The "EXPERIMENTAL PHILOSOPHY": Francis Bacon (1561-1626 AD)

One of the most remarkable products of the reaction against Aristotelian philosophy, in the form that was handed down by late Mediaeval philosophers, was the rise of an entirely new philosophical system which came to be called 'Empiricism". This was particularly associated with British philosophers, and was both instrumental in the rise of modern science, and a by-product of it. Its first major exponent was Francis Bacon - although he was certainly influenced by earlier ideas (for example, from Roger Bacon) his ideas were very new in many cases, and had a very large influence on later work by British scientists. Later on Locke (a friend of Newton's) took it much further, and subsequently Berkeley and Hume took the whole idea of empiricism to an extreme. Although Bacon's contribution was the earliest and in some respects the crudest approach, in some ways it was the most durable, and certainly it had the largest impact on the development of science.

LIFE of FRANCIS BACON

Francis Bacon was born in London on January 22, 1561, at York House off the Strand. He was the younger of two sons of Sir Nicholas Bacon, a successful lawyer and Lord Keeper of the Great Seal under Queen Elisabeth I. His mother Anne was a scholar, daughter of Sir Anthony Cooke, who translated ecclesiastical material from Italian and Latin into English; she was also a zealous Puritan. Bacon's father hoped Francis would become a diplomat and taught him the ways of a courtier. His aunt was married to William Cecil, later to become Lord Burghley, the most important figure in Elisabeth's government. Thus from a very early age Bacon was immersed in the affairs of high state.

In April 1573, at age twelve, Bacon was sent to study in Trinity College, Cambridge, where he was under the special care of the Master of the college, John Whitgift (who later became Archbishop of Canterbury). He found himself "*amidst men of sharp and strong wits, and abundance of leisure, and small variety of reading, their wits being shut up in the cells of a few authors, chