these two kinds of laws. Empirical laws are, first, the result of frequent observation alone; second, their reliability is measured by the inequality between the number of cases in experience in which they have held good, and the number of exceptions; third, they indicate the existence of causes which produce the results that have been observed, but these causes and the laws of their action are as yet unknown. On the other hand, established laws are, first, based on satisfactory reasons which explain the phenomena; second, they have an objective reality in the present constitution of the universe; third, we are enabled by them to predict the future, and that future, when it comes and is fully understood, verifies the law by still more clearly indicating the connection of cause and effect. Ultimately, all empirical laws ought to become established laws, so far as they are true, and subverted in every other respect. Much as has already been done in this direction, a far wider field remains to reward with its wonders the investigations of vigorous and careful students.

EFFICIENCY OF CAUSES.

The question whether there are efficient causes or not, is one on which the mass of men will have little difficulty. We all act on that principle. Even those who theoretically deny that there is any such thing as causation, and assert that all which we call causation is, in reality, only invariable sequence, nevertheless act on the presumption that there are

real, true causes, and are compelled to adopt that phraseology. Without digressing too far, it may be well to notice the following reasons for believing to the full in the efficiency of causes:

1. The first source of appeal is to our own consciousness. If we cannot believe it, we cannot believe any knowledge whatever. Now, there is no knowledge of which I am more fully conscious, and more positively certain, than that, when I, by my hand, press on the lever A B at A, and the weight



W rises in the air, my weight is the true cause of its motion. When I take away my hand, it falls again. Or you take direct hold of the weight, and as you lift, it moves upward. Now no amount of argument can convince an ordinary mind that your lifting is not the actual cause of its rising. You feel the resistance of its weight, and increase your exertion, and by and by you overcome its weight, and it rises with your hand. You have before you a quantity of powder, and on it you let fall a spark of fire. An explosion follows, and every time we repeat it the assurance grows more absolutely certain, if that is possible, that the spark caused the explosion. Old and young, learned and unlearned, at once see the connection of cause and effect. In all our efforts to produce the results we desire, we endeavor to accomplish our ends by putting into operation the causes by which they are effected.

2. In entire harmony with this affirmation of our own

consciousness, is the testimony of the general consciousness of mankind. The convictions of men, especially the universal unrecognized convictions of men, are indicated by their language. You ask a man why he believes the price of coal will fall, and he replies, *because* the miners are working for lower wages, and more capitalists have gone into the business. His answer begins with the word *because*, or *by cause of*, as setting forth the reason of his views, and then he proceeds to state an adequate cause. Another says the price of wheat will be high. If you ask him why he thinks so, he may say there is war in Europe, and so the waste of breadstuffs will be great, thus increasing the demand, while the large number of men taken from the fields to enter the army will reduce the supply, and *therefore* the price will be high here. That word *therefore*, meaning for this reason, shows that the results he predicts are, in his judgment, to be caused by the means he has stated. If we observe all classes of men, we shall see not only that they thus use these significant words (*because*, when they state the results first and the causes afterwards, and *therefore*, when they state the causes first and the results afterwards), but also that the whole structure of their language indicates that they reason on that connection of cause and effect. These two words, *because* and *therefore*, have their equivalents in every language of men. People of all tongues, in their doubts and controversies, recognize that as having weight in the matter which marks a cause. That which does not rest on some form of this relation of cause and effect is nowhere allowed much weight. That this relation of true cause to actual effect is the real secret of the convincing power of an argument, and this the correct analysis of the reasoning process in the minds of men, may be tested by any one who will try it with children, or any miscellaneous gathering of people. If he will show the presence of a cause, they will show that they appreciate the argument;

and if they undertake a reply, in their reply they will be found to proceed on the same basis. They may be wholly ignorant of all the technical terms of both inductive and deductive logic; know nothing of illicit process, undistributed middle, or concomitant variations; yet they will use this connection of cause and effect as the force of their argument; and when these methods of inductive logic are explained to them, they will recognize them as the true statements of their mental operations in regard to caused truth;—just as the uneducated see mistakes in grammar, and when they have studied the science of grammar, recognize its rules as the true tests by which they have always judged of the correctness or incorrectness of language. In the home life of mankind, at their daily occupations, they make experiments precisely on the methods to be hereafter explained; and these methods have no meaning to them, unless there is real efficiency in causation. To no one thing do the languages and actions of men give a more positive confirmation than to this assertion of the reality of causes, and the dependency of effects on the active agency of these causes.

3. This same truth of the efficiency of causes will become next to self-evident by the consideration of the difference between two sets of cases. The application of fire to gunpowder has not more regularly been followed by an explosion, than day has been followed by night; and yet no sane person believes that day is the cause of night, as they believe the fire caused the explosion. All the crows we have seen were black, and yet we by no means so confidently believe that the next crow will not be white, as we believe that the next living man, held for an hour under water, will be dead, even though we never saw a person drowned. Once it was supposed all swans were white; but when a species of black swans were found, it was not looked on as if we should see an ox living after the head had been taken away. One

case, in which a barometer was carried up a mountain, was enough to determine that the mercury was sustained in the barometrical tube by the pressure of the air; since as it went up the mountain side, and so left less air above it, the column of mercury fell to a still lower point. Many people use old horse-shoes to keep away witches, yet who believes that a witch would be hindered by a horse-shoe? If we ask why our confidence is so strong in one set of cases, and so utterly fails in the other, the answer is plain. We perceive a cause, and a sufficient cause for the explosion of the powder, the death of the man under water, the death of the headless ox, and the fall of the mercury as the barometer is carried up the mountain side. We see no cause whatever for the night in the preceding day, or for the blackness of crows, or the whiteness of swans, or fear of horse-shoes by witches. Every instance that manifests a cause, furnishes us with sufficient reason to believe that the rule is universal, and that the same effect will always be secured by the same set of circumstances. This leads us to the other important consideration.

4. The Positive Philosophy, which denies all efficiency in causation, utterly fails to explain the self-evident difference between these two classes of cases. Every attempt to explain the reasoning process must, of course, account for this obvious difference. If we admit force in causation, the difficulty is at once removed, and all is plain. If, however, we attempt to reduce all to mere uniformity of succession, and say that all that is in it is, that always after the stopping of a man's breath his death happens, there is no explanation of this difference in the above classes of cases. No more accurate or able thinker of this school of philosophers has appeared than John Stuart Mill; and yet, after considering the specific example of the blackness of crows, he asserts that all the instances that have been observed since the beginning of the world, in support of the general proposition

that all crows are black, would not outweigh the testimony of one unexceptionable witness that, in some new region of the earth, he had caught and examined a gray crow. He then changes the form of the question, and proceeds thus: "Why is a single instance in some cases sufficient for a complete induction, while in others myriads of concurring instances, without a single exception, known or presumed, go such a very little way towards establishing an universal proposition? Whoever can answer this question, knows more of the philosophy of logic than the wisest of the ancients, and has solved the great problem of induction." That last sentence is a frank confession that, on his own theories, the difference between the two classes of cases is inexplicable. We are, therefore, left no alternative but to accept the only other theory, especially when we find that accepting it, the whole mystery is gone utterly.

As a result, therefore, of these considerations, we conclude that effects in the universe are actively and efficiently produced by their several causes. That which is asserted by many to be a self-evident truth, is thus found to be not only axiomatic, but the conclusion of the most perfect induction, supported by the undivided testimony of all instances, THAT EVERY EFFECT MUST HAVE ITS CAUSE. And since we are not able of our own volition immediately to produce effects, but are compelled to produce them mediately, — that is, by the means of their causes, — our knowledge of these causes, and of their several effects, is the limit of our power. We can only increase our power by increased knowledge. In the highest sense, therefore, it is true that *knowledge is power.*

CAUSES DEFINED.

What, now, is a cause? Ordinarily, by a cause we mean the new and inconstant agency which precipitates the effect. But it will not do to limit the word to these, as if the spark

of fire was the whole of the cause of the explosion of the powder. The powder was evidently also part of the cause of the explosion, since without it the spark would have been harmless. So, further, there was needful to produce the result some means of keeping the powder together, otherwise the spark would have had to travel from grain to grain, instead of the fire being communicated from one grain to another. All of these are real causes, and none must be left out of view, if there is to be a complete survey of the subject.

Some have introduced the term *concauses* to designate those causes, which seem to play only a passive part in the production of the effect. Perhaps a better division would be into subordinate and operating causes. The subordinate causes are those whose work is merely to give occasion or possibility for the operating causes to act. They merely furnish the opportunity, but do not act themselves. Thus, to have an explosion, the explosives must be held together by some vessel. The vessel is a subordinate, not an operating cause. Its material is of no importance. To have a fire, you must have some means of keeping your combustible materials together — such as a stove, a stone, or the ground; but all that the stove or the ground has to do is the subordinate part of holding the fuel together. These are, therefore, causes, but subordinate causes. They are, indeed, necessary for the effect, but the material of which they are composed is of small account.

The operating causes are those which contribute efficiently to the result. They again may be divided into dormant and active. The dormant are those which, when the occasion comes, take part in the work, but must have the active to set them in motion. They produce no results themselves. They sleep, as we might say, until they are awakened into energetic action by the presence of the active causes. If they are let alone, no result comes. Thus the elements of

life in the seed, as it lies stored away for future sowing, are dormant causes. Properly kept, no action is apparent. There must be moisture, heat, and light to set them at work, when they bring into existence a new plant.

The active causes are those which set the dormant in motion, and so seem to be the immediate causes. They are, therefore, often spoken of as *the causes*; as if nothing else assisted in producing the effect. The spark is the active cause of the explosion of the powder. The sunshine and the moisture are the active causes which set the life of the seed to taking up substance from the earth and atmosphere, and so constructing a tree. The photographer has all three classes of causes at work in making his pictures. His stands and cases are subordinate causes. His chemicals are his dormant causes, and the light and its colors, which he lets fall on the prepared plate, are the active causes.

It is obvious from this that in regard to the subordinate causes, there may be very great variety without materially affecting the result; but that to have in any exact sense the same effect, there must be the same dormant and active causes. The artist must have some apparatus of some kind for preparing his negative and holding the pictures he would copy; but it is a mere matter of convenience what its construction, or color, or material may be. To have, however, the same kind of a picture, he must have the same kind of chemicals, and the same kind of light. The distinction between photograph, ambrotype, and ferrotype, is dependent mainly on differences of dormant causes. The stands, and cases, and sunlight, and people, may all be the same; but the results are very different. Strictly speaking, the same effects are only produced by the self-same causes. For all practical ends, however, we may be able to modify this statement somewhat, in regard to the subordinate causes. But we are only able to do this when we have attained a clear knowledge of all the causes, and have fixed on the exact

work of each, so as to know whether it is a subordinate, dormant, or active cause.

THE DIFFICULTIES OF IDENTIFYING CAUSES.

Since caused truth depends on volition for its existence, there can be but two ways of finding out what is the fact.

First, The author whose will determined the matter may tell us ; or, we may wait until the volition has been carried into execution, and then see for ourselves. Thus, it is the farmer's business to decide how many acres he will sow in grain, and he may tell us what his purpose is in regard to the matter ; or, wanting this, we may wait until he has done his seeding, and then look at his farm. His information and our own observation are therefore the only means by which we can attain a knowledge of his determinations.

The course of nature has been determined by the will of God. As in the case of the farmer, so here, there are but these two ways by which we can learn this course of nature, including these relations of cause and effect. Either God must reveal it to us, or we must examine for ourselves. While God has seen fit to give us a revelation in regard to religion, he has not spoken to us on this subject of science, for the purpose of relieving us of the labor of discovery. Our only method, therefore, for learning this course of nature, is to look at the facts as we find them, and from these facts learn these relations of cause and effect.

Before we enter on the study of the methods by which these laws of nature are attested in the facts which surround us, it is important to get a clear conception of the difficulties in the way of such a discovery of law from facts, which these methods are intended to overcome. These difficulties are easily reducible to the one general difficulty of the great complexity of the action and interaction of causes. But this appears in so many forms that distinct statements of it are

required, under these various phases. It will, therefore, be developed into five difficulties, thus showing it in as many different aspects. This will prevent our undervaluing our task, and prevent our judging too uncharitably of those who make mistakes.

First Difficulty. — Causes, perhaps, never act singly. In almost every case the three classes are all present — subordinated, dormant, and active. It may, possibly, be too much to assert confidently that no one cause ever acted alone; but it is very certain such cases are almost unknown to men. Coming thus in droves together, it is difficult to decide what part each takes, or to which of the three classes each belongs. Oftentimes, too, there are occult causes at work, and so hidden that their very presence escapes observation for a long time. Of course, while their existence is not known, their effect will not be recognized. It seems now probable that there is, throughout the spaces of the universe, a very attenuated ether; but, if so, it is so inaccessible to observation that its presence is only presumed from the existence of effects which seem otherwise inexplicable. On the other hand, there are cases where the presence of certain causes appears indispensable to the production of the effects, and yet nothing can be discovered which they do. In obtaining oxygen by heat from chlorate of potassa, sand, and black oxide of manganese, we find it very difficult to tell what the oxide of manganese does. The chlorate of potassa gives off more or less of its six equivalents of oxygen, but the manganese remains unchanged in the retort. It seems to have an influence; but what the nature of it is has not yet been ascertained.

Second Difficulty. — Causes not only coöperate with each other, but they also interfere with each other's effects. If they were always at work in the same direction, or else inactive, the case would be much simpler. Sometimes, however, two causes may be actively at work without any visible effect, because they just neutralize each other. Two engines,

attached to the same end of a freight car, may draw it easily; but if attached to different ends, they may exert their whole power, and no motion in either direction result. So in medicine, there are cases where a patient is suffering from a combination of diseases, in which the remedy that would relieve one disease only aggravates the other. While, therefore, both diseases assail the health of the patient, the medicines are mutually destructive of each other. This interference of causes with one another is a very constant perplexity.

Third Difficulty.—The same general result is produced by different causes. Sickness may be the result of the diet the people have been eating, or the impure air they have been breathing in their unventilated rooms, or malaria arising from decaying vegetable matter, or stagnant water, near by. Moreover, some forms of fever are more or less contagious, and some constitutions have to some extent a hereditary tendency to certain fevers. The treatment may require to be somewhat varied, as one or the other of these causes has been the origin of the disease, yet how difficult to determine with certainty to which of these it is due. So national or commercial prosperity may be produced by a very great variety of circumstances or combination of circumstances. The advertising pages of the agricultural papers are a sufficient proof that there are a great many kinds of fertilizers, which will increase the productiveness of the soil. While, therefore, in strictness, there must be the same causes to produce the same results, yet, to our ordinary observation, the same general results may be produced by many different causes.

Fourth Difficulty.—Naturally, we would expect that either increase or diminution of a cause would proportionately increase or diminish the effect. If it did, this would furnish a ready way to identify causes and effects in many cases. This, however, is by no means the case. In so simple a matter as the effect of heat on water, we have a famous

illustration of this. If we take water at a temperature of say 50° Fahrenheit, and increase its heat, it will expand until converted into steam; but if we reduce its temperature, it will contract until it reaches about 39° Fahrenheit, when it begins to expand as it grows colder, until it reaches the freezing-point, when a very considerable expansion takes place. This last is of itself somewhat of an anomaly. Almost all substances contract in cooling from a fluid to a solid state, but here we see water does just the reverse, under the same process. With a singular perversity it expands both ways from about 39° Fahrenheit, so that the effects of the heat are the same, whether it is increased or diminished from that point.

Fifth Difficulty.— Things apparently related as cause and effect, may both be effects of the same cause. Causes do not limit themselves to the production of solitary effects. As the causes come in clusters, so the effects may start forth in companies. Some may appear immediately, and others, being delayed, will have the appearance of effects of these antecedent effects. This difficulty is especially serious in social science studies. Here the movements, which take place in communities bring about successive results, and these are often mistaken for causes of one another. As causes converge at the point of efficiency, and effects start divergent from the same point, great care is required to avoid the wrong location of these causes and effects.

As has already been stated, all these difficulties are included in the great complexity of the action and interaction of causes. They come helping, hindering, co-operating, counter-acting, aiding, and interfering with each other in such diverse, contradictory, and arbitrary ways, that it is not strange that, from the beginning, men have blundered and been mistaken. But with these difficulties to overcome, we have therein only additional incentives to action, and stronger motives to a careful study of the methods by which these dif

faculties may be solved, and these mysteries wrung from the seemingly unwilling hand of Nature. While, however, Nature seems to puzzle us with her complexities, she is lavish of her facts, in which these secrets are contained. They are strewn all about us in the most profuse abundance, as if to tempt us to their study, each offering the most positive assurance of giving us true testimony. It is not equally obvious in all cases what this testimony is, and, therefore, not a little will depend on our selection for study of those facts whose meaning is most clearly presented.

SELECTION OF FACTS.

Facts are of two kinds — those furnished by Nature, and those produced by ourselves. The first of these are called observations, and the others are called experiments. It is only in a limited number of departments of Nature that we can make experiments. We cannot make a little solar system, and put it to work on our table, as we can mix gases and see the result; nor can we make miniature nations, and try their prosperity, now with a tariff, and now with free trade. In such matters, we can only take the facts as they are furnished to us in Nature and by history, and solve their meaning as best we may. In other departments, however, we can experiment upon Nature. In such cases, we take the facts Nature offers in the regular course of events, and, obtaining hints and suggestions there, we rearrange the causes, that they may act under new combinations, and by this experimentation we, as it were, subject Nature to a cross-examination. To this we are rather invited by Nature, and, make it as rigid as we please, we meet with no reluctance to answer. Sometimes it is possible so to shape our experiments as to make their result an explicit affirmation or denial by Nature of some theory proposed for settlement. When it was asserted by one set of philosophers that

the fall of bodies was proportioned to their weight, and that, therefore, a ball of lead weighing two pounds would fall twice as fast as one weighing one pound, and others said that bodies of the same material, no matter what their weight, would fall in the same time, the experiment of letting two balls of unequal weights drop from the top of the leaning tower of Pisa demonstrated, in the sight of every beholder, the truth of the last theory; for both struck the ground at the same instant. Such cases of experiments are the supreme desideratum of every investigator.

Both kinds of facts are reliable. Neither natural nor artificial phenomena are to be discredited. Though we may sometimes arrange the circumstances and combinations under which causes act, no act or volition of ours can in the least change their nature or activity, so as to make them act differently under a given set of circumstances at one time and at another. We can only control or influence the action by change of circumstances or combination of causes. All facts are equally trustworthy. So we get the real, exact facts, it matters little whence they come. Our success, however, in reading the laws of Nature set forth and exemplified in these facts, will depend very much on the ease with which they may be interpreted. Scientific induction is observation and experimentation carried on under rigid rules, by which we may the more correctly understand the relations of cause and effect indicated therein. All facts are not equally beset with the difficulties of identifying causes, as explained in the preceding section. Some general remarks are, therefore, to be made on the manner of making these observations and experiments. It is not strictly accurate to speak of making an observation. We make experiments and we take observations. We cannot always arrange Nature for observation; if we do, that is exactly what is meant by making an experiment. When we watch Nature in her own operations, under her own

arrangements, we are mere spectators, and so take an observation. But as out of all observations taken we may select for study those best suited to our purpose, and out of all the experiments that could be made we need actually make only those furnishing the desired information, in the most intelligible form, the same rules will guide in both cases. Observing these rules, we shall be able to expend our strength in the investigation of those facts where there is most likelihood of our reaching clear and correct conclusions. It is not wise to waste time on insoluble mysteries, when we can ordinarily furnish ourselves with facts containing the same truths, but in a much more intelligible form.

Rule First.—Take those capable of the longest and closest inspection.

Very interesting problems, relating to the sun and moon, seem only answerable from observations taken during a total eclipse of the sun. These rarely last over a minute or two. When, then, one was to occur, visible in Siam for seven minutes or more, the whole scientific world was interested, and almost every civilized nation fitted out an expedition with the best instruments, and directed by their most learned astronomers. In all such cases now, photography is extensively employed, since it gives the most exact representation of the eclipse, and, retaining it, enables the student to study it closely after the eclipse is over. One of the great difficulties in the study of mental science is to retain the same mental state long enough for the careful examination of self-consciousness. Mineralogy and natural history owe much of their rapid progress, in some directions, to the fact that many of their specimens can be placed under the microscope, and there watched day after day.

Rule Second.—Take those with the fewest causes at work, and so secure the least complexity attainable.

In the department of social science this complexity and multiplicity of causes is a very serious obstacle. Suppose

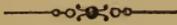
we are studying pauper legislation, and we find a case where, after the passage of certain laws on the subject, pauperism was greatly diminished. If now there was nothing else at the same time which might affect the subject, our conclusions would be quite reliable. But suppose that about the same time the financial market became very prosperous and business very profitable, and as a result labor received very liberal compensation, it would be easy to mistake the results of one set of causes for those of another. As a rule, in these social questions there are a great many causes operating, and too great importance, therefore, is often attached to results that follow certain events, since they may or may not be their results. On this account, therefore, the greater care is needful in examining each several case to determine how much value it has for argument. Sometimes a case can be found where only one feature was modified, and where, from its surroundings, we can have but little difficulty in perceiving that this modification alone was all that could have brought about the result. Such instances will have a superior importance in proportion to their conformity to this rule.

Rule Third.—Take those where the record is most exact, and measure everything that can be measured.

As a rule, estimates are very unreliable. This is especially true if they have been made by those who have not had a previous training in exact measurement. In so simple a matter as estimating the number of persons in an audience, persons who have not had some experience in counting audiences will usually guess from two to three times too many. Not one person in fifty, who has not had practice, can go to the blackboard and mark off on a given line twelve inches of space. But on the other hand, experience can bring this gift of estimating sizes and numbers by the eyes to a wonderful degree of accuracy. A drover can tell very nearly exactly how many cattle are in a given field without counting them. When, now, our future action de-

depends on our knowledge of facts, how very important that we should have the exact facts. The most expert may well count them. Especially is this true if our figures and reports are offered as the basis for others to argue on. We owe it to them, to truth, and to ourselves, to give figures, not from guess-work, but from measurement. No excuse can or ought to be accepted for the neglect of this. Multitudes of reports are utterly valueless because they are not accurate; and no man deserves to be allowed to call himself a philosopher who, in any case, accepts for his data anything less than the most reliable statistics. Every man who patiently and accurately observes any set of phenomena, and faithfully records, not his inferences, but what occurs, is truly a benefactor of his race and a promoter of knowledge.

PART THIRD.
METHODS OF INDUCTION.



GENERAL STATEMENT.

VARIOUS methods have been suggested as the true statement of the process of the mind in reading the laws revealed in the facts so gathered. The work that made Bacon immortal was his effort to state, in the formality of words, these mental operations by which we reach our reliable conclusions. Though highly respectable as a scholar, his attainments in that direction have been far outstripped by many now unknown to fame. His great claim to human gratitude is in this, that he was the first to urge the supreme importance of testing theories by facts, and to insist on the abandonment of every theory, however plausible, which was contradicted by the facts. His aphorisms were designed by him as a kind of proverbial philosophy by which investigation should be directed. Many of them are of little account, but his phrase, "*The proper rejections and exclusions,*" and his explanations and illustrations of instances and examples, were so apt a statement of the mental operations, that they at once passed into the popular thought of scientific men. Indeed, the single phrase above quoted is incontestable proof that, however indistinct some of his utterances were, he really saw the true method of inductive reasoning. What he meant by making the proper rejections and exclusions was that, by selecting test instances and examples, the various

false theories proposed for the solution of a given set of facts should be one by one rejected because the experiment or fact under consideration excluded the possibility of its being true. His "Prerogative Instances" were cases which, between two rival theories, decisively denied the one and affirmed the other. His "Experimentum Crucis" was a case which verified one theory and exploded every other. His book is very well worth the study of every one wishing to make himself familiar with the subject. Perhaps the next most important attempt to formulate these methods in words was that of Whewell, in his work on "The Philosophy of the Inductive Sciences." The same author published another work on "The History of the Inductive Sciences," which is one of the most famous works of his or any age. His effort to explain the philosophy of these studies was by no means so successful as his history. He recommended a system of lines representing the facts collected, that thus by the eye an estimate might be made of results and the uniformities detected. He laid great stress on "Clear and Appropriate Conceptions," and gives many useful rules for their attainment, but these rules have not proved themselves especially practical. He also attempted a classification of methods, naming them *the method of curves, the method of means, the method of least squares, and the method of residues*. Through all of his discussion of these there are most valuable hints, and, as in Bacon's, so in his, there are very many suggestions and rules which are directly in the line of true inductive logic. While not able to complete the science of inductive reasoning, these two made large additions to human knowledge in that direction, and greatly prepared the way for all who come after them. Sir John Frederick William Herschel published a work on "The Study of Natural Philosophy," which is of the very first order of merit, and is counted a standard by all modern writers on the subject. It is peculiarly apt in its selection of and com-

ments on its examples of inductive reasoning. Probably the greatest recent work is John Stuart Mill's "Logic." His names of the methods have now been all but universally adopted. They carry their own recommendation in the aptness with which they express the various processes to which they refer. Although wholly in error as to his notion of what a cause is, yet Mr. Mill uses the word in its proper way, and so, as not unfrequently happens, a word is used correctly and explained wrongly. Mr. Mill reduces causation to mere uniform succession, and thus, with the whole positivist school of philosophers, of which he is one, denies all efficiency in causes. This theory has been sufficiently refuted in a previous section. Mr. Mill gives five different canons or rules, with as many names, but as his third is only a combination of the first and second, and it is to be presumed that every person of sufficient thoughtfulness to use any of these methods intelligently, will use all of them, in every case where they are available, there seems to be no need of making their combinations distinct methods. We shall therefore proceed to the statement of the four methods, under the names given by him, to wit: THE METHOD OF AGREEMENT, THE METHOD OF DIFFERENCE, THE METHOD OF RESIDUES, and THE METHOD OF CONCOMITANT VARIATIONS.

THE METHOD OF AGREEMENT.

ALL THE CASES OF THE EXISTENCE OF A GIVEN EFFECT, HOWEVER THEY MAY OTHERWISE DIFFER OR BE VARIED, WILL AGREE IN THE PRESENCE OF ITS CAUSE OR CAUSES.

This is the statement of the rule, when we are reasoning from effects and are seeking for their causes; but oftentimes we are compelled to reason the other way, from cause to effect. Indeed, in every case where it is possible, especially where our reasoning from effect to cause has led us to a conclusion not absolutely certain, we should adopt this

reverse method, as a test. If we are right as to our hypothetical cause,* its effect will be produced when it is set in operation. But the rule needs some modification to adapt it to this way of applying it, and may be stated as follows :

ALL CASES OF THE EXISTENCE OF THE CAUSE, HOWEVER OTHERWISE THEY MAY DIFFER OR BE VARIED, WILL AGREE IN THE MANIFESTATION OF ITS EFFECT, UNLESS THERE IS PRESENT SOME ADEQUATE COUNTERACTING CAUSE.

When the effect has been produced, and we are looking for the cause, we know there has been no counteracting cause. But when we set causes at work, our experiment may fail, owing to the action of some interfering agent ; and if we at once conclude that, therefore, this was not its true cause, we would drop into great error. Oftentimes the discovery of that hostile agent is as important as the relation of cause and effect, and thus, while it increases the intricacy of our problem, it also adds value and interest to our researches. As a truth variously stated is thereby made clearer, there is added another statement, which is in substance the same as the last. *Whatever antecedent can be excluded, or absent without prejudice to the effect, is no part of the cause.*

Beyond the statement of these rules, perhaps no further proof of their truth is possible than what is found in illustrations of them. Their illustrations, in addition to this use of explaining the rule, will have this advantage, of being samples of the method of their employment, and of reasoning under them. Suppose we are investigating the

* In the statement of the rule the word cause was given both in the singular and in the plural (cause or causes), to indicate that there might be, as indeed there usually is, a concurrence of causes necessary to the effect. Hereafter, however, the word will be used in the singular only, as including all that is needful to produce the effect, both in the way of actual forces and of their relation to each other. The word cause will, therefore, mean the combination needful to the effect.

nature of rust. We begin by looking at all the kinds of rust with which we are familiar, and examining wherein they agree. A little inspection will show that it is not on wood, but on metals. Further inquiry may bring to our knowledge other metals that will rust, of which we were not at first aware. We now notice what the circumstances are wherein this rust comes on these metals. We find it comes on them both in the air and the water, but more rapidly in water. Our next step is to look wherein air and water agree, and we find that while air is oxygen and nitrogen, water is oxygen and hydrogen, thus agreeing in the presence of oxygen. This naturally suggests that the union of the metals with the oxygen may be the cause of the rust. If now the rust is analyzed, it is found to be composed of oxygen and the metal. From these agreements we conclude that rusting is the oxidization of metals.

Suppose we are investigating a case of suspected poisoning by arsenic, we will proceed by the same method. We know what results will follow when arsenic is treated in different ways. If the sulphuret is mingled with finely powdered charcoal, and placed in a small tube of hard glass, and the end that contains the mixture is heated red hot, the arsenic will be sublimed in a small black band or mirror a little higher up the glass tube. So if a suspected substance is mixed in a retort, with zinc and dilute sulphuric acid, and the gas generated is made to escape through a burner, it will, when lighted, deposit a bright black spot on a piece of cold porcelain held over it. So if the substance supposed to contain arsenic is diluted with water enough to make it thin, and hydrochloric acid added to the extent of one-eighth of the amount of the mixture, and the whole heated to near the boiling-point, when a piece of bright copper is dipped in it, there will be deposited on it a thin steel-gray coating of metallic arsenic, which, with further treatment, can be positively distinguished from all other matters that

are similar in appearance. It is asserted that if arsenic is present to the extent of one part in 250,000 of the solution, it will show itself by this last test. If now all these results, known as following the presence of arsenic, should show themselves in a case of supposed poisoning, there would be no hesitancy in declaring that arsenic had done the work; and that argument would be wholly on the Method of Agreement.

If we inquire what crystallization is, we find the cases in which it takes place agree in that a solid is deposited from a liquid state. The prevalence of the cholera in this country has shown this in a marked degree, that intemperance is very destructive to the vitality of certain parts of the human system, inasmuch as scarcely any intemperate persons who were attacked with it recovered. The deaths among the drunken who took it were a very much larger percentage than they were among those of strictly temperance habits. It is believed that yellow fever is largely attributable to filth, since its presence is mainly confined to cities where there are inefficient sanitary regulations. If a housewife inquires what it is that separates the butter from the milk, she will see that, notwithstanding the various shapes, and sizes, and kinds of churns, they all agree in this: that they are methods of agitating the milk, and she will correctly conclude that this agitation is the essential point. It is a strong argument for education that, in all the history of the world, no enlightened people have been for any long time enslaved. It is equally true, and equally instructive, that no republican government has long endured among a corrupt people. These illustrations of truths, proved by the agreement of the facts of all experience, might be multiplied almost indefinitely.

Each of these methods has some feature wherein its use is peculiar. In this way certain rules become important. Thus in experimenting under this Method of Agreement, we are to follow this

SPECIAL RULE.

Vary every circumstance as much as possible, except the hypothetical cause.

The conclusiveness of our experiments or observations will be greatly increased if the cases show a difference in every particular but the hypothetical cause. It is not possible to attain this in all cases; but so far as it can be done, it is desirable. Sometimes it will be found that there are several things, in any one of which a variation will affect the result. This will facilitate the analysis of the combination of causes by which the result is produced. The fact of a combination of causes will be clearly indicated if there are found several things, the absence of any one of which will defeat the result. Some writers, in order to include this condition of affairs, use this phraseology — that the thing in which the cases agree is either the cause or *part of the cause*.

In investigating subjects where experimentation is impossible, the observations taken under as diverse circumstances as possible, and where the agents were as varied as possible, will be the most valuable at first; but in no case should any facts within our reach be neglected. Every case should be examined. If its conditions are very similar to those already reviewed, its testimony will be valuable for confirmation. If its conditions are new and peculiar, its testimony will be so much the more important. The only time when additional cases may be neglected, is when the fewness of the causes, and the simplicity and uniformity of their action, leave no doubt that additional facts of the same kind could furnish no new light, and where we have applied all the tests of inductions, which are given in the section on that subject.

This method labors under this defect — that it is always exposed to error from the presence of occult causes not immediately obvious. The multiplicity of causes also makes

it a rare case that observations shall not have quite a number of points of agreement which are of no importance. To obviate these uncertainties of this method, we have recourse to the next method.

THE METHOD OF DIFFERENCE.

THE CASES WHERE THE EFFECT IS ABSENT, HOWEVER SIMILAR THEY MAY BE TO THOSE WHERE THE EFFECT IS PRODUCED, WILL ALWAYS DIFFER FROM THEM IN THE ABSENCE OF THE CAUSE.

This is the general principle. It has, however, some exceptions. Thus the absence of the effect, as has already been noticed under the preceding method, may be due to the presence of some adequate counteracting agent. In that case, it would not be correct to conclude in accordance with this rule. So, also, the presence of a cause may be accompanied with other manifestations, which are not efficient agents, and yet appearing and disappearing with the cause, they may be mistaken for the cause, inasmuch as they may be more obvious. Great care must, therefore, be taken to ascertain whether the hypothetical cause, whose presence or absence we are watching, is a true cause or not. In order to make this point more obvious, the rule of this method is sometimes stated in the following words: *If the presence of any given effect is removed from any given set of circumstances, on the removal of a given cause, or in case of its absence, its presence is obtained by the introduction of that cause, then that agent is at least part of its cause.*

The general application of these principles is to the active causes; yet the same processes will apply to the determination of the character and influence of all the other causes, whether they are subordinate or dormant. If they are subordinate, then various other things may be substituted, provided they are all capable of doing the same subordinate

work. By this means, it is usually possible exactly to measure the nature and importance of these inferior agents. Several may be able to do the work, and yet, from the peculiar character of the work, they may not do it equally well. It is a great matter to be able to determine what subordinate agent is best suited, even for subordinate service. If the causes are dormant, changes cannot be made and the result be the same in all its features. The sameness of the result will depend on the end we have in view, or at least this is the ordinary estimate of the human mind, and the common use of language. Looked at from one point of view, and considering some ends, very different effects are called the same; and although called the same in that sense looked at, with another thought before us we call them very different. In strictness, no result ought to be identified with another similar one, unless the dormant as well as the active causes are the same; and their sameness will be admirably tested by this method of difference.

Suppose a farmer is inquiring for the reason of the failure of certain of his fields to produce good crops. He will begin to study them by the Method of Difference. He will compare them with fields nearly similar in the same neighborhood, which, notwithstanding the similarity, are very productive. He may see that in the other cases there are streams of water, which always keep them damp in the protracted dry seasons, while his own fields are without such moisture. He may thence conclude that the soil is not well adapted to retain moisture, and if so, there are two ways of further investigation. He may by cutting new drains or water-courses be able to irrigate part of his poor field, and leaving the rest without irrigation, he experiments on his own land. Should the result be that the watered land has its productiveness greatly increased, his course is to bring water to all such fields, if possible. But suppose this should fail, and the watered land be no better than the other, he

will be disposed to try fertilizers, on the supposition that certain valuable elements are wanting in the soil. Unless, now, he has some previous observation to give him a hint that a particular element is probably the one that is wanting, he will naturally try several on different parts of the same field. We will suppose that on one part he puts lime, on another phosphates, and on another ammoniated manures; and when the harvest comes, the part on which the phosphates were spread is by-far the most productive, the result will be a very plain indication that these phosphates furnish the needed elements of fertility. In such experiments on the farm, it is important that the various fertilizers should be used the same season, otherwise it is very possible that the very great differences observed may be due to other causes. Many neighboring farmers come to directly opposite conclusions concerning the same manures, because all try them in different seasons; and so the results are mixed up with the effects of the weather, and numerous other causes affecting vegetation.

The department of chemistry affords the most beautiful experiments, illustrating this process of reasoning by the Method of Difference. If a vessel is filled with a solution of acetate of lead, and into this solution two thin platinum wires are inserted, and these are connected with a small voltaic battery, and then the voltaic current is sent through the solution, the lead will be slowly severed from the atoms with which it is combined, and begin to crystallize on one of the poles of the battery, taking forms of magnificent beauty. When seen, they will look like vegetable growths, springing up so rapidly that their fern-like forms seem to grow before the eye. If now the current is reversed, these fronds will at once begin to dissolve on the pole where they were growing, and in a little they will begin to grow on the other pole. Reverse the current again, and again they commence growing as at first, and dissolving where they grew

before. It is completely proved that this crystallization is due to the voltaic current separating the elements; for the change of the course of the current is the only difference in the two cases.

Suppose the subject for inquiry is as to the element in the air by which combustion is supported. The air is composed of three parts of nitrogen and one of oxygen, mechanically and not chemically united. If, then, it is the nitrogen that maintains combustion, and that nitrogen is obtained pure, and so separated from the oxygen, a taper ought to burn in it with as great or greater brilliancy. When this is tried, the lighted taper is immediately extinguished. By the Method of Difference, therefore, it is shown that nitrogen is hostile to combustion, instead of a supporter of it. When now the same method is tried with pure oxygen, everything that is dipped into it burns with very greatly increased rapidity. A candle, when blown out, will be at once re-lighted when it is inserted in oxygen, if the least spark of fire is still found in the wick. A red-hot iron inserted will burn with the most brilliant sparks. When taken out the burning at once ceases, to be resumed again if it is replaced. A steel watch-spring, when heated red hot and inserted in oxygen, is one of the most magnificent experiments that can be made. Here the proof is positive that the oxygen is, and the nitrogen is not, the supporter of combustion.

Before further illustration, it may be well here to introduce some remarks on the application of this Method of Difference. As its nature is just the reverse of the Method of Agreement, its special rule is exactly the reverse, and is as follows:

Maintain every circumstance as nearly the same as possible, except the presence or absence of the hypothetical cause.

If many variations are allowed, the difference of result may be due to these variations, and not to the supposed cause. Herein lies the difficulty of the application of this

method to natural phenomena, where we can only take observations and cannot make experiments. The variations are numerous, and often great, and so no one case is sufficient to prove or disprove any but one fact, and there are many involved. Where we can for ourselves arrange our experiments to suit our own objects, we can vary but one thing, and so secure a definite result. This is the importance that attaches to conducting agricultural experiments on the same season instead of different seasons. When experiments tried in different seasons are compared, there is so much due to difference in temperature, and the order of the succession of the extremes of heat and cold, and the differences of moisture, and such like causes, that often the results are of no value whatever. So in social science studies, certain laws are passed on specified subjects, and a given result follows. But at the same time, other laws were passed, other financial changes took place, new machines were invented, and the whole change may be due to these last. Indeed, very notable results are oftentimes due to sudden and almost unaccountable currents of popular sentiment and public prejudice. If, then, these are attributed to legislation or finance, we shall fall into great error.

To illustrate this point, as well as the general subject further, suppose a physician is attending a patient, whose disease has not yet developed itself sufficiently to indicate its exact character. He has found one remedy prove of no avail, and wishes to try the effect of another. At the same time that he prescribes the new remedy, he also changes the diet and the regulations for ventilation, with a different temperature of the sick chamber, and prohibits all conversation, and enjoins as much sleep as possible. It is evident that the good results which follow can with no confidence be attributed to the new remedy. The failure of the previous remedies may have been wholly due to bad nursing, and the very favorable results now manifested may

be the beneficial effects of these previous remedies, when by better nursing their effect and operation was not impeded. It may be wise medical practice to change many of the remedial measures at once; but if the sole object in view is to test the effect of any one agent, the experiment must be made by introducing or withdrawing it alone, without any other changes.

One of the strongest arguments to prove that Sir Philip Francis was the author of the Letters of Junius, is of this same nature, in that, as soon as Sir Philip Francis was sent to India as Governor of India, Junius ceased to write. He could not write political lampoons in England when he was ruling in India. By this same means, the character of criminals is detected. Suddenly a well-known vicious character appears in the city, and at once a certain class of depredations begins to be reported. In a short time the police learn that he has left the city, and immediately these depredations cease. Now, although no eye has seen him in his robbery, and no evidence available for his arrest is to be obtained, yet if this feature marks his frequent visits to that and other cities, no man will doubt that he is the guilty party. The iron worker finds his fire injuring his metal, and so begins to investigate the composition of his coal, and discovers sulphur in it. Thinking that this sulphur may be the cause of the annoyance, he first burns or chars the coal, so driving off the sulphur by heat, and leaving the pure carbon. He now finds his iron work free. He then returns to the use of the native coal, and the same injurious results follow again. He has now identified sulphur as an injurious element in his working iron, and so, instead of using the natural coal, he puts it through a coke-oven, and thus frees it of these foreign elements.

The fundamental truth, on which both the Method of Agreement and the Method of Difference are based, is this:

Effects will appear and disappear with the appearance and

disappearance of their causes. This will always hold good, unless, as has already been suggested, the effectiveness of these causes is destroyed by some interfering agent. This danger is always to be guarded against when we are reasoning from the presence and absence of causes to their effects; for the absence of the effect, while, of course, it will always occur in the absence of the cause, will also occur when that cause is present, but overcome by some interference. But if we reason from effects, we know that on their appearance there is no adequate interference.

On the general principle stated above, it has seemed to some that there ought to be a method, called the joint Method of Agreement and Difference. It may, therefore, be well to urge here that careful reasoners will not only employ the one method that may seem to them best adapted to the particular subject in hand, but will strive to use every method that may even in a less degree be available. The errors of the one will be likely to be detected by another. The hints suggested by one may be confirmed or confuted by another. The Methods of Agreement and Difference are peculiarly suited to be used together, and probably are more frequently used together than any other two; but when they are thus used together, it is not a new method, but the use of two methods, with no new rules and all the old ones. Also, not only may these two be used together, but any two may be used together, as the nature of the case will call for; and there have been, and will be, cases where all four methods will be used and lend their aid. Too much stress cannot, therefore, be laid on the importance of combining any or all methods, whenever practicable. If we are on the trail of truth, every indication will point the same way; and if we are misled, it is of first importance that we should abandon the pursuit just as soon as the error is shown. By all means, therefore, let us in every case resort to all the methods, if they can be applied.

METHOD OF RESIDUES.

WHEN IN ANY PHENOMENON WE FIND A RESULT REMAINING AFTER THE EFFECTS OF ALL KNOWN CAUSES ARE ESTIMATED, WE MAY ATTRIBUTE IT TO A RESIDUAL AGENT NOT YET RECKONED.

The difficulty of this method is such that two other statements of it will be given, which, though the same essentially with the foregoing, will tend to make the meaning clearer by putting it in different words.

When unexplained residual effects are detected, they are usually to be attributed to unestimated remaining causes.

Subduct from any phenomenon such part as is known by previous inductions to be the effect of certain antecedents, and the residue of the phenomenon is the effect of the remaining antecedents.

This method is not very available in ordinary affairs, nor, indeed, in any department is it generally valuable beyond its use for suggestion. When astronomers were watching the recurrence of the eclipses of Jupiter's moons, it was discovered that while they occurred nearly at the predicted time, they did not occur exactly at it. It was an interesting question to discover the reason of this error. It was noticed that it was of itself subject to regular increase and diminution. At a certain time the eclipse would occur as calculated; then it would begin slowly to fall behind, and this delay would gradually increase until it reached a maximum, when it would begin slowly to gain, until it returned to this point of agreement. Now the cause of the eclipse was well understood, and nothing was observed to conflict with the received theory. There was, however, this residual variation after all causes had been estimated. Finally, it was suggested that possibly this variation might be due to the fact that light required time to pass through space. This was a cause that had not been considered. Indeed, the

thought that light took time to move was itself new. But to confirm the theory, or rather as the thing which suggested it, the time of the eclipse was found to vary as the distance between this planet and Jupiter varied. The delay increased as the two planets went further and further apart, and diminished as Jupiter returned from apogee to perigee. Now, the difference of these distances was the diameter of the earth's orbit, and such a great distance would make the time which light required in its motion perceptible, when it would not be perceptible in passing short distances. Other experiments confirmed the suggestion thus made by the Method of Residues.

The same line of argument has given reason to the hypothesis that all space is filled with a very attenuated ether. This was suggested as the explanation of the marked tardiness of the return of Encke's comet. All the data needful to determine its orbit and motion had been accurately obtained, and there ought, therefore, to have been no difficulty in fixing its periods. But it was noticed that it invariably fell behind the time which these calculations fixed for its return; and when it returned, the most accurate observations gave no new elements, nor any change in the previous elements, to account for this delay. Encke's comet, however, was the lightest of these heavenly bodies, and so its small amount of matter, compared with its volume, would make it very susceptible to retardation, from having to pass through the supposed ether of the heavenly spaces. The interference of the ether with its motion was similar in nature, but very much less in degree, to that offered by the air, when we try to throw a pith-ball to a great distance. If this ether exists, its presence is very difficult to prove, and yet this residual phenomenon gives it great plausibility. The vibratory theory of light seems to demand something of the same sort.

The method of estimating the area of the circle, by mul-

tipling its circumference by half its radius, was also suggested by a constant observation of residues. Thus, if in a circle we inscribe an octagon, and draw radii from the extremity of each side, we will have eight triangles, whose area is the product of their base by half their altitude. The sum of these triangles differs from the surface of the circle only by the spaces included between the circle and the eight cords, which are the sides of the octagon. If now we double the number of sides, we will greatly diminish this external residue, and the sum of the sixteen sides will approach the length of the circumference. If now this process is indefinitely continued, and we have a polygon of an infinite number of sides, the sum of these sides will approximate, as we might say, infinitely near the circumference, and the altitude of each triangle approach infinitely near the length of the radius. If the two could be made to exactly coincide, the circumference would be exactly the sum of the sides, and the altitude precisely equal the radius, in which case the area of the infinite-sided polygon would equal the area of the circle, and could be found by the multiplication of the circumference by half the radius. This method always seems open to the theoretical objection that this residue between the sides of the polygon and the circle never can, even in infinity, absolutely disappear. It may, however, be a property of the circle, that its area is equal to its circumference multiplied by half its radius. In any case, this constant study of these residues furnished the suggestion by which the rule was reached.

This explanation and illustration of this method will readily enforce the special rule for its employment. It is:

Take cases, where the known antecedents and consequents are best known and easiest estimated with exactness, and where the residues are fewest and best defined.

The method will be of little avail, unless we are reasonably certain of the amount of influence exerted by the

supposed known forces. If we do not know their power, we cannot know what the residue is at all. And if these residual forces are very numerous or poorly defined, there is but little hope of valuable results. There are, however, cases in which all these complications are present. We cannot always get our cases cleared up and simplified to our mind, and must take them as we can get them. In social and political studies these complications are sometimes very great. We are, therefore, always to be on our guard against placing too much reliance on inductions only hinted at by this method in the midst of multitudes of facts. In the history of chemistry, this method, however, has had its value as fully vindicated as in the department of astronomy. Thus when Arfwedson was analyzing a certain mineral, he made a sulphate from a small portion of what he supposed was magnesia, but, to his surprise, there was a small excess of weight beyond what the elements he had obtained, as he supposed, would account for. This residual phenomenon called for investigation, and the discovery of lithia, and the before unknown metal lithium, was the final result. The same method of investigating residues has been a very fruitful source of discovery of new metals. A very beautiful illustration of the application of this method is found in the department of physics. In the investigation of the nature of sound, its mode of propagation had been so well determined as to give very clear data from which to calculate its velocity in the air. But when it was attempted to verify the calculation by experiment, it was found to agree so well in the main, as to leave no doubt that the theory was correct, while yet it did not account for the whole velocity. This residual velocity was for a long time an extremely curious, and yet apparently insoluble, problem. At length the happy thought came to La Place, that this might arise from the heat, which ought to be developed by the condensation, which must necessarily take place at every vibration, by

which the sound is conveyed. This residual cause was, however, a matter capable of exact calculation, and when that calculation was made, it was found exactly to furnish a complete explanation of the residual velocity; and so furnished a striking confirmation of the value of the Method of Residues, as well as of the general methods of induction. As an illustration of how, beforehand, the Method of Residues may be indicated, as the proper one to be adopted by investigators of a particular subject, we quote from Whewell's History of the Inductive Sciences some suggestions in regard to the then present condition of inquiries into the laws and causes of tides.

“Looking at this subject (the tides) by the light which the history of astronomy affords, we may venture to repeat that it will never have justice done it, till it is treated as other parts of astronomy are treated: that is, till tables of all the phenomena which can be observed are calculated by means of the best knowledge we at present possess, and till these tables are constantly improved by comparisons of the predicted with the observed fact. A set of Tide-observations and Tide-ephemerides of this kind would soon give to this subject the precision which marks the other parts of astronomy; and would leave an assemblage of *residual phenomena*, in which a careful research might find the materials of other truths as yet unsuspected.”

These illustrations will enforce the remark made at the outset of the treatment of this method, that its greatest value was for suggestions. By it we are enabled to clear away all needless matters, and so fix attention on those things where the desired truth seems to be concealed. Attentive inspection of either of them may indicate novel and beautiful truths, but when we are able to eliminate from our observations all known causes and effects, and so leave exposed alone the yet unknown connections of cause and effect, the probability of the detection of the truth is greatly increased.

Our vision is often hindered by the very great number of things exposed to our view, so that what we fail to recognize in the mass, we see and are able to examine minutely when it alone is left for inspection. There is a famous picture of two old dead trees, at one time said to stand on the island of St. Helena. On looking at the picture there seems to be nothing very peculiar about it, and you may even be told that there is the figure of a man on it, and yet be wholly unable to discover it. If, however, your attention is called to the profile of Bonaparte, outlined by the trunks and branches of the two trees, you will scarcely be able to see much else in the picture beside that familiar form standing between the trees. Just so it is with us in the pursuit of truth. As we look at the confused mass of facts, we may know that the mystery we seek to unravel is there, but we can scarcely hope to detect it in the crowd. When, however, all else is removed, and we come to inspect the remainders, these truths will so seem to stand out that it appears strange that any difficulty could be found in their discovery. All was dead tree with leafless limb before, but now in the midst there stands out the wonderful thing God has made.

METHOD OF CONCOMITANT VARIATIONS.

WHEN A VARIATION IN A GIVEN ANTECEDENT IS ACCOMPANIED BY A VARIATION OF A GIVEN CONSEQUENT, THEY ARE IN SOME MANNER RELATED AS CAUSE AND EFFECT.

All the other methods require a possibility of the removal of certain causes. There are, however, some agents that cannot be wholly removed. No means known to man will enable us to free ourselves from the action of gravity. That strange force goes through all the obstacles we can put in its path. So it will be very difficult to escape from some degree of heat, be it greater or less. In such cases the employment of the methods that require the removal of causes

is not practicable. We can only endeavor to disengage ourselves from their control, or neutralize the distracting force of their presence. So, also, there are some classes of subjects in which experimentation in any form is very difficult. This is especially true in all historical studies. What then can be done? Resort must be had to this method, which does not require the removal of any cause, but aids us in seeing their effects even while in action and mixed with other causes. All that is required is that the intensity or quantity of the cause should vary. If it does, it would be a very remarkable thing indeed, if that variation did not show itself in a corresponding variation of the effect. Thus, for a simple illustration, take the effect of heat on iron. We have an iron bar with one end fixed, and we mark the length of it, and then heat it, and we find that it is longer now than before. We let it cool, and it begins at once to grow shorter. We heat again and it expands. We need nothing further to convince us that one of the effects of heat on iron is its expansion. That has been determined by this Method of Concomitant Variations. The increase of the cause is accompanied by the increase of the effect.

When we consider motion in absolute space, no reason can be assigned why it should not always continue in the same direction in which it may at any time be moving. Yet as a fact, we see almost no motion whatever in a straight line. All things are moving in curves, and for all terrestrial motions there is a rapid tendency to come to a state of rest. Is, then, rest the natural state of bodies, and are curved lines the natural courses of motion? Both of these questions have been answered in the negative by the Method of Concomitant Variations.* Thus if we take the motions of bodies with which we can experiment, we at once recognize the interference of the atmosphere as an obstacle tending speedily to bring bodies moving through it to a state of rest. When we try to run, and especially try to run against the wind,

we feel the interference to be very great. If now we reduce this interference, by setting a pendulum in motion in a vessel from which the air is partially excluded, or from which part is pumped out, we find it will swing for a much longer time than it will in the open air. The more completely we remove the air the longer will the motion produced by the same amount of force continue. This increase of time, as the interference is diminished, points directly to the truth that the stoppage is due to hindrances. Another hindrance is found in the friction at the point where the pendulum is suspended; but this may also be very greatly reduced. The increase of time during which a pendulum will continue to oscillate, when these hindrances are so far as possible removed, is most remarkable. Borda prolonged the time during which a pendulum would move when so drawn from the perpendicular, that in the air it would come to rest in a few minutes, to more than thirty hours, by thus reducing the friction, and placing it in a vessel from which the air had been removed. This and all other experiments made tend to show that moving bodies only come to rest because their motion has been hindered by obstacles in their path. The same line of argument applied to projectiles gives the same conclusion with reference to curved motions. When the cannon-ball is shot from a tower it curves to the ground. But it meets, on leaving the cannon, two forces — the air resisting its passage, and gravity dragging it to the ground. Both of these are well enough known to have their effect exactly estimated, and when the experiment was made on as large a scale as possible, it was found that the curvature diminished in just the ratio in which these interfering forces were removed. By this suggestion, from the Method of Concomitant Variations, it followed that it might be that the true law was, that a body propelled by a force sufficient to secure a given rate of motion in a given direction, would follow a right line in that direction at that rate until inter-

ferred with by some obstructing or diverting force. If this was true, then it gave a basis for most interesting calculations, since all curved motions must be accounted for by interfering forces. Many instances were accessible where these forces could be calculated, and, as confirming the theory, it was found that they exactly met the case calling for just the curve, which was actually described by the moving bodies. In Newton's investigations, as to the effect of gravity, he proved that the orbit of the moon was exactly that which, according to these laws, would be described by a body of the volume of the moon, moving at its velocity, when drawn from the course of a straight line by a force equal to the attraction the earth exerts on it at its distance. The orbits of the heavenly bodies are not circles but ellipses, with the body around which they revolve in one of the foci. Moving in such an orbit, they are much nearer the body at the centre at some times than at others. The earth is estimated to be three million miles nearer the sun when it is in its perihelion than when it is in aphelion. Here then is an opportunity for applying this Method of Concomitant Variations on an immense scale. As the force of attraction increases as the square of the distance diminishes, the force exerted by the sun on the earth must sensibly increase as the earth comes from its aphelion, or point farthest from the sun, to its perihelion, or point nearest the sun, and unless this increased force is counteracted by an increase of velocity, the earth must inevitably fall into the sun. But both of these are ascertainable quantities, and we find that this increase of attraction is beautifully counteracted by just the increase of velocity needed to overcome it. So, on the other hand, as the earth moves away from the sun to that part of its orbit farthest from it, if its velocity was maintained, it must now as certainly fly off altogether as it was certain to fall into the sun before. Here again the equilibrium is maintained by its slowly diminishing rate of movement, so

that the increase of attraction is matched by an increase of velocity, and the decrease of attraction is compensated by a decrease of velocity.

These illustrations again lead us with ease and clearness to the fundamental principle on which this method is based, which is, that *causes should act proportionately to their quantity or intensity*. We have, therefore, this other statement of its general rule: **WHEN INCREASING OR DIMINISHING THE INTENSITY OF A CAUSE IS FOLLOWED BY THE INCREASE OR DECREASE OF ANY EFFECT, THEY ARE RELATED DIRECTLY OR INDIRECTLY TO EACH OTHER.** This relation is not always an immediate relation to each other, as in many cases they may reach each other through some one or more intervening agents. Time and care may thus be required in tracking out the route of this action. An illustration of these intervening agents is found in the case of the ivory balls suspended in a row so as to touch each other. If the one at the end is swung back and let fall against the row, only the one at the other end will move. Now, although all the rest remain stationary when it flies out, yet the impulse, no doubt, was communicated through them from the first to it. This simple case is an example of what occurs in much more complicated forms in many other cases. If now we, by the increase or diminution of any cause, observe a corresponding increase or diminution of an effect, we may be reasonably sure that they are related, while we may not be sure of how many operations may intervene.

Another case needs our attention also. There are cases where an increase of a supposed cause is followed by a decrease of its supposed effect. This seems to contradict the method, and, of course, to be of little or no available use. On the contrary, however, it may lead to very valuable results. It shows just as clearly as the other that there must be a relation between the two. Moreover, it suggests what that relation most probably is: namely, one of interference.

Thus, if we have certain agents, A, B, C, D, at work with a given effect, X, produced, and we find that as D is increased X is diminished, and that the decrease of D is followed by the increase of X, the conclusion is very probable that D, instead of being either an active, dormant, or subordinate cause of X, is an obstacle whose entire removal would give a clearer view of the relations of the true agents, and whose presence is only useful in practical affairs as a regulator. Thus the tighter the brake is drawn in a car the slower its motion, and the more it is relieved the faster is its motion. This shows by its concomitant variations that, instead of the brake being a cause of the motion of the car, its office is to prevent or reduce it.

As for the special rule to be remembered in the application of this method, it is the same as that of the Method of Difference. *Maintain all the conditions as nearly identical as possible, except the increase or decrease of the hypothetical cause.* The method is indeed a modification of the Method of Difference, in that it considers minute differences of intensity, while the Method of Difference considers an entire absence of causes. The two are, however, sufficiently distinct to require separate treatment, for, like addition and multiplication, which are theoretically one, yet their applications are very different. So of this last method, it can be used with great effect when the other is not available. In the department of social science it is of very great value. Scarcely any other method is available to such questions as the influence of education on crime. Every criminal knows something, and no one knows everything. All that can be done, therefore, in investigating such matters, is to look at large numbers of instances, in the hope of detecting concomitant variations enough to indicate a law, and then watch its application. There are a large number of similar cases, such as the beneficial or injurious effects of legislation on rates of interest, and in regard to paupers and tramps. So in regard

to many questions of health and disease, no other method is available in the circumstances.

These subjects, however, bring to light a very important qualification in regard to the conclusions we may reach, since the variations which may hold good for a certain amount of increase or diminution will not always hold good when we pass beyond that. The rule, that if a little is good more will be better, can hardly ever be trusted as true. How far it is true, is itself a very important problem. Just where the maximum of efficiency is reached is a very important matter to know. Every one familiar with theoretical and practical mechanics can readily recall instances where machinery, whose construction was exactly in accordance with the rules for the composition and resolution of forces, has utterly failed to work, because some new and unforeseen obstruction interfered, which was not indicated in the experiments on a small scale. Two lines may not diverge from each other enough in a short distance to make the difference appreciable, while this difference may be very great when they are protracted to great lengths. The Method of Concomitant Variations is, therefore, to be cautiously employed when its results are assumed as true beyond the limits wherein it has been tested.

FOUR METHODS ILLUSTRATED.

It is proposed now to present two illustrations of these methods, and both shall be famous ones from the history of science. The first is the elegant series of experiments made by Sir Humphrey Davy, in the decomposition of water. At the time of which we speak, it was believed that water was composed simply of oxygen and hydrogen. When, however, on one occasion, Mr. Davy was decomposing water by the galvanic current, he discovered an acid and an alkali on the poles of his battery. The question at once proposed

itself as to the source of these. The decomposition of a salt would give them, but, so far as he knew, there was no salt of any kind in the water. However, he also knew that glass was a silicate of soda, and as the vessel containing the water was glass, he suspected that its decomposition furnished the acid and the alkali. True, he could see no mark of it, and he could feel no roughness, such as would probably have been found if the glass was decomposing, but the result seemed to point directly to it as the cause. To determine the question, he resolved to apply the Method of Difference, and the result was, that he got an answer by the Method of Agreement. He said, if it is the glass, and for the glass I substitute a gold vessel, the gold will not decompose, or if it should, being a metal, its result will not be an acid and an alkali. He, therefore, made the experiment, expecting to find no trace of either, when, to his surprise, he found both acid and alkali in as large quantities as before. From this it was evident that the glass was not the cause, for, by the Method of Agreement, when the glass was removed the effect remained, showing that the cause was not disturbed. After much thought another suggestion came to this effect, that the perspiration of the body was salty, and if he had allowed the water to touch his hands, the decomposition of that might account for the acid and alkali. Again he tried the Method of Difference, by carefully excluding all possibility of any perspiration reaching the water, and now repeating the experiment, he found a perceptible decrease in the quantity deposited on the poles of the battery, but very considerable amount still there. Here was now an answer by the Method of Concomitant Variations. It pointed to the impurities of the water as the source of the acid and the alkali. The diminution of that source had decreased the result. If, however, this was correct, the Method of Residues would suggest that the remaining acid and alkali must be due to some remaining impurities. The next step

was readily suggested, for it was then, as now, a well-known fact that water from the earth's springs, or wells, almost always contains what are called natural salts of lime and other substances. Following out this hint, he determined to settle the question whether the acid and alkali were wholly due to the impurity of the water, or whether water itself contained other elements besides mere oxygen and hydrogen. In either case, the result would be a valuable addition to knowledge. Here again he employed the Method of Difference, for now he took rain-water, the purest form in which Nature furnishes water, and then distilled it, hoping thus to get rid of every possible impurity. When, however, the experiment was repeated, there they were, but the quantity was greatly diminished. All four Methods now pointed to the same conclusion, namely, that notwithstanding all his precautions, he had still left some source of impurity, and that this impurity was the cause of the slight remaining trace of acid and alkali. The Method of Agreement indicated it, because every impurity, as it was removed, showed that it had contributed its share to the original amount. The Method of Difference pointed the same way, for as the impurity was removed, the acid and the alkali were. The Method of Concomitant Variations indicated the same thing, since diminishing these impurities decreased the quantity. The Method of Residues concurred in suggesting that what remained was due to some remaining impurity. It was not easy, however, to imagine what the source of that remaining impurity was. After much pondering of the question, this happy thought occurred to the philosopher — May not the water absorb impurities from the air, which comes in contact with its surface? This seemed at least not improbable. If the suggestion was true, however, that also was a source of impurity which could be entirely removed, and then the acid and alkali should disappear, or at least should be so far diminished as it was due

to that source of impurity. Taking, again, therefore, his vessel of distilled rain-water, he placed it in the receiver of an air-pump, and at once pumped off the air, as completely as possible. When, now, the water was decomposed, neither acid nor alkali appeared, even in the smallest trace. This experiment was conclusive. The whole of the acid and alkali was due to the impurity of the water. Oxygen and hydrogen alone form water.

The other illustration of these four Methods will be taken bodily from Mill's Logic, in the words and comments there given. Mill quotes it from Sir John Herschel's work, entitled a *Discourse on the Study of Natural Philosophy*, adding to Herschel's statement only a few brief remarks. The illustration is so elegant and so famous, that it is quoted by almost every writer on this subject, and is called *Dr. Wells' Theory of Dew*.

"Suppose *dew* were the phenomenon proposed whose cause we would know. In the first place we must determine precisely what we mean by dew; what the fact really is whose cause we desire to investigate. We must separate dew from rain, and the moisture of fogs, and limit the application of the term to what is really meant, which is, the spontaneous appearance of moisture on substances exposed in the open air when no rain or *visible* wet is falling. This answers to a preliminary operation which will be characterized in the ensuing book, treating of operations or steps to induction. The state of the question being fixed, we come to the solution.

"Now, here we have analogous phenomena in the moisture which bedews a cold metal or stone when we breathe upon it; that which appears on a glass of water fresh from the well in hot weather; that which appears on the inside of windows when sudden rain or hail chills the external air; that which runs down our walls when, after a long frost, a warm moist thaw comes on. Comparing these cases, we

find that they all contain the phenomenon which was proposed as the subject of investigation. Now all these instances agree in one point, the coldness of the object dewed, in comparison with the air in contact with it. But there still remains the most important case of all, that of nocturnal dew: does the same circumstance exist in this case? Is it a fact that the object dewed *is* colder than the air? Certainly not, one would at first be inclined to say; for what is to *make* it so? But . . . the experiment is easy; we have only to lay a thermometer in contact with the dewed substance, and hang one at a little distance above it, out of reach of its influence. The experiment has been, therefore, made; the question has been asked, and the answer has been invariably in the affirmative. Whenever an object contracts dew, it *is* colder than the air.

“Here, then, is a complete application of the Method of Agreement, establishing the fact of an invariable connection between the deposition of dew on a surface, and the coldness of that surface compared with the external air. But which of these is cause and which effect; or are they both effects of something else? On this subject the Method of Agreement can afford us no light: we must call in a more potent method.

“That dews are accompanied with a chill is a common remark; but vulgar prejudice would make the cold the effect rather than the cause. We must, therefore, collect more facts, or, which comes to the same thing, vary the circumstances; since every instance in which the circumstances differ is a fresh fact; and, especially, we must note the contrary or negative cases, *i. e.*, where no dew is produced; for we are aware that a comparison between instances of dew, and instances of no dew, is the condition necessary to bring the Method of Difference into play.

“Now, first, no dew is produced on the surface of *polished metals*, but it *is* very copiously on glass, both exposed with

their faces upwards, and in some cases the under side of a horizontal plate of glass is also dewed. Here is an instance in which the effect is produced, and another instance in which it is not produced; but we cannot yet pronounce, as the canon of the Method of Difference requires, that the latter instance agrees with the former in all its circumstances except one; for the differences between glass and polished metals are manifold, and the only thing we can as yet be sure of is, that the cause of dew will be found among the circumstances by which the former substance is distinguished from the latter. But if we could be sure that glass, and the various other substances on which dew is deposited, have only *one* quality in common, and that polished metals and the other substances on which dew is *not* deposited have also nothing in common but the one circumstance, of *not* having the one quality which the others have; the requisitions of the Method of Difference would be completely satisfied, and we should recognize, in that quality of the substances, the cause of dew. This, accordingly, is the path of inquiry which is next to be pursued.

“In the cases of polished metal and polished glass, the contrast shows evidently that the *substance* has much to do with the phenomenon; therefore let the substance *alone* be diversified as much as possible, by exposing polished surfaces of various kinds. This done, a *scale of intensity* becomes obvious. Those polished substances are found to be most strongly dewed which conduct heat worst; while those which conduct well resist dew most effectually. The complication increases; here is the Method of Concomitant Variations called to our assistance; and no other method was practicable upon this occasion; for the quality of conducting heat could not be excluded, since all substances conduct heat in some degree. The conclusion is that, other things being equal, the deposition of dew is in some proportion to the power which the body possesses of resisting the passage of

heat; and that this, therefore, (or something connected with this,) must be at least one of the causes which assist in producing the deposition of dew upon the surface.

“But if we expose rough surfaces instead of polished, we sometimes find this law interfered with. Thus, roughened iron, especially if painted over or blackened, becomes dewed sooner than varnished paper; the kind of *surface*, therefore, has a great influence. Expose, then, the *same* material in very diversified states as to surface, (that is, employ the Method of Difference to ascertain concomitance of variations,) and another scale of intensity becomes at once apparent, those *surfaces* which *part with their heat* most readily by radiation, are found to contract dew most copiously. Here, therefore, are the requisites for a second employment of the Method of Concomitant Variations; which in this case also is the only method available, since all substances radiate heat in some degree or other. The conclusion obtained by this new application of the method is, that *cæteris paribus* the deposition of dew is also in some proportion to the power of radiating heat; and that the quality of doing this abundantly (or some cause on which that quality depends) is another of the causes which promote the deposition of dew upon the substance.

“Again, the influence ascertained to exist of *substance* and *surface* leads us to consider that of *texture*: and here again we are presented on trial with remarkable differences, and with a third scale of intensity, pointing out substances of a close, firm texture, such as stones, metals, &c., as unfavorable, but those of a loose one, as cloth, wool, velvet, eider-down, cotton, &c., as eminently favorable to the contraction of dew. The Method of Concomitant Variations is here, for the third time, had recourse to; and, as before, from necessity, since the texture of no substance is absolutely firm or absolutely loose. Looseness of texture, therefore, or something which is the cause of that quality, is another circum-

stance which promotes the deposition of dew ; but this third cause resolves itself into the first, viz., the quality of resisting the passage of heat ; for substances of loose texture are precisely those which are best adapted for clothing, or for impeding the free passage of heat from the skin into the air, so as to allow their outer surfaces to be very cold while they remain warm within ; and this last is, therefore, an induction (from fresh instances) simply *corroborative* of a former induction.

“ It thus appears that the instances in which much dew is deposited, which are very various, agree in this, and, so far as we are able to observe, in this only, that they either radiate heat rapidly or conduct it slowly : qualities between which there is no other circumstance of agreement, than that by virtue of either, the body tends to lose heat from the surface more rapidly than it can be restored from within. The instances, on the contrary, in which no dew, or but a small quantity of it, is formed, and which are also extremely various, agree (so far as we can observe) in nothing except in *not* having this same property. We seem, therefore, to have detected the sole difference between the substances on which dew is produced, and those on which it is not produced. And thus have been realized the requisitions of what we have termed the Method of Difference, or the combined use of the Methods of Agreement and Difference. The example afforded of this indirect Method, and of the manner in which the data are prepared for it by the Methods of Agreement and of Concomitant Variations, is the most important of all the illustrations of induction afforded by this most interesting speculation.

“ We might now consider the question, upon what the deposition of dew depends, to be completely solved, if we could be quite sure that the substances on which dew is produced differ from those on which it is not, in *nothing* but in the property of losing heat from the surface faster than the

loss can be repaired from within. And, although we never can have that complete certainty, this is not of so much importance as might at first be supposed; for we have, at all events, ascertained that even if there be any other quality hitherto unobserved which is present in all the substances which contract dew, and absent in those which do not, this other property must be one which, in all that great number of substances, is present or absent exactly where the property of being a better radiator than conductor is present or absent; an extent of coincidence which affords the strongest presumption of a community of cause, and a consequent invariable coexistence between the two properties; so that the property of being a better radiator than conductor, if not itself the cause, almost certainly always accompanies the cause, and for purposes of prediction, no error will be committed by treating it as if it were really such.

“Reverting now to an earlier stage of the inquiry, let us remember that we had ascertained that, in every instance where dew is formed, there is actual coldness of the surface below the temperature of the surrounding air; but we were not sure whether this coldness was the cause of dew, or its effect. This doubt we are now able to resolve. We have found that, in every such instance, the substance must be one which, by its own properties or laws, would, if exposed in the night, become colder than the surrounding air. But if the dew were the *cause* of the coldness, that effect would be produced in other substances, and not solely in those whose own laws suffice to produce it whether there were dew or not. That supposition, therefore, is repelled. But there were only three suppositions possible; the dew is the cause of the coldness; both are caused by some third circumstance; or the coldness is the cause of the dew. The first is refuted. The second is inapplicable: the cause of the coldness is a known cause; a radiation from the surface greater than can be supplied by conduction: now this, by its known laws,

can produce no direct effect except coldness. There remains only the third supposition, that the coldness is the cause of the dew: which, therefore, may be considered as completely made out.

“This law of causation, already so amply established, admits, however, of most efficient additional corroboration in no less than three ways. First, by deduction from the known laws of aqueous vapor when diffused through air or any other gas; and although we have not yet come to the Deductive Method, we will not omit what is necessary to render this speculation complete. It is known by direct experiment that only a limited quantity of water can remain suspended in the state of vapor at each degree of temperature, and that this maximum grows less and less as the temperature diminishes. From this it follows, deductively, that if there is already as much vapor suspended as the air will contain at its existing temperature, any lowering of that temperature will cause a portion of the vapor to be condensed and become water. But, again, we know deductively, from the laws of heat, that the contact of the air with a body colder than itself, will necessarily lower the temperature of the stratum of air immediately applied to its surface; and will therefore cause it to part with a portion of its water, which accordingly will, by the ordinary laws of gravitation or cohesion, attach itself to the surface of the body, thereby constituting dew. This deductive proof, it will have been seen, has the advantage of proving at once, causation as well as coexistence; and it has the additional advantage that it also accounts for the *exceptions* to the occurrence of the phenomenon, the cases in which, although the body is colder than the air, yet no dew is deposited; by showing that this will necessarily be the case when the air is so undersupplied with aqueous vapor, comparatively to its temperature, that even when somewhat cooled by the contact of the colder body, it can still continue to hold in suspension

all the vapor which was previously suspended in it: thus in a very dry summer there are no dews, in a very dry winter no hoar frost. Here, therefore, is an additional condition of the production of dew, which the methods we previously made use of failed to detect, and which might have remained still undetected, if recourse had not been had to the plan of deducing the effect from the ascertained properties of the agents known to be present.

“The second corroboration of the theory is by direct experiment, according to the canon of the Method of Difference. We can, by cooling the surface of any body, find in all cases some temperature (more or less inferior to that of the surrounding air, according to its hygrometric condition) at which dew will begin to be deposited. Here, too, therefore, the causation is directly proved. We can, it is true, accomplish this only on a small scale; but we have ample reason to conclude that the same operation, if conducted in Nature’s great laboratory, would equally produce the effect.

“And, finally, even on that great scale we are able to verify the result. The case is one of those (rare cases, as they will be found to be) in which Nature works the experiment for us in the same manner in which we ourselves perform it; introducing into the previous state of things a single and perfectly definite new circumstance, and manifesting the effect so rapidly that there is not time for any other material change in the preëxisting circumstances. Let us quote again Sir John Herschel: It is observed that dew is never copiously deposited in situations much screened from the open sky, and not at all in a cloudy night; but *if the clouds withdraw even for a few minutes, and leave a clear opening, a deposition of dew presently begins, and goes on increasing. . . .* Dew formed in clear intervals will often even evaporate again when the sky becomes thickly overcast. The proof, therefore, is complete, that the presence or absence of an uninterrupted communication with the sky causes

the deposition or non-deposition of dew. Now, since a clear sky is nothing but the absence of clouds, and it is a known property of clouds, as of all other bodies between which and any given object nothing intervenes but an elastic fluid, that they tend to raise or keep up the superficial temperature of the object by radiating heat to it, we see at once that the disappearance of clouds will cause the surface to cool; so that Nature, in this case, produces a change in the antecedent by definite and known means, and the consequent follows accordingly: a natural experiment which satisfies the requisitions of the Method of Difference."

A careful study of this example will justify in our minds the remark of Sir John Herschel, in quoting it, when he calls it "one of the most beautiful specimens of inductive experimental inquiry lying within a moderate compass." It is also worthy of remark, that while it so perfectly illustrates the scientific application of these methods, it at the same time exemplifies the use of these methods in the practical affairs of every-day life. Although we may not recognize the fact, and may be wholly unconscious of its truth, we are every day coming to conclusions, and acting on them, which, if we could trace out the mental processes by which we reached them, we would find based on just such logic. For discipline, therefore, nothing can be better than to investigate the beliefs we entertain, and, reviewing the grounds of them, determine to which of these methods each step or argument belongs. Ambitious students should pay great heed to this last suggestion. If followed it will enable them with promptness and clearness to analyze the argument, and expose the fallacy or confirm the position of those with whom they come in contact.

CLASSIFICATION BY THE FOUR METHODS.

This is the most suitable place to introduce some remarks on a few matters which cannot be exhaustively treated in

so brief a work. We first return to the subject of Classification, on which already (page 23) something has been said. The difficulty of this matter has been recognized by all students of nature. There is general agreement that it is a natural tendency of the mind to group things in classes. By this means it relieves itself of a vast amount of valueless labor, in that it burdens itself only with the peculiarities in which things agree, or are marked by their disagreement, and so needs not to recollect the unimportant differences. When it reaches the groupings of objects, as nature has associated them, the task is greatly simplified. To reach that natural or scientific classification is, however, very often a long and tedious process. Two things are involved in it, both of which are difficult. There must first of all be a settled *principle of classification*. The peculiarity of the Linneæan system of botanical classification was mainly the adoption of the flowers, with their stamens and pistils as the basis. Dr. Agassiz, in his work on "Methods of Study in Natural History," claims it as one of his most important contributions to the science of zoölogy, that he recognized form as determined by structure as the true basis of classification of families. This was a remarkable instance of the value of a basis, for as the distinction was one of form, it readily struck the eye, and so was recognized; and the secondary work of locating the individuals in their appropriate families had proceeded quite satisfactorily before the true reason for the division was found. That the work could not be brought to perfection without such a basis was very evident, since different authors made such different assignments to certain individuals, and the same author so frequently changed his own assignments in newer editions of his works.

What now were all these philosophers doing but repeating the process of comparison, and testing the results by the Methods of Agreement and Difference. The basis they sought was such a set of marks as would result in giving a

class, where the presence of each mark would be the sign of all the other marks. Here, too, the Method of Residues served a good purpose, since, when all those which properly and evidently belonged to the ascertained classes were taken out, and the others left by themselves, the as yet unknown classes among them were detected, and whether one or many, the logical process was the same. Nor is the Method of Concomitant Variations without its use in this same work of classification. In chemistry the basis of distinction among the acids is due to the amount of oxygen which they contain. So the different kinds of iron are supposed to be marked by the amount of carbon found in them; steel having more carbon than refined iron, and malleable iron less carbon than cast iron. All these methods are thus of very great value, and are constantly used in this first and very difficult work of determining the basis of the classification.

This done we come to the next step, which is much more simple than this first process. The task now is to go over each individual, and, on the basis heretofore adopted, locate the proper place of the individuals in this arrangement of nature. Here the work is almost wholly one of applying the Methods of Agreement and Difference. If we have the right marks, by which each class is characterized, then careful inspection will tell us in each case to which class a given individual belongs. Thus, if you bring to a conchologist a lot of shells, and watch him at his work of cataloguing and describing them, you will see him go through exactly the process we have described. He will take them, one after another, and looking them over for the features by which the several orders, families, genera, and species are to be distinguished, he will assign them to their proper place, and give them the agreed upon name, which shall indicate their possession of these characteristics. So, if you take a seed to a botanist, he will open it, and will tell you that, if planted, it will grow from without, by adding rings, "because," and

then he will follow up that word because, by giving his reason; namely, that it agrees with the seeds of exogenous plants, in that it is dicotyledonous, or has two seed lobes. He will also tell you that it will probably have leaves with veins crossing each other, which is another peculiarity of plants of that class. All this is obviously by the Method of Agreement, and he will decide as to all the other seeds you may bring him by the same process. The whole operation is one of comparison. The decision is reached by the Methods of Agreement and Difference, and success depends on the intelligence with which these methods are employed. No progress whatever can be made without their use.

This enables us to repeat, with very decided emphasis, the importance of careful observation. It is easy to accept superficial inspection for satisfactory examination, and proceed thus on utterly incorrect suppositions. Scientific success and greatness depends largely upon the exactness and certainty of the comparisons made. Every year hundreds of lives are lost, because ignorant or heedless physicians, hastily examining their patients, decide that it is one form of disease from which they are suffering, and treat them for that, of course, without success, because they have not had it, and do not have it, and are dying of an entirely distinct malady. The case presented the usual symptoms which identify the disease, if the knowledge and care requisite to discover it had been used; but that knowledge was not possessed, and that requisite care was not taken, and the patient died — the fault all belonging to the doctor. Although the results have not been so fatal and alarming, yet they have been just as truly the result of incapacity in the domain of natural history. Theories, classifications, and hypotheses have followed each other in rapid succession, whose only basis was the superficial character of the study of their authors. In political life the same is constantly occurring. Windy politicians, catching a faint notion of

some resemblance between the present conditions of public affairs and the circumstances that produced some great prosperity or calamity before in history, claim public attention, and the mass of men, being as heedless and unscientific as themselves, follow their lead, and the end is other disasters, produced wholly by the impetuous ignorance of leaders and their followers. Reliable conclusions can only be reached by the classification of all the circumstances into the three divisions of causes — subordinate, dormant, and active; and then, by the Methods of Agreement and Difference, determining by careful comparison whether the agreements cover all the really essential causes, and whether the differences are such as to fatally interfere with the result. In the long run, remembering how inexorably nature's causes work out their true effects, our work of reasoning is very largely classificatory. If we are correct as to the group of causes to which those at work in any case belong, we will not need to doubt the certainty of the result.

The remarks on Classification already made may be summed up in three important rules.

RULE FIRST.—*The Classification must proceed on a definite principle, which must be maintained throughout.*

RULE SECOND.—*The classes must include all the inferior classes or all the individuals. The classes must make up the whole.*

RULE THIRD.—*The classes must exclude each other; that is, it must be impossible for any individual to be in more than one class of the same grade.*

These rules are those usually given for division, but division is only the reverse of classification. Division takes things in the aggregate, and separates them into groups; while classification takes the individuals as found in nature, and combines them into groups. In both cases the above must be observed, and a regular, systematic gradation of groups maintained. All the individuals should find their

places in one of the lowest rank of classes, and these classes be combined into larger and higher groups, and so to the highest.

ANALYSIS.

The discussion of this subject is here introduced, not as being inseparably connected with this part of the present treatise, but as so indirectly connected, as to make it appropriate; and so important as to make its presentation valuable. There is so much fallacious reasoning, based upon insufficient analysis, that the subject must be left incomplete, without some rules for the proper conducting of analysis. What then is analysis?

Analysis is the process of decomposing compound bodies, so that they are resolved into the elements of which they are made up, and determining in what proportions and relations these elements must be combined, in order to form the original substance. All parts of this definition are important. Of course analysis may be attempted, but cannot be accomplished with simple elements. It only undertakes to resolve those bodies, which are made up of simple elements, into the various uncompound substances of which they consist. But more is required in analysis than to determine that in a given compound body a certain substance enters as an element. That is one step, and an important step, too, in analysis, and is part of what is known as qualitative analysis. To complete, however, even qualitative analysis, this further labor is required; namely, of determining *all* the elements that enter into its composition. If we take a piece of limestone, we get some information when we determine that there is calcium in it, and we have more when we learn that there is carbon in it. But this is not enough. Very many specimens of limestone also have iron ore in them, and some have magnesia, and these iron ores and magnesia have many other elements combined with them. Sufficient

analysis must determine what are the elements, and the only elements present in that particular specimen which has been furnished. How is such a conclusion in any way possible of attainment? Here we rely on the methods of Agreement and Difference. We depend in the whole process on the uniformity of nature's agents and operations. In the case of the limestone, we conclude that calcium, carbon, oxygen, iron, and the like, are present, because the same manifestations are found that these substances have always indicated heretofore. Because these substances agree in their chemical, physical, and mechanical properties with those with which we are familiar, we are assured of their identity.

When we undertake the second step of analysis, and try to answer the question *how much of each of these*, as well as what substances, are found in the compound, the difficulty is greatly increased. This will be seen when we reflect that two new sources of error are now to be encountered. The first is that, in our process of analysis, we may ourselves introduce into the case elements that were not there before, and we be ignorant of their amount, or even of their presence; and so be led to fix on them as part of the original compound. In this way an additional quantity of some element, already present, may also be introduced, vitiating thus the whole process. On the other hand, we are liable to have elements, or a certain portion of the elements of the original compound escape, without our measuring them, or even detecting their existence at all. For example, in chemical analysis, it is extremely difficult to procure perfectly pure chemicals; and yet, without these, the whole is utterly valueless, since the impurities of the chemicals will, in a greater or less degree, affect the results, and when these results are thus affected by new and unknown agents, they are of no use whatever. So, in distillation and filtration, it is easy for substances to escape, and no conclusive results are reached unless that escape is noticed and accurately

measured. Suppose the subject under investigation is magnetism, and to find out what magnetism is, we proceed to analyze a piece of soft, unmagnetized iron; it would be of no avail except to show what it is not. Is it much better to analyze a dead carcass to find out what life is? In all these steps it is by the same methods that we proceed, so far as the logic is concerned. It is comparing things together, to see wherein they agree and wherein they differ. Our analysis is aimed at fixing these points.

Mere qualitative and quantitative analysis, however, is not enough to answer all our questions. We shall greatly err, if we suppose that the same elements, and the same amounts, will always produce the same compounds, and act in the same way. To illustrate this: there is a kind of chemical combination that will take place between certain substances, just when they are disengaged from one combination, and before they enter into another, or when they are, as it were, *in transitu*. It will not occur before or after that particular nick of time when they are in what chemists call the *nascent* state. Is not the relation of the elements, their condition at that time, therefore a most important matter? Four very well known elements seem to make up almost the whole of organic bodies; namely, carbon, hydrogen, oxygen, and nitrogen. Besides these, there are present phosphorus, calcium, and other well known inorganic elements, in larger or smaller quantities. But wherein lies the difference between them in their organized and unorganized condition? We may not say positively, that it is in the relations under which they are combined, for it is not certainly known wherein it consists. It is strongly suspected that it is merely a difference of relation. The indications all point that way. If it could be proved so it would be a valuable point of knowledge gained. If it should so turn out, it is obvious that the question now left for solution is not one of qualitative analysis, nor yet of quantitative analysis, but one

of relative analysis. Once a druggist, who had prepared for me a medicine, according to a physician's prescription, came in great haste, and asked that it should be exchanged for another bottle, which he brought with him. Of course suspicion was at once aroused, that he had, at first, given the wrong medicine, and that possibly serious consequences might follow the single dose administered from the first mixture. On inquiry, however, I found that the physician, in writing the prescription, had placed the elements in the wrong order; so that as they were combined, some of them were precipitated, instead of being held in solution, and so, while the first mixture had no injurious drugs in it, there were some medicinal elements that were absent which were intended to be in it. When the drugs were combined in another order, the solution was perfect, the compound clear, and no sediment in the bottom of the vial. Here again it was a matter of relation, and an analysis that would have given the exact quantity of each element used, would not have determined all that was needful to know. The analysis and determination of the relations would be not less important than either of the others.

These considerations make it clear that some method of testing and proving the completeness of our analyses is of very great moment. Mere analysis will not do, for while by it we may find out certainly that certain things are present, it can rarely be so conducted as to exclude the possibility that others have escaped our detection. Moreover, it gives us little knowledge of the relations and historical circumstances under which the combination was formed. Another method, however, is available, and while, perhaps, not immediately and always conclusive that our analysis is complete, yet it greatly increases our certainty, by very greatly diminishing the liability to the intrusion of foreign substances. This additional step is synthesis. As analysis decomposes substances into their elements, so synthesis is the reverse

process of combining these elements, so as to reform the original compound. If by taking the substances, which by our analysis we have detected as entering into the composition of a substance, we can by them reconstruct that which we have torn down, we are reasonably sure of the exactness of our knowledge. Suppose a man asserts that he understands clock-work, and, to test him, you give him a clock, and after carefully taking it apart, he immediately puts it properly together again, so that it will run correctly, you ask no further proof. If, however, when he thinks he has put it together it will not run, that is just as conclusive against him as the other result was for him. So when we analyze water we find one part oxygen and two parts hydrogen; and when we mix one part oxygen with two parts of hydrogen, we are able to recombine them by explosion, and the result is water. These illustrations might be greatly multiplied, but as the subject will come up again, when we treat of Tests of Induction, it may be dismissed now, by repeating, that no analyses can be finally accepted as conclusive, which do not include qualitative, quantitative, and relative analysis; and that all analysis must be proved by synthesis or recombination.

THE QUESTIONS OF INDUCTIVE LOGIC.

The natural method of procedure, in treating of a subject, is to map out the field as almost the first thing done. This course, however, labors under the disadvantage of unpreparedness on the part of the student. Many advantages are gained by securing some familiarity with the theme, before we call attention to the determinate field of investigation. In this work we have adopted both methods. Early in our work we saw that the special field of inductive logic was Caused Truth, as distinguished from both Necessary Truth and Error. Having now attained some familiarity with our

subject, we are prepared to fix definitely before us the questions which are proper to ask in our inductive logic, and which, up to the limit of knowledge in each branch of science, it is able to answer.

The Duke of Argyll, in his work "The Reign of Law," undertakes to limit scientific knowledge to answering three questions, What? How? and Why? It is possible that, by a sufficient enlargement of the meaning of these, they may be considered exhaustive; but there are at least three other questions that are always being asked by the human mind, and their answer more or less affects the answers of those given above. And herein lies the difficulty in their proper classification, for they may be asked under or in connection with each of them. These questions are, Who? Where? and When? We must consider all of these. Beginning then with the first, The What is answered by the facts — by knowledge gained through inspection. Our sources for that are either in what we learn ourselves, or what others have learned by the powers of mind and body, and put on record. Two things, however, always connect themselves with every fact, and this knowledge will go to make up its character. These are the conditions of Space and Time. All caused truth connects itself with these conditions, so that while necessary truth is true, and equally true in all space and at all times, the truth of caused truth may be said to be dependent on these. What is true in one place is not true in another, and what is true at one time may never have been true before nor since. Complete knowledge, therefore, of the What must include also the Where and the When. Thus, there is no doubt that, within certain distance, the loadstone will attract soft iron, but the strength of that attraction is measured by the matter of distance in space. So the matter of time has very much to do with all such matters as the growth of plants, and the effects of geologic forces. It is, therefore, a very unsatisfactory piece of information to

say that a certain valley has been filled up. We also want to know how it was located, and how long it required for this process to complete the work. So in all cases where the information can be obtained, answers to both these questions are important. The answer to the question of space, the Where, can always be secured, if it is a matter of knowledge at all, inasmuch as everything that is caused is caused in some place. It is equally true that it must have been caused at some time, but the time may not be so easily ascertainable, since the effect may continue after the fact, and so enable us to see that it was done, and where it was done, but not when it was done. Thus, if I see a smooth-washed stone, I may know that the location of it was at some time submerged, but when that occurred I cannot tell from these facts.

When now we pass to the second of the three questions mentioned by the Duke of Argyll, we have another collateral question rising into importance. It might, indeed, have been asked in connection with the What, but its answer would have been very difficult, so long as we rigidly excluded both the How and the Why. When we come to these two, however, the question Who is always pressing us. When I look at the beaver's dam, and note how it is constructed, I can at once exclude from the possible agents mere chance or vegetable growth. The same is true when I look at the method on which the bird's nest is built. The Where and the When are still important, and every truly scientific observer will take pains to ascertain and record them, but not less important is the information as to the Who. Thus in the case of the beaver's dam, although the naturalist is sure it was not an accident, and did not grow, it deeply interests him to know what sort of an animal did construct it, and what trait of its nature and instinct is gratified by it. He learns the habits of birds from seeing them build their nests and nurture their young. This very

question demands an agent, whose method it asks, and so, even if we may not assign a rational agency in each case, there must, at least, be a real agent. Unless there is an actor, there can be no How to his acting. So no more can there be a question How, if there is no efficiency in causation. If the relation of cause and effect is mere sequence or succession, all is accident, and there is and can be no How in the case.

All argument on this subject is better deferred, to come up under the third question, Why. Very many philosophers assert that there is no such question in science as the why, or the wherefore. This is true of the whole school who hold to what is known as the positive philosophy. But, however, men may say it ought not to be asked, and no attempt made to answer it, the mind always has asked it, and it is therefore to be presumed always will. Just as surely as men reason, so surely they will find this question coming up to their own minds, and pressing itself upon them from the lips of others. If, therefore, any argument as to the field of scientific inquiry may be drawn from the hungerings of the mind, this question cannot be in any wise excluded. Nature's normal appetites do not often lead us astray. Even the philosophers of the positivist school are constantly appealing indirectly to this same principle. Even Comte could construct a system of education and government, and when you ask for the reason for his adjustments and regulations, there they are with their why and wherefore. No man can carry on a day's work without constantly having before his mind the object sought to be accomplished by each act. When, then, he comes to investigate other things, he instinctively proceeds on the principle that there must also have been some object before the mind of the doer. Moreover, this question, Why, receives abundant answer. Often it is the only question that can be satisfactorily answered. In multitudes of instances it receives

much fuller and clearer answer than the preceding question, How. Thus take the naturalist, studying the body of a bird. How that bird was made, and whence the origin of its species, are questions of very great difficulty; but he can see a reason for the structure of almost every bone and muscle of its frame, and the most odd and exceptional peculiarities reveal for themselves a reason. Who will tell us how the human hand was made, and give us any reasonable ground for faith in his assertions, if we refuse all notion of its uses? Yet any child can understand why its structure should be as it is, and what great advantages we derive from its structure. So in almost every case, the extent and value of the knowledge which is connected with this question, Why, is far beyond that of the How, which all admit is a scientific question. Anatomy is the science of the structure of the body. Physiology treats of the office of the several parts, and hygiene of the means for preserving their healthy action. What now is physiology, but the answer to the question why, asked of our anatomist? Its importance none can dispute. So take the fact of the qualities, quantities, and distribution of the metals, and no man can tell how they were distributed, or how it comes that iron, which is so much more available for the uses of man than gold, is so much more abundant, and more universally distributed. All can see at a glance that gold never could take the place of iron in the economic uses of man. A why for all this is not difficult to give, but to tell how it was brought about, is not yet accomplished. A ready answer comes, if we ask why it is so much easier to answer this question, Why, than the question How? The causes that produced a given result, work their result, and then pass away. The result, however, remains. The how it was done is thus a matter of history, and if no record is kept, may be irrecoverably lost. The result remaining is open to inspection, so long as it remains. The object sought, the why, or the function, is thus perma-

ment, while the mode of producing the instrument ceases on the production of the machine. Thus watches are made by the use of very perfect machinery. No man can tell by looking at the watch how it was made; for as soon as it was made, its connection with the machinery at the manufactory ceases. Yet the adjustment of its parts continues, and at any time all we need, for the study of the relation of the wheels is present, and we can see why one wheel has just so many more cogs than that wheel into which it works. It is that one wheel may go round just twelve times as often as another. So as I examine a piece of elegant cabinet work, I cannot tell whether it was made by machinery or by hand. That is a point of history on which the article itself gives but little information. It carries, however, always with it the reason for the planning of its doors, and drawers, and slides, and pigeon-holes for papers. There are many things which might have been done in a dozen different ways, and only by some record of those present at the time can we know as a fact, in which of all the various possible ways it was actually done. But the reason for its doing is always there. No man can look at the Suspension Bridge at Niagara, and not know at a glance why it was built. Would any one ever guess, by looking at it, that the first cord that was thrown across was gotten over by tying it to a kite-string, after the kite had been flown over, and allowed to light on the other side? And if the suggestion had come to them, that it might have been done in that way, by what process of logic could they now prove from the bridge, that as a fact, that was the method actually employed. It is thus evident that things themselves carry always with them the answer to the question, Why, but the answer to the question, How, is often either a matter of record, or by loss of records a matter absolutely unattainable.*

* The importance of this line of thought is often overlooked. Thus it is specially true in geologic and natural history studies. For ex-

If, now, there is such a question Why, there must always be a question Who, for the why is a question of mind wholly. Possibly there could be a What, and a How, and a Where, and a When, without any mind or thought, but there cannot possibly be a Why without mind and design. All effort to answer it is an endeavor to discover the mental conclusions or objects sought by him who planned it. Since, then, there is so much controversy about the admission of this question Why, and so much importance attaches to it, and so much, especially in relation to the question Who, which depends on it, the next section will contain a further discussion of it, under the aspect of the doctrine of Final Causes, or Design.

FINAL CAUSES, OR DESIGN.

The expression, final causes, is one that has an important part in the history of philosophy, and therefore may not be lightly discarded. Its associations, however, are very apt to mislead us. Our notion of a cause is of something going before, and as an active force, bringing about the result we call its effect; while final causes are not something going

ample, it is the very smallest part of the problem to prove that the various species of animals might have been made through the process of the so-called natural selection. It has never been suggested that they could not have been created by an Almighty God. We have a professed record by the eye-witness and workman informing us that they were created. Thus the old question of the credibility and interpretation of the Bible is left exactly where it always has been, even after it is proved that it was possible to develop these by the method of selection. Suppose a case in court, where the prosecution shows by hotel registers that the accused went from New York to St. Louis by way of Pittsburg, Crestline, and Indianapolis, would it overthrow this for his attorneys to prove that there was a route by way of Buffalo and Chicago, and another by way of Baltimore and Cincinnati? No doubt he could have gone by that route, but did he?

before, but rather something to be brought to pass afterwards. The final cause is the object aimed at in making the preceding efforts. Thus, in military tactics, the ultimate triumph of the whole cause for which the general is fighting, is the final cause or object aimed at; but under this, and subordinate to it, but promotive of it, each separate movement has its own immediate object or purpose, through which it is hoped to promote the other. So, in the erection of a monument, the final cause or object had in view is the tribute to the virtues of the dead, or a testimony in favor of some principle with which they were identified. In order, however, to the proper erection of that monument, it is necessary to rig a derrick and build a scaffold. These are subordinate objects, having ultimate and final reference to the great end of all. So, between the thing done or the adjustment made and the end sought, there may be many intermediate results sought. Each of these is of the nature of a final cause in a lower degree, and differs radically from the antecedent efficient causes.

Our conception of final causes will be made clearer by looking into the logical process by which the use of the term may be justified. This rationale of its use seems to be this. The result reached is brought about by the agency of the antecedent efficient causes. These causes were put in operation by some mind. This intelligent agent was moved to put them into operation by some purpose; so that, if we trace the chain of causation, we find it stated in this way: the result was produced by a cause; that cause was set at work by some mind; that mind was induced to its course by some purpose; and, thus, that purpose is the final cause, beyond which we cannot go, or can at least only go by taking into our view some higher purpose or broader design. Take, for instance, the erection of a monument. The derrick was erected to lift the stones to their places. The marble shaft was lifted to its position by the horse-power at-

tached to the derrick. The derrick and machinery were built by the mechanics. Team, machinery, and materials were managed by the workmen. The workmen were employed and directed by the architect; while he, in turn, is incited to carry out the purpose or design of those who employed him. When, therefore, we begin to ask what was the cause of the causes, we are led back to the design of the mind where the plan originated. Design thus seems to be a clearer word for expressing the same thing which is meant by final causes.

This doctrine of final causes, or design, thus divides itself up into three points, each of which will help us to understand the others and the whole subject. We have adjustments, functions, and purposes. Adjustments are made with a purpose in view. Functions are the uses of the matter or means employed. Purpose is the end to which the adjustments and functions tend. We have all three of these clearly distinguished in the erection of a house. The adjustments are the architect's location of the flues. The functions are that one flue is for smoke, another for hot-air, and others for ventilation. The purpose is to have the house suitably warmed for the promotion of health. Therefore, the purpose answers to the question *Why*, the adjustment answers the question *How*, as it relates to the mind of the designer, and the function answers the question *How*, as it relates to the forces and laws of nature. The whole three — adjustment, function, and purpose — are manifest everywhere, and when they are taken away, science is dispossessed of half its vitality, interest, and beauty.

If, now, we contrast designs or purposes and efficient causes, we shall find them marked by four important points of difference.

1. Purposes are in the mind alone, and so are subjective; while causes inhere in things or objects, and so are objective.

2. Purposes attain their realization after the event, and so are subsequent in time; while causes are always antecedent in time, and are followed by their effects.

3. Purposes are indicated by adjustment and function; while causes are learned by observation and experiment.

4. Man's purposes may utterly fail or be obstructed; but the causes he sets in motion always act out their effect, regardless of consequences.

No fact of every-day experience is more obvious than this last. The teacher before his class, with all kindness of design, intends to exhibit to them some experiments, showing the action and power of natural elements. Unintentionally he brings two elements together, of whose explosive qualities he is ignorant, and then they do their work, and the discharge follows, precisely as if the explosion, with its mangling of limbs and destruction of buildings, was what was intended. An American general conceives that a fortification could be demolished by exploding a large amount of powder near it. The thing was tried. An old boat was heavily loaded with giant powder, and thrust up close to the enemies' guns, and then discharged with admirable precision, and the hostile fort was not injured any more than if it had been struck by a ball from a pop-gun. The powder went just to the length of its efficiency, and neither wish nor prohibition could change it in the least. Nature's agents pay no attention to consequences. They give no heed to the wishes of those who furnished the active causes to the dormant, but inexorably work out their native result, and this even when they are counteracted by some sufficiently powerful opposing agent; for they then just go the length of their power, and stop. Thus, in such cases of counteraction, as in all others, they do their work. Our control over them is by measuring the force we first let loose, and by properly managing the antagonizing agencies. In both cases, however, it is obvious that there is some design or purpose in

the first starting of the causes to action, as well as in the attempt to regulate the action by opposing agents. We never can get away from this end had in view, unless we utterly deny the existence of mind altogether. And, if we have this question Why, we cannot exclude the question Who, for a purpose implies a proposing mind. It will not do to limit this question Why to those things which we have seen done by persons, whose purpose we knew, for our induction has gone far beyond those cases. We have seen so much of the character of the work done by mind, with a purpose in view, and so much of the disorder of chance, where there is neither control nor plan, that the Methods of Agreement and Difference fully justify us in making the distinction in those cases which are new to our observation. A young man may never have seen an electrical machine when he enters college, but it so bears the marks of adaptation to some design, that he will be anxious to ask what it is for, and how it does its work, and will be glad to know and admire him by whose ingenuity it was invented. His information will be increased when he knows where it was first constructed, and when the success of the discovery was verified. The same is true in all investigations. We may not be able to get answers to all our questions, but the business of science is perpetually to strive after answers to the questions, What, How, Why, Who, When, Where, and fame awaits every discoverer of a new answer.

PART FOURTH.

STEPS IN INDUCTION.



STATING THE QUESTION.

IN all processes, some methods are better than others. It is always desirable that clear notions should be had of what we are attempting, and no time needlessly wasted. These remarks have a strong application to our reasoning processes. Very much time, and much valuable labor, are utterly wasted by foolish efforts to do useless things. We propose, therefore, to give some directions how we should proceed in this matter, in order to obtain the most reliable results in the least time.

The first thing always to be done is to *get a clear statement of the problem*. Otherwise we are laboring at random, and if we accomplish anything, it will be rather by a happy chance than by any good effort on our part. To get this clear statement of the problem, there is often large knowledge needed. In the first place, it is important to know all that is already known on the subject. Otherwise, we may occupy our time in rediscovering what has already been found out. Many things have been independently discovered. Two workers have devoted themselves, at about the same time, to the same task, and both have reached the true result. More frequently, however, men have expended their strength in solving difficulties for which a solution had already been furnished, if they had only known it. Furthermore, cases

occur where the supposed unsolved problem is only an unknown problem in appearance. Full knowledge of the whole subject would show that it was only an apparent difficulty. Words are very often mistaken for things, and when we come to separate out what we know from what we do not know, and state our question in exact words, it resolves itself. In other cases, the distinct statement of the question brings such related knowledge forward to suggest the line of investigation, that the way is comparatively easy. No great discovery ordinarily is made all at once by one person. Generally, some investigator starts the question. This sets all students in that department to thinking. Then one promulgates a theory, which further investigation overthrows. In it, however, there may be a suggestion which some one else takes up, and although making but little progress, still he adds something. It is a wide step from Watt's steam-engine to the modern machinery of steam, and all this progress has been made by slow stages of success and failure. So it has been everywhere. Great help, therefore, is secured by a definite statement of what is to be done, and keeping that constantly in view.

Still further, the exact statement of the question will indicate clearly what is not known. It seems like a paradox to say, that before we are well prepared to undertake the solution of some scientific question, we must not only know all that is known, but also all that is not known; for how can we know what is not known, and if we know it, is not that enough. There is, however, a very important sense in which we may know just what is not known. We do know the measures and causes of many of the tides, but there are certain irregularities whose existence is known, and their amount measured and tabulated, and the cause is not known. As another more familiar illustration, take the case of a young man who proposes to write on the Saxon immigration to England. He first sits down and draws out a set of topics,

concerning which he already has certain facts, and concerning which there are other facts which he must know, and which he is sure he can get from history, and he notes these by asking the question, and leaves the answer to be supplied afterwards. Many questions of history are yet in that condition. It is asserted by some that the original inhabitants of the British islands were cannibals. This others deny. The answer to that question is a specific question for study; and where a point is thus stated, it gives great aid by pointing out what methods are available, and what sources of information we may apply to with the hope of obtaining decisive facts. This last is of great importance. Many facts are easily accessible, but they are of no value when they are obtained. Other facts are decisive of the whole question. These last Bacon calls Prerogative Instances. They speak by authority and end controversy; and a clear statement of the question points out the direction in which we may look for such facts. Attention is thus directed to the facts which are significant. Previous to the occurrence of the total eclipse of 1869, which was visible in this country, scholars interested in the study of the sun and moon published very widely a list of questions, to which answers were requested from all who observed that eclipse. By this means the attention of all was called to the things most noteworthy, and hundreds made observations on these points, without knowing why they were so important.

Another way by which the question may be definitely stated, and attention called to the significant points, is by the formation of good blanks. This is an extremely difficult task. No person is competent to get up a blank who is not thoroughly familiar with the subject in all its bearings. Multitudes of blanks are issued, which are so indefinite in the inquiries they make, and so senseless in the points about which inquiry is made, that when they are filled up they are worth no more than mere waste paper.

The following suggestions will aid in the construction of good blanks. The heads should be distinct. No one question or column should call for an answer to more than one point. No two questions should cover the same point. It is out of character to ask, How many persons in a town cannot read and write? for some can read who cannot write, but probably none can write who cannot read. It would be proper to ask how many can neither read nor write. An examination of blanks will reveal endless violations of this rule. Mixed questions are extremely common. Another suggestion is, that the questions should call for short, definite answers. Some questions, from their very form, cannot be answered either briefly or clearly. The reply must be a mere guess in any event, and then the reasons will modify the reliance to be placed on that estimate. Wherever it is possible the answer should be called for in figures, and then exact measurement or numbering should be insisted on. Nothing is so valuable as exact numerical statements. Nothing reveals small concomitant variations so readily as tables of exact figures. In such tables, the point where the variation begins can be easily detected, as also the point of its maximum and its termination. Under such circumstances the detection of its cause is made as easy as it is possible to make it. It will often, even in such cases, be extremely difficult, but so far as help can be obtained from this direction, it will be thus secured. Another advantage derived from insisting on numerical replies is, that it excludes estimates, and requires measurement and enumeration wherever it is possible. But while by these means mere estimates and guess-work are excluded from portions of the blanks, it is not always best to leave them out of view altogether. Often there are matters wholly out of reach of measurement, which would, nevertheless, throw very much light on the whole matter. Space should, therefore, by all means, be left for such memoranda. They ought not to be included among

exact data, but kept separately, so that without bringing in confusion they may furnish suggestions. In calling for these additional matters the attention of observers should be directed to all indications and results that might have a meaning. In this way observation and experiment would be carried on under a system of topics, just as an author, in investigating a subject preparatory to writing on it, finds it wise to map out the directions which his reading is to pursue. Of course it is important, finally, to call all the information, obtained by filling these blanks, to a common centre for comparison and compilation.

GATHERING THE FACTS.

The discussion of blanks above led directly to the importance of gathering the facts on every subject of investigation. We sometimes hear of "dry statistics." Every such expression is at total variance with every principle of scientific investigation. Statistics contain all the vital sap that is in any science, and nothing has just claim to the name of science which cannot vindicate its theories and laws by statistical data. The early progress of astronomy, as compared with other sciences, was due to the early gathering of its facts in tables of observations, so that when Kepler, Copernicus, and others came to the study, they had at hand the memoranda of fulfilments and failures, by which the facts justified or contradicted the hypotheses of their predecessors. The testimony of Dr. Whewell to the vast importance of reliable statistical tables, in regard to the tides (see page 69), has already been quoted. What he there says on that subject is just as pertinent to every other subject which may need investigation. Sir John Herschel, in his "Discourse on the Study of Natural Philosophy," speaks extendedly in behalf of this important matter of gathering facts, and calls attention to this point, that, while the work of analyzing

and explaining the facts, belonging, as that work does, to the higher and more difficult department of induction, requires the highest grade of scholarship and native genius, this work of gathering facts into tables, and collections of specimens, may be done by any and all who are willing to aid the progress of knowledge. He goes on to illustrate and enforce the remark thus: "What benefits has not geology reaped from the activity of industrious individuals, who, setting aside all theoretical views, have been content to exercise the useful and highly entertaining occupation of collecting specimens from the countries which they visit? In short, there is no branch of science whatever in which, at least, if useful and sensible queries were distinctly proposed, an immense mass of valuable information might not be collected from those who, in their various lines of life, at home or abroad, stationary or in travel, would gladly avail themselves of opportunities of being useful. Meteorology, one of the most complicated but useful branches of science, is at the same time one in which any person who will attend to plain rules, and bestow the necessary degree of attention, may do effectual service." Take this very subject of meteorology, which was so good a case in point in his day. In our own day we see it making rapid progress before our eyes, as it is furnished with the facts collected by extensive and systematic observations carried on by the Weather Bureau of our own and other governments. When it was at first proposed to predict the coming of storms, long enough before their arrival to enable the shipping to do much to avoid danger, or protect property from their violence, most persons heard the suggestion with incredulity. At present it is capable of proof, that these prognostications have saved, year by year, many times the cost of the whole department just in the single direction of ocean commerce. Such results never could have been attained without the numerous observations made and collated for study. As Sir John Herschel says,

hundreds of persons can be employed to make these observations who know but little of the science. A very few accomplished scholars are needed to direct the work, and study the results, while others can be employed to read instruments, and make records from them, and do that work as well as the most scholarly. The departments of social science are now very much in the condition that this science of meteorology was then. Enough has been done to show that immensely more might be done, if only reliable statistics were accessible. These statistics, however, are not extant, and, until they are collected, very many of the social theories cannot but be guesses, based on estimated suppositions. Perhaps as severe a thing as ever was said in the British Parliament, was the assertion of a member in regard to one who had just delivered a speech full of statements and inferences from them, that "the gentleman draws on his imagination for his facts, and on his memory for his illustrations." He was not the first, and it is to be regretted that he was not the last, man whose imagination furnished what should have come only from observation or information. From these sources (inaccurate and wholly imaginary facts) come, perhaps, more false conclusions than from false reasonings on real facts.

While, therefore, no great amount of knowledge is needful for a good gatherer of facts, there are certain other things that are indispensable. And first among these is one which cannot be too much insisted on; namely, absolute impartiality in the acceptance and registration of all the facts. It seems a strange thing to say, but it is, if possible, a stranger thing to see that people have prejudices against classes of facts. They try to bend the facts to their own will, or else, deciding for themselves beforehand that certain classes of facts are of no value, they overlook and neglect them. Those who devote themselves to this work of collecting statistics or facts in any form should have no opinions.

Wooden men would be best, if they had brains enough to make records. So all devices to make instruments self-registering are extremely important. Then a mere machine collects the facts, and there are no preconceived notions to interfere in the matter. Another equally important and closely related characteristic, that ought to be possessed by statisticians, is scrupulous care in the separation of the facts from all inferences from them. It is a natural tendency of the human mind to draw these inferences from the facts before it. This is, indeed, the secret spring of all induction. One of our most common fallacies, therefore, is to confound the two, and treat an inferred fact as if it was an observed fact. The moment we step over from the plain facts to our inferences from them, we leave the office of the statistician and enter on the work of the philosopher, and so have no right whatever to include the results of our speculations among the facts furnished us by nature. These last all may rely on, but the former have no kind of claim to be put in the same category. As a general principle, this will receive the assent of all. It is to be regretted that so few, especially of the young, who assent to it, will heed it as scrupulously as they ought. It seems an easy rule to follow, but in fact its observance is extremely difficult. Any one who has been much in courts will remember how many times they have seen honest witnesses, in their examination in chief, testify to the very points on which the case seemed to turn, and yet under the sifting process of cross-examination, when they were forced to distinguish carefully between what they knew of their own knowledge and what they had heard or inferred, it became evident to all, even to themselves, that their testimony was of very little account. Such people are sometimes accused of perjury. Their crime was probably only stupidity. It was their business to tell the facts, and let the court and jury draw the inferences, but they proposed to do the work of all. This is both ridiculous and

wicked in such trials. It may not be so wicked, but it is surely as absurd, for one who proposes to furnish facts for scientific investigation to thrust his inferences in as reliable facts also. These inferences have their place, and a most important one it is, as we shall hereafter see, but it is of the first moment that the facts, when gathered as facts, should be kept separate from all else but facts, and then facts and inferences are ready for the service of all who would contribute to human knowledge. This gathering of all facts is, therefore, the next step after the clear statement of the problem.

DETECTION OF LAW.

This is the third and supreme step in the process of induction. All else is subordinate and preliminary to it. Even facts are of comparatively small value, except as they bear on this process by revealing, confirming, or overthrowing some law. This is, therefore, the legitimate place for inferences. The very achievement that distinguishes genius is its accomplishment of this work of drawing the correct inference from the furnished facts. It may be, and perhaps is, impossible to tell just how the mind works, as to its subjective operations, in doing this thing. Who will tell us how the mind thinks? and this is a process of thought, or, better, one of the ways of thought. As to the process, so far as it may be said to be objective, these inductions or inferences are reached by these four methods of Agreement, Difference, Residues, and Concomitant Variations. As the attention is closely held to the array of facts kept in view in the memory, or otherwise offered for our consideration, agreements and differences and variations are seen or supposed; and then, pursuing these hints, the suggestion forms itself into an hypothesis, then is confirmed into a theory, and is finally verified into a law. We may now, therefore, distinguish these terms, for they mark the steps through which the

mind passes in discovering a law among submitted facts. There is first formed an hypothesis. This is a mere supposition that would seem to explain a few facts which stand out prominently. No great value as yet attaches to it. Now, however, it is in a shape to be formulated into words, and then it will stand out more sharply defined for the consideration of the mind. As facts are now viewed in its light, they will range themselves into one of three classes, as they may seem to confirm or contradict the hypothesis, or have no bearing on the question. These last being set aside out of view, more study and attention will be given to those which do have a direct bearing on the subject. This further study may suggest new explanations of seemingly antagonistic facts, by which they will confirm instead of contradict the supposition. This study may also suggest experiments, or special points or directions for observations, where something decisive may be anticipated. As the investigation proceeds, the facts become so numerous which confirm the suggestion, that it is entitled to some measure of confidence. So far as there is a distinction recognized by writers in these two terms, it is that when an hypothesis becomes thus somewhat probable, but not established, it is a theory. Very often, however, these words are used without reference to any difference of meaning. Both are thus used as contradistinguished from law, which is a theory established by all the facts.

It is not often, however, that this first hypothesis suggested to some patient student, maintains its position unchanged until it is acknowledged as an established law. More frequently, additional facts point out some modification that must be made, in order to accommodate the new facts which demand explanation. A not uncommon fallacy in inductive reasoning is to proceed after such a modification is made, assuming that the modified hypothesis will suit the facts already explained, as well as the original supposition. A

train-manager, in running a railroad, may not push an extra train up to another station to get it out of the way of those which follow, without also carefully reconsidering whether that will not thrust it into the road of those that are coming in the other direction. Every change necessitates an entire review of the location of all. So when, to suit some new fact, a theory is modified, the whole list of facts must be re-surveyed, lest that very modification makes it wholly inconsistent with some fact with which it harmonized in its unmodified form. In doing this work of constructing and modifying theories to suit the facts given, it will be seen what extensive knowledge is required. It is mere blundering to undertake to explain the intricacies of nature's operations, without knowing very fully what the facts are in the case. Not only must the speculatist be familiar with that particular science in which his studies lie, but also knowledge of cognate sciences is almost equally important. Cicero's common bond not only subsists between all literature, but even more between all sciences, and he who is familiar with all will best understand the unsolved problems of any one of them. The spread of true astronomical theories gave a wonderful impulse to the study of mechanics; and the development of the laws of mechanics in a marvellous manner aided the progress of astronomy. It is scarcely possible to pursue geology intelligently without very great familiarity with botany and comparative anatomy; and how can the problems of zoölogy be at all understood, or even approached, without a knowledge of fossil forms as well as of the living species? It is just so everywhere; so that, for the highest act of mind in induction, every sort of knowledge is of use, and extensive learning indispensable.

Another faculty which is of vital importance in this work is a lively, vivid imagination, by which these facts given by this extensive knowledge can be clearly and steadily held before the mind. People are apt to think that imagination

is a faculty whose use is confined to the field of the orator, artist, and poet. It is, however, not less valuable to the student of nature. When Kepler undertook the study of the movements of the planets according to the Copernican theory, he saw at once that, if these planets moved around the sun, the orbit must have some form. He clearly stated the question when he asked himself what was the nature of that orbit in which they revolved. The facts were at hand, and his observations gave him ready access to more facts as he needed them. He proposed, as his first hypothesis, that the orbit was a circle, and the sun was located in the centre. That was the simplest supposition. A very little comparison of the facts showed that this was incorrect. Abandoning that, he made another, which also proved incorrect. Proceeding in this way, he made nineteen hypotheses in regard to the circular orbit and the place of the sun, every one of which the facts proved untrue, until he concluded that the orbit could not possibly be a circle at all. The next simplest figure that would seem to offer any hope of being the right supposition was the ellipse. He then tried that, supposing that the sun was in its centre, when this also proved untrue. It was thus not until twenty false hypotheses had been imagined, adopted, and overthrown, that he made the right one, that the orbit was an ellipse, with the sun in one of the foci. When this was tested, it was found to meet all the requirements, and is now a universally accepted law. He has not told us how many false ones he made, tested, and discarded, in his search for the rule that the squares of the periods are to each other as the cubes of the distances. But he has told us that he began with the simple numbers, with only a faint, vague hope that some proportion might be found to exist among them, and that he worked away with these until he felt sure he must have exhausted every possible combination. He then proceeded to a like consideration of the squares, until he had, as he supposed, tested every possible

combination of which they were capable. This was enough to have led any ordinary man to despair. Instead of abandoning the project, however, he kept on imagining new proportions among the simple numbers and their squares, and the squares and the cubes. At last he hit upon the right proportion, and taking the three terms, he proceeded to find the fourth, hoping it would coincide with the term he had supposed. But, alas, he made a mistake in his computation, and threw it aside for some days. Still, the fact that it seemed to turn out more like a true proportion than the others led his mind back to it, and, as he said, as if guided by some good angel, he was led to go over the arithmetical calculation again, when, to his exquisite delight, he detected his mistake, and correcting this, beheld his fourth term unfolding itself as the true term he sought. This history is wonderful, as showing how near he was to losing all, just when at the point of discovery, and how his whole labor was stimulated by his vivid imagination, and made successful by his indefatigable patience. In this work of detecting the law amidst the facts gathered, the office of imagination is to hold up the possible new combinations of the facts, that the law may be seen through them. To the unimaginative mind, all facts are mere opaque quantities, showing nothing but what is on their surface. To the vivid imagination of the scientific scholar, they are the transparent fluids in which float the great laws of the universe. It is, therefore, of first importance, next to knowledge, that we should cultivate that faculty by which we can see things in new relations, and conceive the results that would follow the placing of them in these new conditions. These imagined hypotheses and theories are often wrong, but the ability to make them is indispensable to all discovery except that which comes by mere hap-hazard blundering. In every discovery reached by scientific processes, this work of the imagination, conceiving and representing to the mind the possible

explanations of the phenomena, is always first. After this hypothesis is thus furnished by the imagination, the next step is to test its truth. The method for this scientific verification will occupy the sections immediately following.

VERIFICATION. EXPLANATION OF FACTS.

The difference between an hypothesis, a theory, and a law has been already explained. In narrating the experiences of Kepler in his discoveries to illustrate the use of the imagination in furnishing new hypotheses, the importance of this matter of verification was also exemplified; for no sooner had he learned that some hypothesis he had formed was not correct, than he set his imagination to work, and developed a new one. Immediately he proceeded to test this new hypothesis, as he had done the former ones, to see if it had any better foundation than they had. A most interesting and instructive history could be written on exploded scientific hypotheses. It would be a valuable contribution to our knowledge, if we could find out just why each particular theory was abandoned as incorrect. In many cases it would be obvious just how it was shown to be manifestly untrue, and so given up even by its author. Many false theories, however, have had very able defenders, and the struggle between them and some true theory has been long, and sometimes fierce. To know just what points, and in what order, and why, the false theory had to give up, would be a clear illustration of the negative side of the subject in hand. That negative side would throw great light on the positive side now under consideration. It is proposed to show what rules a true hypothesis must comply with, in order to justify our acceptance of it. In doing this, as large use will be made of the history of exploded hypotheses as possible for the sake of the contrast.

It must, therefore, be noted at the outset, that no theory

has any claims to confidence which cannot verify itself by some or all of these methods and rules. All truth is provable by some line of argument. Even the intuitive truths, which are perceived to be true as soon as they are understood, and true not only up to the limits of our experience, but in all time and all space, must, nevertheless, be equally justified by all facts, and so comply with all the tests for verification. It is not true, therefore, as is sometimes argued in opposition to the belief in intuitive truth, that it claims to override and disregard all experience. We do, indeed, and all men must, believe that everywhere two and two are four, and all right angles are equal. These things, however, instead of overriding all experience, are in exact harmony with it. It is thus seen to be true by direct inspection, and this is confirmed by every fact bearing on the subject. While, however, some inductions, like our intuitions, are affirmed by all experience, there are others which are confirmed by some facts, and apparently refuted by others. It is thus possible to have hypotheses in every varying stage of verification, from merest hypothetical guess or fancy up to the utmost certainty. Through all these stages almost every established law has come. Some have been hunted after, as if in darkness, until a flood of light broke in on the whole question by some brilliant thought of the patient student, and from that on, all investigation only added new proofs to the same effect. Other discoveries, when they were first promulgated, had only a few facts in their favor, and many seemingly against them; but step by step they won the ground, until the very facts that were urged as conclusive against them, were shown, when rightly understood, to be the strongest in their favor.

The importance of this branch of the subject cannot be overestimated. If this verification is neglected, and we proceed to act on our suppositions as if they were true, we shall fall into grievous, and often fatal error, and will deserve the

disasters that befall us. Oftentimes, in every-day life, circumstances will make thorough verification impracticable, but no excuse will apologize for the neglect of such verification as may be possible in the time and place. A military commander, judging from such facts as are within his knowledge, assumes that his enemy has retreated, and so neglects the usual precautions, when he is suddenly surprised and destroyed. If his conclusion was correct he could easily have verified it, by sending out a reconnoissance, and neglecting that, his whole course was an inexcusable blunder, due to bad logic in view of the facts. So there is great satisfaction to be derived from attaining conclusive proof of the correctness of our theories. All can remember how difficult it was to get a sure way of proving our addition in arithmetic, but when we came to subtraction, the addition of the remainder to the lower line should always give us the upper line; and the multiplication of the divisor by the quotient always gave the dividend, as our proof in division. It is just such satisfaction and confidence which is to be gained by a proper testing of our inductions. It is quite possible to arrive at the highest certainty. The notion that the planets revolve around the sun is directly contrary to our observation; and yet what could we believe with more confidence than we do that truth of astronomy? The belief in the criminal's guilt, when the evidence is wholly circumstantial, is based on the indications found in the facts; and yet so strong may those circumstances and facts be that no one has a shadow of doubt in the case. Thus this cumulative evidence becomes conclusive to every rational mind. When this point is reached we have what has heretofore been called a perfect enumeration. Imperfect enumeration was one of the fallacies named in the formal logics, but they gave no rules for avoiding it. They could offer illustrations, which could show how obvious it was in extreme cases, but no aid was given for testing, and the definition of a perfect

enumeration left the whole subject as obscure as before. A perfect enumeration was said to be one where the instances affirming the suggested law were sufficient to establish its truth. The all-important inquiry remained, as to how it could be told, *where* the instances were sufficiently numerous to do this. There are yet some matters, as will hereafter be seen, in regard to which the reasons for the rules do not appear to be well settled. The rules themselves, however, will be recognized as those which receive the approval of men in their ordinary common-sense reasoning, and are of great value. This difficulty especially belongs to the Rule of Simplicity. It is to be remarked, however, that the concurrence of two tests on either side are very much more than doubly as conclusive as one of them. It is like human testimony. If one man tells you a certain fact, you think it is probably true. If, then, another tells you essentially the same fact, in such manner as to exclude collusion, you are more than twice as certain as before, since it is extremely unlikely that two men should be independently moved to fabricate the same story. If, now, their statements are confirmed by a third independent witness, and no contradictory circumstance appears, there will be little doubt remaining as to its truth. So it is with these tests. The great conclusions of science are established by the coincident testimony of every Method of Induction, and every rule for verifying their correctness. These rules of verification will be now explained, and are five in number; namely, THE RULE OF HARMONY, OF SIMPLICITY, OF CONCURRENCE, OF SUFFICIENCY, AND OF PREDICTION.

RULE OF HARMONY.

A TRUE THEORY WILL HARMONIZE AND EXPLAIN ALL THE FACTS.

This test is so familiar in all sorts of subjects, that but little explanation or illustration will be required. There

will not be much controversy as to the reliability of this rule. Its application is usually where this controversy begins. The most familiar example of the application of the test is in the criminal trials of the court-room. The arguments of the attorneys, as addressed to the jury, are almost all directed to that one point. The prosecution strives to show that the theory of the prisoner's guilt will explain all the facts elicited in the testimony; while the defence endeavors to show that there are facts which the theory of his guilt will not explain. In all their previous efforts to secure testimony, they were hunting for facts bearing on that point. The one making as prominent as possible his theory, and the other opposing it; both agreed that the true theory would explain every fact in the case. So in the history of science the same thing is true. In the conflict between Newton and his followers, in defence of the emission theory of light, and those who held to the wave theory, neither ever doubted that the truth must harmonize and explain every fact presented. And so Newton's theory of *fits of easy transmission* was an effort on his part to account for the *colors of thin plates*, as they are seen in the colors of the soap-bubble and elsewhere. This was the most complex and intricate solution ever offered in behalf of the radiant theory of light as opposed to the wave theory. The falsehoods told by children and criminals, when they are caught in doing wrong, are told under the pressure of the same instinct of reason. To explain their conduct they fabricate facts, which, if true, would justify their course, and so, although they lie, they admit their obligation to make the theory and the facts all harmonize. When Samuel, by divine authority, anointed Saul to be king over Israel, he ordered him to destroy the Amalekites utterly, even unto their herds and beasts of burden. When he met Saul on his return, he asked him if he had done as he had been commanded, and Saul said he had. Samuel instantly re-

plied, "What meaneth then this bleating of the sheep in mine ears, and this lowing of the oxen which I hear?" That fact was absolutely irreconcilable with the theory of his obedience, and at once convicted Saul of his falsehood, although he afterwards tried to get out of the difficulty. Excuses he could offer in abundance, but there was no reply to the inconsistency of the facts with the theory, and so God rejected him from being king. The whole art of deception in war proceeds on the same principle. Each general tries to conceal such facts as will reveal his true condition and designs to his adversary. Sometimes twice as many camp-fires are lighted as there is any use for, to make the army seem larger than it is; and again not half as many as are needed, in order to lure the enemy into battle. When Washington found himself in a position where he could march his army in view of the enemy, and then counter-march behind the hill, he kept the whole army marching in the circuit, until it had all gone two or three times over the visible space; and so he gained time, because they thought they had seen three times as many men as he really had. In all these cases, as in every other, the rule is absolute, that the truth will harmonize and explain every fact affected by the case.

The fundamental principle which underlies all this, is that which was laid down at the very outset in contrasting truth and falsehood. *All truth is consistent and harmonious.* Each truth is consistent with itself, and equally consistent with every other truth. We quote from the charge of Judge McLure on the trial of Jacobi for the murder of his wife in Allegheny County, Pa. "Truth is not only consistent with itself, but with all truth, while errors are not only at war with truth, but are always quarrelling and wrangling with each other." It is scarcely possible to imagine any falsehood which would not come in conflict with truth at some point. On the other hand, we are absolutely certain that

truth can be harmonized. We may not at once be able to see how it can be made consistent, but that is the effect of our ignorance, not the fault of truth. Further study of the facts already gathered, and especially further collection of facts by experiment and observation, will clear up the mystery. Just so far, however, as the facts seem to be inconsistent with the theory, that theory is to be doubted. It may be true, but it certainly is not established. Before it can assert its right to men's belief, it must clear up every contradictory fact.

The real source of error, however, is not either in denial or disregard of this rule, but in the admission of facts, and submission of the theory to the requirement that it should explain them. Enthusiasts in favor of a pet theory, like an over-zealous attorney, admit for consideration only such facts as the theory will explain, and insist on excluding all others from the view. Two or three remarks made in connection with the collection of facts are so important, and so relevant here, that they must be repeated. It is of the very first importance that there should be honesty in the acceptance of *all the facts*. No apology can be made for the exclusion of any fact. To do so is to court deception and error. What is to be said of any study of man which leaves out of consideration his mental operations, his moral feelings, and social instincts? Thus we have socialists, who, seeing that much of the evil which is in the world comes from efforts to get and to hold property, assert that all would be just right if all property was held in common; and as jealousy and ill-will often spring out of the marital relation, all these evils are to be cured by abolishing it, and making free-love universal. Their theories explain a few facts, and they exclude the rest. Others, seeing that drunkenness and gluttony produce murder and disease, instantly propose to cure human ills by a system of diet and restraint. Darwinism would explain development by the survival of

the fittest in the midst of the conflict of life, and proves it by showing how individual members of a species have a struggle in the superabundance of their reproduction to gain food for all. If this was true, it is evident that the strong species, like lions and eagles, would be far more enemies of the weaker species, like lambs and quail, than the enemies of each other; and so before the weakest of the lions and eagles would die by the strongest eating all the food, the whole breed of sheep and feeble birds would be utterly destroyed. Some modification of the theory of conflict of life is, therefore, indispensable. Huxley in his "Lay Sermons" alludes to this, when he says, "Any admissible hypothesis of progressive modification must be compatible with persistence without modification through indefinite periods." The most rudimentary and primordial forms of life are unquestionably extant; which could not be true if this conflict of life through scarcity of food existed.

Another remark made in relation to the gathering of facts needs repetition here. The fact is to be taken just as it is, and not mixed up with any inferences. It is the fact that is to be explained, and not inferences from it. Many a fact is capable of an explanation, when somebody's inferences are inexplicable. This has been over and over again illustrated in regard to the Scriptures. Science has made some new discovery, and at once the cry is raised that this overthrows the truth of the Bible, because it contradicts it. A little closer and more honest study reveals the fact that it is not what the Bible says which is contradicted, but what was inferred from it. It was not the Bible that was upset, but the commentators. When it was asserted that the planets moved round the sun, and not round the earth, the reply was that this was not true, because, if it was, Venus would show phases like the moon, and she did not. The assertion that she did not was only an inference, as if a man looking at a carriage, three miles distant, would say it was not

decked with flags. The flags may be there, but he cannot see them, and so it was with Venus's phases. The examination of the fact must be so minute and particular, as to justify negative evidence before its inconsistency with other truth is sufficient to overthrow them. In order to prove that a certain man was not in a given audience, it will not do to bring a witness to swear he did not see him, unless he can swear that the whole number was not over ten or twenty, and that it was impossible for him to have been there without his seeing him. So no scientific negation is justifiable until the investigation is complete, and excludes the likelihood of error.

From what has now been said, an important question arises as to where the limit is to be placed in the admission of facts which any theory should be required to harmonize and explain. Surely every possible fact is not to be considered in the verification of every theory. In investigating the wave theory of light, it is not necessary to inquire whether Thomas Young was an Englishman or not. His nativity has no bearing on the conclusiveness of his discoveries and arguments on that subject. So there are, of course, multitudes of facts on other subjects than the one under consideration, whose explanation has nothing to do in the case, and, therefore, they need no consideration. The usual statement is to say that it must explain all related facts. The question, however, still remains as to what facts are related. The very object of legal rules, as to the admission of evidence, is to secure all related facts, and to exclude all others. No iron rule can be laid down by the mechanical and unintelligent employment of which this point can be decided. Appeal must still be had to the general judgment of men, and that judgment is most likely to be brought out in answering the question, Ought the theory to explain a given fact? Usually the relation between the two is so obvious, that the obligation of harmonizing them is a matter of

almost direct perception. In other cases it is not so clear, but if there seems to be a relation, it will be the business of the defenders of a theory to show that there is no relation, and that, therefore, nothing can be argued in regard to that theory from that fact. In a criminal case, if the defence undertakes to exclude the proof of a fact, they must either show that the fact has no bearing on the case, or that the method of proving it is objectionable. The first point alone interests the scientific student, for as to the second he little cares how a thing is proved, so its truth is made certain to him. The great point is, what are the facts, and does the theory indicated by some or all of the methods, harmonize with and explain all the facts gathered which relate to the case in hand? If the theory does so explain them, it has met and satisfied the first test of the truth of hypotheses, and that test by which false theories are most frequently overthrown.

RULE OF SIMPLICITY.

It is generally true that a false theory will not explain and harmonize all the facts, even when modified and changed. Some facts seem utterly to overthrow it, so that they make it wholly untenable. There are other cases, however, where there are two theories, both of which will give an explanation of the facts. What is to be done in such a case? There is a very practical answer, on which men act as a rule. TAKE THAT THEORY WHICH OFFERS THE SIMPLEST AND CLEARST EXPLANATION. This is especially employed by juries in the courts. Very few criminals fail to have some sort of an explanation of every fact furnished in the evidence. Their lawyer will go through the case, and often with great plausibility will try to show that all may be understood by accepting the notion of his innocence; yet the jury and public opinion convict the man. They say there were too many things to explain away. The story was not straight enough. The

same thing is true in science. Take the Ptolemaic theory of astronomy. There was scarcely a motion of the heavenly bodies which it did not explain and account for by a system of epicycles. All it had to do with each new aberration was to add a new epicycle. When now the theory of Copernicus was proposed, it commended itself to scientific men, because it did away with all this complexity. Kepler enumerates eleven motions of the Ptolemaic system, which are done away with by the Copernican system as wholly unnecessary. The best illustration, however, of this distinction between true and false theories, is found in the struggle between the emission and the undulatory theory of light. This is probably the longest and most famous conflict in history, as it was a conflict wholly between scientists, and then between those who agreed as to the methods of argument. The emission theory had for its supporters Newton, whose scientific authority was unequalled in his day, and others then and since of almost equal ability. That theory asserted that light was a substance emitted in rays from luminous bodies. This perfectly explained reflection. As for refraction, it also had an answer, that the ray entering a denser medium was attracted downward by the increased quantity of matter. When it came to polarity, it added the notion of rays with sides. When it came to the colors of thin plates, it added the mystery of "fits" of easy transmission. When now the theory reached this complexity, with numerous other subordinate appendages required by other facts and experiments, the minds of scholars began to recoil from it, and insist that it could not be true, or it would not find such difficulty in explaining facts so simple. During Newton's lifetime, therefore, there were those who were seeking some other and simpler theory. In his day it was suggested that, instead of being material, a ray of light was simply the vibration of an extremely attenuated ether. This explains reflection as well as rays. Refraction is due to one edge of the

wave striking the dense medium first, and so being retarded; while the other edge goes on, and so its face is turned a little. Polarity is the reduction of all the vibrations to a single plane. The colors of thin plates are directly referable to the length of the waves. In all this there is no new hypothesis demanded. But the best statement of the influence of this complexity of the one theory, and the simplicity of the other, on the question of their probability, is the following quotation from Whewell's "History of the Inductive Sciences," Vol. II., pages 107 and 108, Appleton's edition of 1870.

"When we look at the history of the emission theory of light, we see exactly what we may consider as the natural course of things in the career of a false theory. Such a theory may, to a certain extent, explain the phenomena which it was at first contrived to meet; but every new class of facts requires a new supposition — an addition to the machinery; and as observation goes on, these incoherent appendages accumulate, till they overwhelm and upset the original framework. Such was the history of the hypothesis of solid epicycles; such has been the history of the hypothesis of the material emission of light. In its simple form it explained reflection and refraction; but the colors of thin plates added to it the hypothesis of fits of easy transmission and reflection; the phenomena of diffraction further invested the particles with complex hypothetical laws of attraction and repulsion; polarization gave them sides; double refraction subjected them to peculiar forces emanating from the axes of crystals; finally, dipolarization loaded them with the complex and unconnected contrivance of movable polarization; and even when all this had been assumed, additional mechanism was wanting. There is here no unexpected success, no happy coincidence, no convergence of principles from remote quarters; the philosopher builds the machine, but its parts do not fit; they hold together only while he presses them; this is not the character of truth.

“In the undulatory theory, on the other hand, all tends to unity and simplicity. We explain reflection and refraction by undulations; when we come to thin plates the requisite ‘fits’ are already involved in our fundamental hypothesis, for they are the length of an undulation; the phenomena of diffraction also require such intervals; and the intervals thus required agree exactly with the others in magnitude, so that no new property is needed. Polarization for a moment checks us; but not long; for the direction of our vibrations is hitherto arbitrary — we allow polarization to decide it. Having done this for the sake of polarization, we find that it also answers an entirely different purpose, that of giving the law of double refraction. Truth may give rise to such a coincidence; falsehood cannot. But the phenomena become more numerous, more various, more strange; no matter — the Theory is equal to them all. It makes not a single new physical hypothesis; but out of its original stock of principles it educes the counterpart of all that observation shows. It accounts for, explains, simplifies, the most entangled cases; corrects known laws and facts; predicts and discloses unknown ones; becomes the guide of its former teacher, Observation; and, enlightened by mechanical conceptions, acquires an insight which pierces through shape and color to force and cause.”

If, now, we inquire why this rule is valid — why truth is thus simple and incomplex, it will be found to be a very difficult question to answer. That it is so is the common verdict of mankind, and the testimony of all observation; but there are many things we do not know, and most probably this is one of them as yet. It is to be remarked, however, that great stress is to be laid on the application of this rule, on the tendency of the theory to become more and more complex, with the increase of facts, and new phases of facts; or its ability to maintain its simplicity without failing in its explanations. The study of the emission theory of light, in

all the diversities of the suppositions it is compelled to make, as to the shape and character of its beams, will lead us to justify his expression, who called it a "mob of hypotheses." Another illustration of the same increasing complexity of a false theory is found in the Cartesian doctrine of vortices, as an explanation of the mechanism of the heavens. Descartes suggested that matter was originally angular, and that being thrown into a circular motion, it tended to separate into vortices, where the corners were rubbed off. Thus, the figure and general rotary motion was explained. The variation from the exact circle was accounted for by supposing these vortices to come in contact with each other, and so compress their curves at the point of contact. The comets were supposed to have the power of gliding into and out of these vortices, and so they were conceived of as flying through space in a serpentine course. Each star and sun was a centre for a vortex, and the satellites moved in a vortex, of which their primary was the centre. As now the courses of the planets and satellites came to be closely observed, every new motion required some new addition to be made to the vortex, until the whole matter became involved in a universal vortex of confusion.

Another illustration is found in the history of the Linnæan system of botany. This is an important illustration, as it is taken from the classificatory sciences, and shows the use of the inductive methods in those departments of study. A classification is artificial or scientific, as it finds its divisions running along distinctions found in nature or not. The scientific or natural division will bring together objects as nature has grouped them. An artificial classification will separate those which nature has obviously united. The great point, therefore, is to get the true basis of division, and make our distinctions on that ground. Linnæus took the sexual divisions of plants as his basis, and so made the number, position, and other characteristics of the stamens

and pistils of the flowers the method of distinction. For a while this was the almost universal mode of botanical study. The progress of the science, however, by and by came to show that on this basis of division plants which were evidently closely related were widely separated; and others were brought together with nothing in common but the numbers of their stamens and pistils. To rectify these difficulties more elements were introduced, and when it came to plants which had no true flowers, the employment of it was extremely difficult. Linnæus did not himself adhere to it in his classifications, because he found it required such complications to keep related plants together. When, now, after this Linnæan system had become almost universally accepted, the present system, called technically the Natural System, was proposed by the two Jussieus, uncle and nephew, of France. The fundamental basis of this classification was the character of the seed as to its lobes or cotyledons. Thus some are without cotyledons, others have one, and others two. That this is a true distinction, with its foundation in nature, seems probable, because the monocotyledons are endogenous, while the dicotyledons are exogenous; that is, the former grow inward and by lengthening, as corn, while the latter add rings to the outside, as the oak does. This last furnishes, in the physiology of the plant, a basis which seems to keep all the related plants together, while maintaining its simplicity.

These illustrations of true and false hypotheses thus justify the rule; so that, whether we see a reason for it or not, the fact is, that truth is more simple, consistent, and harmonious than error; and its defenders find it a plainer path than the path of error. Perhaps no test receives more universal acceptance, and more frequent application by unscholarly people, than this. In every-day life, in judging of the most trivial affairs, we hesitate about accepting any explanation, where explanations have to be further explained. We ex-

pect truth to unfold itself, as we say naturally, that is with simplicity and directness.

RULE OF CONCURRENCE.

Thus far, theories have been considered as hypotheses, suggested at first as obvious explanations of a limited number of facts, and pushing their way to general acceptance by their ability to explain every fact known, as connected with the subject, and this in a simple and natural manner. Another thing which characterizes true inductions is now to be attended to. Often inductions are reached by starting at separate and apparently very widely separated clusters of facts; or a conclusion is reached by considering one set of facts, and then leaving these and attending to another set of facts, we are suddenly delighted by finding ourselves brought to the same conclusion. This is called the Consilience of Inductions by Dr. Whewell, in his work (now out of print) entitled, "The Philosophy of the Inductive Sciences." In his fourteenth aphorism concerning science, he states it thus: "The Consilience of Inductions takes place when an induction from one class of facts coincides with an induction obtained from another different class. This Consilience is a test of the truth of the theory where it occurs." This concurrence or consilience of inductions had a very remarkable effect on the reception of Kepler's laws and Newton's theories of gravitation. The questions to which Kepler addressed himself were really those of mechanics involved in the composition and resolution of forces, and the motions resulting from them. Instead, however, of studying these abstract mathematical problems as abstract problems, he was studying them in the concrete case of the motions and directions of the heavenly bodies. It was easy to see, however, that if his theories were true at all, they were equally true of all motion and all force, anywhere and on

any scale. Here, then, was just the chance for this concurrence of inductions. If the theories were true, the conclusions reached by studying the stars would also be reached by studying forces. As a fact, the two did go on hand in hand. From the time of Kepler onward, mathematicians made wonderful advancement in the science of mechanics, and as fast as that science progressed, its revelations threw new light on the suggestions of astronomy, and the discoveries made by astronomers gave new directions to the students of mechanics. This was especially true after Newton's discovery of the law of gravitation. By that law there was given the other principal force with which the centrifugal force found in the planets, in their motion in their orbits, was compounded, and, of course, their curved motion was the resultant of these two forces. Indeed, Newton's discovery of this law was itself just such a concurrence of inductions. By the rapidity of falling bodies at the earth's surface, he had a basis for calculation as to what that rate would be at the distance of the moon. By the moon's monthly revolution round the earth, and her distance from the earth, he had her rate of motion. By these two, sufficient mathematical knowledge enabled him to calculate just how much the moon's course would diverge from a straight line or tangent. It was found that this divergence was not enough, if the moon moved round the earth in a circle, but that it was just what was required if it moved in an ellipse. But, furthermore, even that first calculation did not come satisfactorily near the truth, as it showed that while the moon curved from this straight line or tangent so as to be thirteen feet from it at the end of one minute, yet, according to the supposed force of gravity, she should have been more than fifteen feet from it in that length of time. Here the concurrence was encouraging, but far from satisfactory. Not long after, a new calculation of the earth's radius was made in France, and it differed very much from what had been ac-

cepted as true before, and, of course, used by Newton in his estimate of the earth's mass. The moon's distance is also calculated with the earth's radius as one of the given quantities, and a change in the radius would proportionally change the calculated distance. With these corrections, he went over his calculations again, and the result was found to agree with the phenomena to a remarkable degree of precision. If, however, these concurrences gave great confidence in the induction thus reached, there was still another group of facts which might be investigated, and if the induction from them added another concurrence, the probability would be very great indeed that the law was universal. This last group of facts was the course of the planets around the sun. The mathematical problem here was much more difficult, but Newton's transcendant mathematical talents enabled him to solve it, and its results confirmed fully the inductions from previous calculations. There was no hesitancy, then, in making the one further step, that as this law of the attraction of matter directly as its mass, and inversely as the square of the distance, holds good on the earth, and between the earth and the moon, and between the sun and the planets, it was a universal law of matter. To this same point all inductions, gathered in other ways from other facts, have pointed.

In Tyndall's American lectures on light, he gave a most beautiful illustration of this concurrence of inductions. In explaining the presence of visible and invisible rays of light, he came upon the question of the proportionate amount of heat and light in a ray. By the use of the thermo-electric pile he was able to measure the amount of heat in the visible and invisible spectrum. In his statement of it he follows first Dr. Whewell's *method of means* to get his data, and then represents them by curved lines. Thus he lets a straight line represent no heat at all so far as the ray is concerned. As soon as the pile begins to show itself affected by the heat, he

erects from the straight line a short perpendicular, at double the amount of heat a perpendicular twice as long, and so proportions the length to the amount of heat. Connecting the top of these perpendiculars he gets a curved line, which represents to the eye the degree of heat. Then making twelve such experiments most carefully, he compares them, and takes the *mean curve* of them all. From this it is discovered that the invisible or heat rays are about 7.7 times the other. He then gives another method of determining the same thing. He first estimates the total emission from the electric lamp, and then by means of the iodine filter, determines the limit of the ultra red emission, and as the difference between these two will be the luminous emission, it is found that the invisible is eight times that of the visible. "No two methods could be more opposed to each other, and hardly any two results could better harmonize."

This concurrence of inductions often manifests itself in another way, which, when it occurs, is a very strong confirmation of its truth. It is not an unfrequent occurrence that empirical laws shall vindicate themselves by such frequent recurrence, that, although there may be no possible explanation of their regularity, yet much confidence may have grown up in their reliability. Thus even among the ancient Chaldeans the eclipses of the moon were known to come in a regular order of succession. The Copernican theory of the revolutions and the doctrine of gravitation explained why they should come in that order. So, also, Hipparchus detected and computed the amount of the precession of the equinoxes. He could, however, give no reason for this slow retrograde motion. When, now, the theory of universal gravitation was discovered, it at once explained this phenomenon, by the unequal diameters of the earth, the amount of matter being greater under the equator, and this, owing to the obliquity of the plane of the equator to that of the ecliptic, kept drawing it over very

slightly at each revolution. Thus in both these last cases the true theory suddenly explained facts, which were not before supposed to be at all related. This is called the *subsumption of apparently unrelated facts*. When it occurs, it cannot fail to make a deep impression on the mind. Another instance of this same thing was in the sudden light thrown on the tides of the ocean by this theory of gravitation. It seems all plain to us now, but before the law was proposed and clearly developed, by what freak of imagination could it have been conceived that the same force that makes an apple or stone fall could make the tides rise up? And yet when that doctrine of the universal attraction of matter was proposed, and the fluidity of the ocean taken into consideration, it not only made plain why there were tides at all, but it explained the difference of spring and neap tides, and morning and evening tides, and a very great variety of other variations. This sudden and unexpected explanation of apparently unrelated facts furnishes the propriety for Dr. Whewell's word *consilience*, or jumping together of inductions. Here were phenomena on which the minds of philosophers were laboring, and all at once, as by a flash of light, the whole matter is made plain. Every test is satisfied. Every fact is at once explained. The whole matter maintains the utmost simplicity. No new complexity is added, but a whole tangle of complexities is unravelled. There is a concurrence of inductions from the most varied directions. An experience of this same kind often occurs in the detection of crime and the conviction of criminals. At the outset all that seems certain is that there has been great villany. Who did it, or how it was done, no one knows. Some suggest one theory, and some another. The detectives are all baffled, and the lawyers are all at fault. Every fact, large or small, that can be gathered up has been carefully investigated. Theory after theory is tried, but some fact or other shows its impossibility. At length some

one makes the correct suggestion, and then it is marvellous how every fact points the same way. Things that seemed just to contradict each other are seen to be perfectly consistent, and, indeed, necessary to each other. As new facts are brought to light, they only serve to confirm what is already known. As in science, so here: things that did not seem to have any bearing on the subject, or connection with it, now evidently are part of the same chain of events, and a common interdependence is manifest all through.

In this connection it is important to note how hypotheses clear up exceptional cases. It is often said that exceptions prove the rule. Nowhere is this more true, or true in a more obvious sense, than in the history of science. The secret of this is that the true hypothesis reveals the causal reason, why there should be such an apparent exception; which, instead of being a real exception, is a preëminent instance of conformity to the rule. The most remarkable instance of these exceptions, coming up to confirm a law, is in the case of the discovery of the cause of what are known as the Secular Inequalities of the motions of the members of the solar system. Thus it was long known that the moon's motion in her orbit was slowly accelerating; that is, the rate is a little faster than it has been heretofore. A similar acceleration is going on in the case of Jupiter's mean motion, but there is a retardation in the case of Saturn. Here was something that seemed wholly exceptional. In the first place it looked like an anomaly that there should be any variation from year to year, and an indefinite number of hypotheses were suggested to account for it. But in 1787 La Place discovered that this acceleration of the moon's mean motion was due to the influence of the sun's attraction on it, and that, after a very long period of time, that action would be converted into a retardation; and that in the case of Jupiter and Saturn, it was due to the mutual attraction of the two planets on each other; and further,

that while now the effect of this action was to retard Saturn and accelerate Jupiter, in course of time it would also be in that case so changed that Jupiter would be retarded and Saturn accelerated. So accurate was this last calculation that he fixed the length of time during which one planet is retarded and the other accelerated. That period is nine hundred and twenty-nine years and a half. In speaking of this apparent exception, La Place says: "And thus the lot of this great discovery of gravitation is no less than this, that every apparent exception becomes a proof—every difficulty a new occasion of triumph. And such is the character of a true theory—of a real representation of nature."

This, then, is the nature of the test of the Concurrence of Inductions. THE SAME CONCLUSION IS REACHED BY REASONINGS FROM DIFFERENT SETS OF FACTS. Phenomena, hitherto not supposed to be related, are shown to be explicable on the same principles, and thus their correlation is discovered. Exceptional cases, hitherto seemingly contradictory, are shown to be consistent, and, instead of controverting the law, are its most conclusive proofs. This test may not always be found applicable. There may occur cases when it does not come in the way of a true theory to be confirmed by these happy concurrences. When, however, a theory is thus confirmed, it is among the strongest proofs of its correctness.

RULE OF SUFFICIENCY.

In speaking of the difference between final and efficient causes, attention was called to the fact that nature's forces, when once let loose, always did their work, whether in our plan the results brought about were all included or not. If the causes are put in operation, the effects appropriate thereto will be brought about, whether we intend them or fear them. Even if they should be precisely the reverse of what we want, still causes and forces pay no attention to

our desires, but, as we might say, blindly work out their result. Now this fact of the inevitable accomplishment of all their proper results by causes, furnishes us a means of testing the correctness of our inductions as to the causes in any particular case. If, for example, our induction leads us to assign a cause, and the necessary results of that cause are not present, then we may be reasonably sure that our hypothesis is not correct. If all the results that ought to be produced by its presence are found to be on hand, then there is great probability that our theory of the case is true. It will thus appear that while facts require theories to explain them, theories also require facts to bear them out. Hence our test of the *Sufficiency of the Facts*. Theories thus at times demand new facts never before observed. Allusion has already been made to the objection raised to the Copernican theory of astronomy, from the absence of phases in the planet Venus. It was correctly argued that if Venus revolved round the sun, she should show phases like the moon, so that there should be a quarter Venus and full Venus, as there is a quarter moon and a full moon. When, now, Galileo succeeded in constructing a telescope sufficiently powerful, he beheld Venus showing phases exactly like the moon. Thus a fact demanded by the theory was forthcoming when men were enabled to observe it. So when the theory of universal gravitation was proposed, it was at once seen that if true certain other things would also be true, which had never been observed before; namely, that the motions of the heavenly bodies, instead of being in right lines across the face of the firmament, should be in waving tracks, as drawn and released by this force. So when they perfected their astronomical instruments to such a degree, that variations so slight, as they must appear to us, could be detected, it was found that they did not move in right lines, as they seemed to do to the naked eye, but that there was just the waving motion demanded by the theory. The

last planet of the solar system was discovered just in that way. It was supposed for many years that Uranus was the outermost planet of our system, but observations of the course of that planet failed to satisfy the calculations to the requisite degree of exactness. The only way to explain these aberrations was to suppose that there existed another planet exterior to Uranus. No one knew that he had ever seen such a planet. It had, indeed, been before seen, but was supposed to be a comet, and as it changed its place it was lost sight of. About the years 1843-6, the variation of Uranus became so great that, taking its amount and direction, there were furnished sufficient data to solve the problem of its location. It is well known that this difficult mathematical calculation was successfully performed by Le Verrier, a Frenchman, and Adams, an Englishman, and that the planet Neptune was discovered by Galle, at the Berlin Observatory, September 28, 1846, in the exact spot fixed by their calculations. It is scarcely possible to conceive a stronger proof of the theory than was thus given in its pointing out a fact before it was observed.

An equally instructive discovery was made in the science of optics very much in the same manner. The phenomenon of polarization had, by the undulatory theory of light, suggested that at four special points at the surface of the ether wave in double-refracting crystals, the ray was divided, not into two parts, but into an infinite number of parts, forming at these points a continuous conical envelope, instead of two images. This was the conclusion arrived at by Sir William Hamilton, of Dublin, a profound mathematician, who based his calculations on the results reached by Fresnel, a Frenchman. No eye had ever seen such an envelope. There was no evidence of its existence except that, if the theory was true, such a thing should exist. Mr. Hamilton requested a friend of his, Dr. Lloyd, to try it and see. This he did with the utmost care. He took a crystal of arragonite, and cut it

just where the theory said it ought to be cut, and fixed it just as the theory said it should be mounted for observation, and looked just where the theory said the envelope should be seen. *And there it was.* The fact called for by the theory was found just in the right place.

This test of the sufficiency of the facts is often of the greatest importance in legal trials. It very rarely happens that an innocent person can be convicted, and every fact demanded by the theory of his guilt be found forthcoming. So, in the case of a criminal, it very rarely happens that any important fact made necessary by the theory of the prosecution is wanting, and every fact demanded by the defence is present. This is especially true where a prisoner sets up a false alibi. Sometimes the prosecution is unable to get a case strong enough to require the defence to set up any theory at all. The case breaks down by its own weakness and inconsistency. But whenever the prosecution so gathers the web of evidence around him that a reasonable man would say: "Well, he may be innocent, but it begins to look very much as if he was guilty," it becomes important for him to advance such a theory of the facts, which he does not deny, as will harmonize them with his innocence. In such a case, he too must submit to the test of the sufficiency of the facts. This test was conspicuously applied in the case of Jacobi, already alluded to. His defence was, that the body found in the woods, so decomposed that it could not be recognized, was not the body of his wife. In charging the jury, it was ruled that, if it was not the body of Mrs. Jacobi, then she must be somewhere else, and no attempt had been made to account for her absence, which had awakened so much alarm in the community. As a still further fact called for by the theory of the defence, some other woman must have been lost about the same time. The state of decomposition in which the body was, fixed the time at about the time Mrs. Jacobi disappeared. No other woman had

disappeared from that neighborhood about that time, and it was hardly possible for any one to have done so without exciting the same concern that had been manifested in regard to the fate of Mrs. Jacobi. Here were facts called for by the theory of the defence which were not found, and their absence made very seriously against the theory.

The most recent illustration of this test in the department of science, is in regard to the doctrine of the development of all animal life, man included, from an original life-form. If this is true, then obviously these steps ought to be apparent and ready for comparison. But the step between man and the highest extant animal yet known is so large, that it is conceded that no variation is sufficient to account for it. Here, then, is a fact called for by the theory, namely, an intermediate species between man and the ape and monkey. This has been recognized by the advocates of the theory of development, and so they have *supposed* the existence of an anthropoid ape. For this the most active search is now going on. The discovery of such an animal will hardly be conclusive in favor of the theory, in the absence of any variation whatever in present species, for the existence of species is one of those cases where the causes that produced them have ceased for the present to act, and only the results remain. It is hard to tell, by looking at a building after the workmen have left it, who built it, or how the great ornamental stones on its cornice were lifted there. It is, however, manifest that the absence of that anthropoid ape is fatal to the theory. It will hardly do for him to be a fossil ape. His place in the scale shows that he must have been a recent, indeed, except man, the most recent species in the list; and when jelly-fishes and other rudimentary forms have been able to survive amidst the devastation of stronger forms of animal life, surely he ought to have been able to hold his own, at least until his next successor should have seen his face.

The famous dogma in regard to falling bodies, put forth with authority by Aristotle, is a case where a fact demanded by his theory failing to be fulfilled, but just reversed, utterly overthrew the theory. Aristotle asserts positively that the rapidity of the fall of bodies is directly in proportion to their weight. If this is true, then a body ten times the weight of another, will fall ten times as fast. Aristotle says it will. As a fact, it has always been found that it will not.

The fundamental principle on which this test is based, is the symmetry and completeness of truth, or, which is for this purpose the same thing, the completeness of nature's action. Nature never overlooks or forgets anything. All consequences and results are fully carried out in every direction. This legitimates the second of Whewell's two great questions of inductions. On the proposal of any hypothesis, the first question is, "Why not?" By this, attention is immediately called to any fact already known which would make the proposed hypothesis inadmissible. This is the question which more directly calls out the application of the three former tests. If the gathered facts require an increased complexity for a possible explanation of all the facts, and there are no concurrences by which it appears that the supposition named would correlate and unify the unrelated facts and exceptions, then there is a reason why not. But suppose no such reason why not appears, the next step is the application of this test of sufficiency in answer to the question, "What then?" If the theory is true, it will draw along with it certain other conclusions which must also be true, and their existence or absence is one of the best tests of its truth. True inductions thus become the pilots of investigation. They direct observation and experiment. These directions or demands for new facts are sometimes called deductions. It is certain that they may be thrown into the form of syllogisms, with the hypothesis as

the universal premise, and the suggested experiment as a case under it, with the conclusion as the demanded fact. Thus, for illustration, the deductive reasoning in the case of the discovery of Neptune ran in this way :

The divergence of the planets from their true orbit is due to attraction by some other body of matter.

Uranus is diverging from its true orbit. There must be some exterior planet to attract it.

This deductive process always follows any great inductive discovery, and is itself one of the most fruitful sources of further discovery. When these further discoveries are made, they again become the universal premises for yet other deductions. The history of the application of scientific knowledge to the uses of man is full of such correct deductions in answer to this question, What then? The lightning-rod was a direct deduction from Franklin's identification of lightning and electricity. The telegraph was suggested as a deduction from the ability to magnetize soft iron by passing a current through a wire coiled round it, while the iron lost its magnetism as soon as the current was cut off. The art of photography was a deduction from the discovery of the chemical effect of light in fixing colors. The mariner's compass was a deduction from the discovery of the fact that the magnetic needle pointed always to the pole star. The number of such deductions, which have furnished the suggestions for new adaptations of scientific truths to the practical affairs of life, is almost beyond computation. The question, "What then?" may not have been consciously before the mind of the inventor, but he was following out the scientific truth to the facts, which must come true, if it is true; and their coming true is a strong confirmation of the correctness of that scientific theory on which his deductions were based.

RULE OF PREDICTION.

This test of Prediction is universally recognized as the final, surest, crucial test. Every writer on the subject assigns it this place. No matter what school of metaphysics he belongs to, or what department of science he adopts as his specialty, every one agrees that the ability to predict what will follow under certain circumstances, is not only the test of the correctness of the scientific theories involved, but also of the familiarity of any speaker with the subject in hand. It is thus not only the test recognized by science, but it is equally the test approved by common sense, and employed by common people in their every-day reasoning. When they discuss the ability of a business man, they offer as the proof of his business capacity, that he advised them on a certain occasion to buy certain articles of merchandise, as he thought the price would rise. They bought as advised, and made largely because of the advance in prices that followed. Under his advice they afterwards sold out, and prices went down as he had warned them they would. Of another they say, he is singularly unfortunate in never buying right, or selling right, or in giving others advice. So we judge of physicians. He who can tell us the course of disease, and the effect of medicine, and can select remedies which will relieve sickness, is consulted and trusted. Every branch of business, and every department of the professions, offer examples confirmatory of this same principle.

The same thing holds good in science. In chemistry the correctness of our inductions, as to the powers and natures of the various elements, is tested by the ability to tell beforehand what result will follow their mixture in different proportions. It is asserted that the explosions that occur with refined petroleum come from the neglect to subject it to sufficient heat, so that the light gases should be driven off. Therefore, when in burning it in a lamp, the oil gets so

heated as to begin to give off this light gas, it mixes with the air, and when the proper proportion is reached an explosion follows. To test this some poor oil is tried, and, although it looks all right, when it is heated to 100 or 120 degrees Fahrenheit, and a burning taper is brought near its surface, it flashes or explodes with the gas. That is just what was predicted, but, being in an open vessel, only a little gas collects, and no danger is to be feared in the experiment when properly made. It is asserted that nothing of that kind will occur with properly refined oil. The thing is tried, and when the oil is heated to 120 or 125 degrees, the burning taper is thrust down into the oil until it is extinguished as if it had been in water. The prediction is again fulfilled.

A conspicuous instance of the popular confidence in this test is found in the reception with which the prognostications of the present head of the Weather Bureau have been received. Similar attempts to predict the weather had been made by almanac makers long ago, and had received almost no consideration, or rather had been met with ridicule, just because it was a rare thing for them to come anywhere near the truth. Besides this utter failure of the almanac makers, almost every one had been pressed by business or pleasure, to try his own hand at guessing whether it would rain or not, as he planned his farm labor, his journeys, or his business. The result of all this was that to call a thing as uncertain as the wind and weather, was to express the most utter want of faith in any assertions about its future course. When, then, Gen. Meyer began publishing his Probabilities of the weather, few expected them to be of any great value, and very many looked upon the whole thing as a useless waste of the public money. Very shortly, however, it came to be a common matter of surprise how exactly these probabilities came true. More experience still further confirmed their correctness, until now no one, whether scientist or lay-

man, who has paid any attention to the matter, doubts that great progress has been made in this matter of meteorology, and that the present head of the Weather Bureau has hit upon many of the true principles on which it is based. That universal confidence with which it is now regarded, is the result of the success of its predictions; over eighty per cent. of which have been verified, so far as they related to New England and the Atlantic States, with a decreasing percentage as you go westward; since the storms and changes progress eastwardly in the main, thus giving more facts from which to gather the eastern predictions than can be obtained for the western. Yet even for the Pacific States more than fifty per cent. are verified. With such a fulfilment of the predictions, no one can doubt but that at least some of the main principles have, indeed, been discovered.

The following interesting fact will show how the leading scientific scholars regard this test of prediction. In 1871, an expedition was fitted out for the purpose of investigating matters relating to natural history, and especially zoölogy, by deep-sea dredgings in the South Seas. That expedition was placed under the direction of Professor Louis Agassiz, who, in the department of zoölogy, had in his day no superior. Before he set out he addressed a letter, through the papers, to Professor Pierce, of the Coast Survey, giving a detailed statement of the kinds of animals he expected to find in these deep-sea dredgings in that part of the ocean. In assigning his reasons for this letter, he puts it explicitly on the ground that if zoölogy is entitled to the rank of a science, it must vindicate its title thereto, by showing its ability to tell beforehand what will be found as the result of its investigations. He declared his belief that it had reached that stage of progress at which it was able to substantiate its claims by that final and surest test. In order, therefore, to show this, he, in that public way, before he started, recorded what he expected to find; so that if the

expedition was successful, it would not be left to him to say whether he found what he expected or not. What he expected was recorded in that letter, and everybody could see for themselves, when he got back, whether he found what he was looking for. In his letter he alluded to what he feared, and what actually occurred, either that he himself should die, and so his predictions be lost before they were verified, or that the expedition should fail, and so its verification be postponed for a long time. The expedition did fail at least in the main. No such success was had as to settle the question of the correctness of his expectations. The eminent professor has since died; but in that letter there is left on record his predictions. Now whether, when those deep-sea dredgings come to be made, as they most undoubtedly will some day, they will meet his predictions or not, is not for our immediate purpose an important question. In any event, his writing that letter for the purposes named in it, and the universal acceptance accorded to it by all classes, settle as beyond all controversy his belief (and the agreement of all others with him in the belief) that this test of prediction was the most reliable and conclusive of all the tests of inductive knowledge.

The fundamental principle on which this test is based, is the uniformity and regularity of Nature's laws and forces. The principle on which the test of sufficiency is based also has application here. Nature not only is reliable for its uniformity of action, but also for leaving nothing omitted or neglected. Every cause works itself out in every case in the same way, under the same conditions. If, then, we have reached a correct knowledge of the nature and power of these causes, we can tell what effect they will produce when we bring them together in our experiments, or find them coming together in our observations of nature. This test is closely allied to recombination as a test of analysis. It is the synthesis of the forces we have theoretically analyzed in our

investigations. If our decomposition has been correct and exhaustive, we must be able to tell what results shall follow the recombination of the elements so found, and until we are able by this recombination to fulfil our predictions, based on our analysis, we are not justified in claiming that our analysis is exhaustive as to quantity, quality, and relation. So it is in our knowledge of caused truth of every sort. We can rely on the same causes bringing out the same results in every case where the conditions are the same. When we are right, therefore, in our inductions, they give us a sure basis for our predictions.

The science of astronomy has furnished many of our best illustrations, and it will again admirably serve us. Shortly after the announcement of Newton's theory of universal gravitation, the eminent English mathematician and astronomer undertook its application to that interesting class of heavenly bodies, the comets. Such investigations as he was able to make enabled him shortly to predict the appearance of a comet in 1758 or 1759, and the question of its return at that time was looked forward to with the utmost interest. In his calculations he had seen the presence of that problem of extremest difficulty, as to the effect of the attractions of the planets upon a comet. He announced the problem, but did not undertake to solve it, and so did not undertake to fix the date more definitely than 1758 or 1759. Before, however, the comet appeared, Bailly, assisted by Lalande and a female mathematician, Madame Lepante, undertook the problem, and fixed the time of its arrival at its perihelion as likely to be about April 13th, 1759; saying that it might vary from that a month or so, as, owing to the near approach of the time and the difficulty of the calculation, they could not fix it more exactly, and yet have it published in time to be a true prediction. This haste in its publication showed, as scarcely anything else could, the importance they attached to prediction as a test of truth, just as the ap-

pearance of the comet at its perihelion, on the 13th of March, 1759, proved, as nothing else could, the truth of the theory, and that the attraction of the planets had hastened its return even more than had been expected. This comet has ever since borne Halley's name, in honor of him who had first secured for the doctrine of gravitation the confirmation of prediction. To what exactness that power of astronomical prediction has since been brought, will be best illustrated by those wonderful scenes in the heavens, the eclipses. Some years ago, astronomers had announced a most remarkable total eclipse of the sun, which would be best seen in Siam. It was specially remarkable and valuable on account of the duration of the period of total obscuration. Generally, eclipses of the sun are not total for more than one or two minutes. This was total about seven minutes. Most civilized nations fitted out expeditions of scientific men for its observation. The French, whose influence is dominant in Siam, sent out a specially complete expedition. The then reigning king of Siam had been taught in his youth our system of mathematics, and having a natural fondness and capacity for such studies, had pursued them until he was able to make out his own calculation of its duration and times. Here now, he saw, was the chance to test European science with his own, and he determined to leave nothing undone to make the test thorough. According to the notions of the scholars of his own country, predicting an eclipse was utterly absurd. He, therefore, selected the best location to be had, right in the path of the total shadow, and procured the most perfect instruments to be bought, for watching the sun at the appointed time, to see what was the truth in the matter. Most of his noblemen opposed him, while the mass of the people were shocked by the suggestion. Everybody, however, was intensely interested. When now the eclipse came, exactly as predicted by the calculations, and more nearly on the time of his calculations than of any others

published, the case was settled. The king's death, not long after, from malarial disease contracted where he was watching that eclipse, is by many believed to be partly attributable to the extreme mental excitement beforehand, and the shock that came with the result. Certain it is, that from thence began a day of most rapid revolution in the domestic affairs of that country. The present king and his nobles are introducing the manners and learning of Western nations just as fast as it can be accomplished. The correctness of this logic from that fulfilled prediction no one can question. The time of the total eclipse of the sun which was visible in this country in 1859, fulfilled the calculations within less than one quarter of a minute as to the duration of the total obscuration, and almost exactly as to the time of the arrival of that total shadow.

Under all these circumstances, it is not strange that students of the logic of inductive reasoning should have unanimously fixed on this Rule of Prediction as the crucial test of inductions. It is a remark that may not be omitted here, that this, which all scientists, Mill, Compte, Huxley Tyn-dall, and all the rest have agreed upon as a final and conclusive test of a right to human belief, is the very test on which the Almighty based his claim to man's faith in him; namely, his ability to predict the future. The field selected by Him is not this of inert, unthinking matter, where blind force and law work their inexorable results, but that field of human science and national history where passion, prejudice, the blood ties of kings, and the affections and hostilities of peoples play so conspicuous a part. It is the standing testimony, available for every generation, that they, seeing the prophecies, and the living and dead nations living and lying just as was predicted, might know on the same scientific grounds that what He spoke was true, just as they know that astronomy is true in its theories. What He has said of man has the support of every test. It explains every

fact offered. It is simple and harmonious, and requires no new complexity as facts are added. It is concurred in by consciousness, experience, and every available source of proof. Every fact demanded by it is forthcoming. Every prediction, whose time has arrived, has been and is now fulfilled. Intellectual acceptance of it is, therefore, obligatory on the most purely scientific grounds.

THE INTERPRETATION OF DOCUMENTS.

Hitherto we have considered how we may interpret nature. The aim has been to read nature's laws and classifications. Nature is like a building, of which we have no copy of the architect's plans and specifications. To learn, therefore, what the plan is, resort must be had to the study of the building itself. But thought is not merely expressed in things done, in machinery constructed, and matters located and adjusted with a view to a given result. Thought may also be expressed in language. When the meaning of that language is obscure, the same methods of comparison are resorted to which we bring to our aid in the interpretation of nature. This subject, therefore, of the interpretation of documents is closely related to the matters already attended to, and is of such importance in the right understanding and composition of public papers, especially legal writings, that it deserves much attention. While it will be treated of here in the light of the Interpretation of Documents, the discussion will be equally instructive as to the proper method of drawing up such papers. On that last point, however, this is to be said in the outset; the perfection of style in the composition of all legal papers is such explicitness, that the meaning will be evident on the face of the instrument. This is presumed to be the ordinary intention of all who use language. It is to express, not to conceal, thought. Hence arises the

FIRST RULE OF INTERPRETATION.

The presumption is always strongly in favor of the plain, obvious meaning of the language. Kent's Commentaries has it that "plain, unambiguous words need no interpretation. The bulk of mankind act and deal with great simplicity. Words are to be taken in their popular, ordinary meaning, unless some good reason be assigned to show that they should be understood in a different sense." It is to be assumed that if a writer had meant something different from what his language expresses, he would have changed his language.

In Greenleaf, on Evidence, the following rule from Chancellor Wigram on the interpretation of wills, is quoted with approval, saying there is no material difference in the interpretation of wills and contracts. "Where there is nothing in the context of a will from which it is apparent that the testator has used the words, in which he has expressed himself, in any other than their strict and primary sense, and where his words so interpreted are sensible with reference to extrinsic circumstances, it is an inflexible rule of construction, that the words of the will shall be interpreted in their strict and primary sense, and in no other; although they may be capable of some popular or secondary interpretation, and although the most conclusive evidence of intention to use them in such popular or secondary sense be tendered." The reference in the above extract shows that the context of the will and its general language may show that there are some peculiarities in its use of words, but the strong presumption is against such use. The whole burden of proof, therefore, is on those who ask for any other than the plain meaning of the terms. It is a lamentable fact, however, that either from persons not knowing what they want to say, or not knowing how to say it, there is a vast mass of even such plain matters as legal documents, where only the

severest simplicity is in place, in which it is next to an impossibility to be certain of the intention. A member of the London bar, in a work on *Civilization as a Science*, speaks thus: "If on any topic, precision and certainty of language are required, they are unquestionably essential in the framing of laws, where doubt and ambiguity may not only be of consequences the most pernicious, but even defeat the very aim and purpose of the law itself. The Parliament of this nation, having in its august wisdom from time immemorial up to the present period, adopted an exactly opposite principle to the one here laid down, it is, perhaps, somewhat presumptuous, if not actually incurring a high breach of privilege, for me to question its soundness. Yet in nearly every case doubt and uncertainty have marred our legal code, upon whatever subject, owing to the loose and unscientific construction. Some laws have failed to attain the very objects which were specially intended to be brought within their scope; while others have been determined to apply to topics with which their framers had no intention of dealing." Severe as this criticism is, unless English law-makers are better than American, it is not unjust. Add now to this the controversies and lawsuits which grow out of contracts differently understood, and wills indefinitely worded, and the necessity for insisting on clear, explicit statements in all such documents must be manifest. Past experience, however, agrees in asserting that such clearness is not found, and is not likely to be found in all cases. This makes further rules of interpretation important.

SECOND RULE.

In all cases of uncertainty and ambiguity, that interpretation should be adopted which other circumstances indicate as the intention of those who had authority to fix the phraseology originally. By those who had authority to fix the phraseology originally, is meant those whose assent was necessary

give the instrument validity. This includes the legislators in the case of laws, the testator in case of wills, and both the parties in the case of contracts. The rule further limits the inquiry in these outside matters to discovering the intention of the parties in using the words they did. The rule of law is rigid in excluding all testimony looking to an addition to, or change of, the words of the writing, on the ground that this would be not interpreting *their* contract, but *making* a contract for them. The design is to secure all available aid in understanding their intention, who were the authors of the writing, in using the words they did. Of course all this presupposes the admitted genuineness of the document. If there is any doubt on that point, that doubt must first be removed. In ancient writings this is often a matter of great skill and importance.

Having, however, fixed on the language of the document, and having found that on its face there are different meanings that may be found in it, there are certain subordinate rules to be followed in determining among these various meanings which one was that intended by the writer. We have, therefore, this

THIRD RULE.

A document is its own best interpreter. Its obscure passages are to be construed in harmony with those whose meaning is plain. This gives what is called the context its importance. Ambiguous words or phrases are made clear by what precedes and follows. Words of doubtful meaning in one place have their meaning fixed by their use in other places. Though men are often inconsistent with themselves, the presumption is that they intend to be consistent, and, therefore, what they write should be reconciled if possible. To quote again from Kent's Commentaries: "The whole instrument is to be viewed and compared in all its parts, so that every part of it may be made consistent and effectual. Its con-

struction must be reasonable, and according to the subject-matter and motive."

FOURTH RULE.

The design the author had in view will aid in determining what his intention was in using his words. For this reason the discussions of legislative bodies are a great help in interpreting laws. They show what vices they intended to suppress, and what rights they sought to protect. So important is this rule in legal matters that it has passed into a maxim, that "where the reason of the law ceases, the law ceases." In illustration and enforcement of this rule, Blackstone, speaking on the interpretation of laws, gives a case put by Cicero of a law intended to induce sailors to persevere in their efforts to save vessels in danger of shipwreck. The law provided that those who forsook a ship in such a time should forfeit all property therein, and that the ship and lading should belong entirely to those who stayed in it. On a given occasion all forsook a ship but one sick passenger, who was unable to get away, and when the ship survived the storm he claimed the property. It was agreed, however, by all the learned that his case was not within the reason of the law, and so his claim was not allowed. The same is true of other writings. Cicero himself would use one style in writing to his son, at school in Greece, on morals, another in defending Archias, the poet, and still another in denouncing Catiline. The Apostle James, in writing against an idle faith, would speak of faith in different language from Paul, when the latter was explaining faith and urging its importance. When the object of each is kept in view the two uses of the word faith are clearly distinct, and there is no inconsistency. To show how empty some of the objections are which are offered to the New Testament history, an author published some historic doubts concerning Napoleon Bonaparte, and the style is different from what it would have been otherwise.

FIFTH RULE.

The spirit and temper of the author must be considered. Butler, in *Hudibras*, would expose a vice in a different way from Chalmers in his sermons. So the language of David in the Psalms is very unlike that of Solomon in Proverbs. Moses, in legislating in Leviticus, is moved by a different class of feelings from those that moved him in his farewell address found in Deuteronomy. A man in writing his will would not adopt the same forms of expression that he would in leasing a house to his tenant. Webster would argue a case in one way, and Patrick Henry in another. Much importance thus sometimes attaches to a knowledge of the life and character of those whose writings we are interpreting. So where collateral writings are employed, they should be the writings of those of like temper and aim, and as nearly similarly situated as possible. This last remark has also special application to the next rule.

SIXTH RULE.

The daily language of an author must be understood to understand his writings. Merchants use a different set of words from mechanics, and every branch of business has a large number of words which are peculiar to itself. As no one is competent to interpret a Hebrew book who is not a thorough Hebrew scholar, no more is a man able to interpret the will of a carpenter, in bequeathing his tools, who does not know the names of the tools. For this reason courts admit experts to explain the trade and professional words found in the contracts and wills of persons of that trade or profession. So Blackstone says: "Terms of art or technical terms must be taken according to the acceptation of the learned in each art, trade, and science." This rule is in one sense only another form of the first rule, for these special words are still interpreted in their plain meaning, when we

become as familiar with them as their author was. Paul was a tent-maker by trade, Luke was a physician, Ezra a priest, and, remembering these things, we can more readily see the force in their language and figures of speech.

SEVENTH RULE.

Documents are to be interpreted in harmony with the surroundings of their authors. This rule is of great importance in studying the writings of those removed from us in time and place. A contract for a substantial, comfortable house would mean a very different thing in Greenland from what it would in Cuba. In our habits, there is no naturalness in the Scripture illustration of the parable of the Ten Virgins, while in the country and age in which it was written, it was a perfectly familiar suggestion. So wills are wholly unintelligible until we know what property, what heirs, and what friends the testator had. Horace's Satires are only half-appreciated until we become familiar with the people, the manners, and the vices of his time. With reference, therefore, to both the sixth and seventh rules, it is true, as was said under the fifth, when collateral writings are employed to illustrate and explain a document, those are of most value and weight which were written by those nearest the author in language, occupation, country, and time.

In the first volume of Greenleaf on Evidence, there is a suggestion in explanation of the reason of all these rules which is so important that it is quoted here. "In all cases in which oral evidence is admitted in exposition of that which is written, the principle of admission is that the court may be placed, in regard to surrounding circumstances, as nearly as possible in the situation of the party whose written language is to be interpreted; the question being, What did the person thus circumstanced mean by the language he has employed?" If this is important to a court when it is called to construe a document, to the same extent and in the

same sense, and for the same reasons, is it important for all who seek for the meaning of writings. When we have so familiarized ourselves with the style, design, spirit, language, and surroundings of an author that, standing in his place, we would use the same words he would, to express the same thoughts, we are in the most favorable situation to know and explain what the thoughts were which he intended to express by the words to be interpreted.

THE ART OF DEBATE.

Mankind are so constituted that both physical and intellectual vigor are attained by exercise. Athletes, gymnasts, and racers are examples of that to which the body may be brought by suitable discipline. Greatness of mind is not less the result of patient and persistent effort. Whoever, therefore, would acquire skill in the methods of reasoning, must seek it by constant practice. Thus far we have spoken mainly in the direction of guiding investigation. The opportunities, however, of exercising ourselves in that kind of inductive reasoning do not furnish so easy and simple discipline as either formal or informal debate. By this last method we are brought, in an agreeable manner, to go through the intellectual process of testing our inductions, and showing whether our suppositions, that they may be substantiated by one or more of the four methods, are correct or not. It is this mental practice which has made debating and conversational societies so useful and deservedly popular. When those who have made themselves at home with these methods and steps of reasoning are called upon to advocate or resist any measure in a deliberative assembly, their skill so acquired gives them very great advantages. In neighborhood meetings, church gatherings, legislative halls, judicial trials, and every like place, ability in this direction, either natural or acquired, is of the utmost practical

importance. The following rules, if followed, will aid greatly in achieving success.

FIRST RULE.

Secure a clear, exact statement of the question in controversy. To do this, get a concise form for the proposition you are to advocate. Get an equally distinct statement of the proposition they are to maintain who differ from you. It is always best where there are to be but two sides, to have the question so stated that it can be answered by yes and no, and the propositions of the affirmative and negative such that both cannot be true or both false, but that one must be true and the other false; so that, proving the falsity of one, the truth of the other is thereby proved. Unless these conditions are complied with, indirect proof will not be available. Indirect proof is where an assertion is proved by showing the falsity of every other supposition. Thus if the question is, "Is the mind of man a spiritual existence?" it is good proof to show that it is not material. The usual method adopted by those who assert that all our ideas are acquired by experience is to prove that they are not innate, which would be valid indirect proof, if it was not for the third supposition, that there are certain principles of intuitive truth in the mind to be called into exercise by experience. This shows that there are many cases in practical life where it is not possible to have such a statement as that recommended above for all voluntary debates. In all gatherings where resolutions are to be adopted, the variety of forms proposed is sometimes very great. Generally, however, it settles down to a very few propositions, from which it is evident the one adopted will be taken. In all such cases, as in every case, it is of great importance to have these propositions distinctly stated, so that there shall be no ambiguous words or phrases. Oftentimes disputants would agree if they understood each other. By all means, therefore, let the points at issue be

put into the briefest terms and in the most explicit language possible. The very object of the pleadings in courts is to get into distinct view just what each side claims; and it would be well if the like exactness was everywhere adopted.

SECOND RULE.

Having thus obtained a clear view of the whole field of controversy, *study all sides of the question.* It is usually best to study the side of those who oppose you first. The mind is easily prejudiced in favor of its own opinions. When so prejudiced, it cannot correctly weigh the views of others. The mind is, therefore, in the most impartial condition at the outset of the study, to take in fairly the arguments of the opposition. Be assured nothing is gained by underestimating the strength of an antagonist, just as it displays no courage to underrate any peril. Having well studied the other side, study your own side in the light of all that can be said in opposition thereto. This is the best method of providing against unexpected arguments and replies.

THIRD RULE.

Adhere to the real question. Neither advance arguments which touch only part of the question, nor be beguiled into answering like arguments from the other side. Not unfrequently, in the discussion of such side-issues, the vital point is lost sight of. Proving part of a question is only justifiable when it can be shown that the rest is either admitted or independently proved. In such cases, this relation of the part proved to the admitted truths, and to the whole question, should be kept prominent.

FOURTH RULE.

Arrange the arguments, thus gathered, so that they shall mutually support and enforce each other. Arguments may be classed under three heads. Some are available for direct

proof, others for indirect proof, and others for refutation. The first class positively proves your position true. The second proves every other supposition false. The third destroys the proofs of the other side. Some arguments may bear in two of these ways, and should be so introduced as to gain the increased weight of this double force. Many direct arguments also refute the opposing arguments. When a cause is to be upheld, against which a prejudice exists, it is usually best to endeavor to allay that prejudice early in the argument, either by setting forth arguments likely to be received with favor, or by showing that the prejudice is groundless. The earlier and last arguments should be the strongest. Weak arguments should rarely be used at all; but if used, they should come in the middle of an address, giving to strong arguments the posts of honor in making the first impressions and last. Sophistry is without excuse or rule.

FIFTH RULE.

Arguments should be presented not only in abstract form, but also in the way of concrete illustrations whenever practicable. All men see a truth, when a case is put in which that truth is involved, more readily and distinctly than when it is stated in a mere form of words. Multitudes of mechanical inventions look very well in theory, but when made, will not work. So it is with many of the arguments we find ourselves relying on, and others urging against us. Many people cannot see the justice of a claim made against them until the case is reversed, and they are in danger of losing by it. A gentleman was objecting to the Bible because he could not understand it, and was asked if he believed a dog he saw had one ear standing up and the other hanging down. He was much puzzled when asked to explain it. For popular oratory this ability to put an argument in the shape of an illustration is of the greatest value. Gough is

said by some to lack logical ability, but it is only by those who think logic must consist in dry abstractions, and so fail to recognize the illustrated argument running through the mass of his anecdotes.

SIXTH RULE.

In refutation directness and brevity give force and neatness.

An argument from agreement is refuted by a case of agreement of the cause with *difference* of result, or *vice versâ*. An argument from difference is refuted by a case of agreement in cause or result. The argument from residues is answered by showing that when properly understood there is no residuum, while the argument from concomitant variations is overthrown by a case where the variation of the cause or effect is *not* accompanied by a variation of the other. The argument from compliance with the tests of induction is answered by showing that the proposed conclusion does not fully comply with the tests. The more direct and obtrusive the force of these replies can be put the better. Often the interrogative form is most effective. A politician was once dilating on the danger of disunion from which the country was saved by the compromise measures of 1850. He was asked, if the Union was in such peril, why it was that government stocks did not fall? The argument from government credit could not have been put more sharply.

SEVENTH RULE.

An opponent, with whom we are willing to argue, has a right to be treated by us with as much respect as we desire to receive from him. This requires fair consideration for all his arguments at their honest weight. It absolutely forbids all personalities, and all charges of improper or indirect motives. It requires that while we may show fully and strongly the evil consequences of any doctrine or policy, we shall not charge these evil consequences on the advocates themselves,

unless they directly avow them as the expected results. The advocates of a really dangerous doctrine may honestly believe its tendencies will be beneficial. Their mistake, therefore, is one of judgment, and not one of intention. Bitterness and severity are only warranted on rare and momentous occasions, and should be undertaken only by those whose position and ability justify the assumption of some sort of championship, and then with the sense of a painful necessity in behalf of truth.

EIGHTH RULE.

Self-possession and equanimity of temper are always to be maintained. Excitement is seldom favorable to mental effort. Usually it takes away the ordinary use of our faculties. He who in the midst of surprises and questions and noise can keep his coolness, has attained a great point in making the best out of his case. To see a speaker assailed by interruptions, points of order, questions, and explanations, and find him, with perfect calmness, keep right on with his argument, never seriously diverted from the strong points he is making, and yet able by a sentence to bring to his aid every fact in his knowledge, just as it is needed, for answer, reply, or illustration, is a scene to call forth our enthusiastic admiration. That power of self-possession and this instant command of resources, are the elements of a great leader in parliamentary bodies. In large assemblies and in small, such men carry far more influence than their equals otherwise who lack these talents. Bad temper is always a confession of weakness and defeat. It is a characteristic of those who argue for victory and not for truth, and should be left to that sort of pretenders of a desire for knowledge. Why should not an honest seeker after wisdom be grateful to any one who upsets the arguments by which he has been misled? These deserve our thanks and not our anger.

Many other rules might be given, but adherence to these, and intelligent practice, with a careful observation of good debaters, will bring fair success. Constant practice is the main thing. Exercise in analyzing arguments, to determine by what Method they are constructed, is of the greatest value. If they are our own arguments, this will show us where to fortify ourselves. If they are the arguments of our adversaries, it will show us where to assail them. As the crew of an oar-boat, for months before a race, train themselves with the utmost severity, that they may be ready for the struggle, so those who would do their share in guiding the affairs of the community, the church, or the state, with which they are connected, should not merely contribute their unintelligent and awkward efforts when information and sound judgment are demanded, but by disciplining their powers on minor matters, they should be ready always to explain and defend with force and clearness what they believe and why. Many of the greatest names in history are of those who overcame defects by persistent practice, and their achievements are the encouragements to all, especially to the young, to persevere, remembering that "what has been done can be done again." No farm, or workshop, or office, is too small for experiments in relation to our daily affairs, and no home is too humble for an argument. When those who class themselves as the common people shall cease depending on others for improvements in the methods for lightening their toil, and shall, in faith in themselves, adopt their speciality with a determination to understand it thoroughly, seeking information by arguing each doubtful point with any one likely to give information or furnish hints which they can follow, all society shall be greatly benefited by the upward impulse thus given, but they themselves chiefly shall have their self-respect deepened, their mental energy quickened, and their lives made worth the living.

INDEX.

A CIDS classified by their oxygen, 89.

- Active causes, 41.
- Adhere to the question, 164.
- Adjustment, 104.
- Admissible facts, 128.
- Admission of facts, 126.
- Advantages of private effort, 168.
- Agassiz on classification, 88.
- Agassiz's prediction, 150.
- Agreement, method of, 53.
 - Rule of, 57.
 - Defect of, 57.
 - Basis of, 63.
 - Reply to argument from, 166.
- Analysis, what, 91.
 - Qualitative, 92.
 - Quantitative, 92.
 - Relative, 93.
 - Proved by synthesis, 95.
 - Related to prediction, 151.
- Anthropoid ape, 145.
- Arbitrary classifications, 24.
- Arithmetic, its importance, 9.
- Arrange the arguments, 164.
- Art of debate, 162.
- Astronomy, its early progress, 111.

BACON on induction, 51.

- Bad temper condemned, 167.
- Bible interpretation, 127.
- Bible predictions, 154.
- Blanks, their formation, rules for, 109.
- Bonaparte's picture, 70.
- Botany, its classifications, 89.
 - Linnæan, 133.
 - Natural system, 134.
- Brevity effective, 166.
- Burning, what, 61.

CAUSE defined, 39.

- Caused truth and necessary truth, 18.
 - Causes *vs.* Purpose, 104.
 - Causes qualities, 29.
 - Children's falsehoods, 124.
 - Cicero, 159.
 - Circle, its area, 67.
 - Civilization as a science, 157.
 - Classification, 23.
 - As related to causes, 30.
 - By the four methods, 87.
 - Comet, Halley's, 152.
 - Communism, 126.
 - Concauses, 40.
 - Conchology, its classifications, 89.
 - Concomitant variations, method of, 70.
 - Principles of, 74.
 - Inverse variation, 74.
 - In social science, 75.
 - Rule of, 75.
 - Concurrence, rule of, 135.
 - Consequences, opponents not chargeable with, 166.
 - Consilience of inductions, 135.
 - Conversational societies, 162.
 - Copernican theory, 130.
 - Courtesy required, 166.
 - Crystallization, 56.
 - Cumulative reasoning, 25.
- D**AILY language in documents, 160.
- Darwinism, 126.
 - Davy's experiment, 76.
 - Debating societies, 162.
 - Deception in war, 125.
 - Deduction, 147.
 - Demonstrative reasoning, 26.
 - Peculiarities of, 26.

- Design, 102.
 In documents, 159.
 Detection of crime, 63.
 Criminals, 139.
 Law, 115.
 Dew, Well's theory of, 79.
 Difference, method of, 58.
 Rule of, 61.
 Basis of, 63.
 Arguments from, answered, 166.
 Difficulties of identifying causes, 42.
 Direct proof, 165.
 Documents interpret themselves, 156.
 Dormant causes, 40.
 "Dry statistics," 111.
- ECLIPSE** of the sun in Siam, 153.
 Eclipses, succession of, 138.
 Education, 75.
 Efficiency of causes, 34.
 Ellipticity of planetary orbits discovered, 118.
 Empirical laws, 32.
 Peculiarities of, 34.
 Encke's comet, 66.
 Established laws, 32.
 Peculiarities of, 34.
 Exceptions, their use, 140.
 Experiments, what, 46.
 Explanation of facts, 120.
 Explosion of lamps, 148.
- FACTS** always true, 47.
 Facts demanded, 141.
 Facts from imagination, 113.
 Facts not inferences, 127.
 Falling bodies, 146.
 Falsehoods, inconsistent, 15.
 Never in things, 13.
 Come from mind, 14.
 Fatal, 16.
 False reasoning is ruinous, 10.
 Farm experiments, 59, 62.
 Final causes, 102.
 "Fits of easy transmission," 124.
 Four methods illustrated, 76.
 Function, 103.
- GATHERING** facts, 111.
 Geography *vs.* Reasoning, 10.
 Good observers, their characteristics, 113.
 Gough's illustrations, 165.
 Gravitation, 136.
 Greenleaf on Evidence, 156, 161.
- H**ALLEY'S comet, 152.
 Hamilton on Light, 143.
 Harmony, rule of, 123.
 Heat, its effect, 71.
 Herschell's works, 52.
 "How" ceases, 100.
 Hypothesis, what, 116.
 Tested, 120.
- ILLUSTRATIONS**, important, 165.
 Imagination in science, 117.
 Imperfect enumeration, 122.
 Importance of truth, 17.
 Honesty of mind, 17, 113.
 Inconsistent facts, 126.
 Indirect proof, 165.
 Inexorable action of Nature's forces, 105.
 Inferences mixed with facts, 114.
 Intention in documents, 157.
 Interpretation of documents, 155.
 Interstellar ether, 66.
 Invisible rays of light, 138.
 Iron working, 63.
- J**ACOB'S trial, 125.
 Junius, 63.
 Jupiter's moons, 65.
- K**ENT'S Commentaries, 158, 156.
 Kepler's imagination, 118.
 Knowledge needed for induction, 117.
- L**AW distinguished from theory and hypothesis, 116.
 Law of Nature defined, 36.
 Legal arguments, 124.
 Legal rules on admission of evidence, 128.
 Legal trials, sufficiency of facts, 144.
 Light, Emission *vs.* Vibration, 130.
 Time of movement, 65.
 Tyndall on, 137.
 Lightning-rod, 147.
 Limestone, 92.
 Linnæan botany, 133.
 Lithium, 68.

MANURES, 60.

- Mariner's compass, 147.
- Measurements, important, 110.
- Mechanics and astronomy, 135.
- Medical diagnosis, superficial, 90.
- Medical experiments, 62.
- Mental operations in biology, 126.
- Method, its importance, 107.
- Methods answered, 166.
 - Of induction, 51.
 - All to be used, 64.
 - Illustrated, 76.
- Mill's logic, 53
- Mixed truth and falsehood, 16.
- Modification of hypotheses, 116.
- Motion, laws of, 71.

NATURE'S laws, 30.

- Nature's laws never tentative, 31.
- Nature's offering, 28.
- Necessary *vs.* Caused truth, 18.
- Neptune discovered, 143.
- Newton's method with gravitation, 73.

OBSERVATIONS made by all, 111.

- Observations, what, 46.
- Obvious meaning of documents, 156
- Operating causes, 40.
- Organic bodies, elements of, 94.
- Oxygen in combustion, 61.

PHILOSOPHY of the term, final causes, 103.

- Photography, 41, 147.
- Physicians, 148.
- Pleadings in court, their object, 164.
- Poisoning by arsenic, 55.
- Possibility proved by one fact, 25.
- Practice, its importance, 162.
- Prediction, rule of, 148.
- "Probabilities" verified, 150.
- Proving part of the question, 164.
- Ptolemaic theory, 130.
- Purpose, 103.
- Purpose *vs.* Cause, 104.

QUALITIES, causes, 29.

- Qualities, causes, related to classification, 30.
- Questions of induction, 30, 96.

RATIO of distances and times of planets, 118.

- Reading laws in Nature, 24.
- Reasoning, its importance, 9.
 - Its practical utility, 11.
 - On necessary truth, 21.
 - On caused truth, 21.
- Refutation, what, 165.
- Residues, method of, 65.
 - Rule of, 67.
- Rust, 54

SAUL'S answer to Samuel, 124.

- Sciences related to each other, 117.
- Scientific classifications, 24.
- Scientific negation, 118.
- Secular inequalities, 40.
- Selection of facts, rules for, 48.
- Self-possession, 167.
- Severity, when allowable, 167.
- Siam, sun's eclipse in, 153.
- Simplicity, rule of, 129.
 - In court trials, 129.
- Social science superficial, 90.
- Spirit and temper in documents, 160.
- State the question clearly, 163.
- Stating the question, 107.
- Steps in induction, 107.
- Strong arguments, where to place, 165.
- Study all sides of the question, 164.
- Style of language in legal documents, 155.
- Subordinate causes, 40.
- Success, its sources, 168.
- Sufficiency, rule of, 141.
- Surroundings of an author in documents, 161.
- Suspension bridge, 101.
- Syllogism related to necessary truth, 21.
 - In deduction, 146.
- Synthesis, 95.

TELEGRAPH, 147.

- Tests, cumulative, 123
- Theory, what, 116.
- Tides, facts needed, 69.
- Trees of lead, 60.
- Truth consistent, 15.
 - In things, 13.
 - Defined, 13.
 - Consistent and harmonious, 125.

Truth true of itself, 14.
 Truth *vs.* Falsehood, 13.
 Truth simple, why, 132.
 Tyndall on Light, 137.

VARIATION inverse, 74.
 Venus's phases, 127, 142.
 Verification, 120.
 Volition in caused truth, 18.
 Vortices, 133.

WEATHER bureau, 149.
 Weather bureau. facts for, 112.
 Well's theory of dew, 79.
 "What then?" Whewell's question, 146.
 Whewell's works, 52.
 On Light, 131.
 "Why," answerable, 99.
 Always present, 100.
 "Why not?" Whewell's question, 146.
 Witnesses mistaken, 114
 Wooden men for observers, 114.

THE END.

H 152 82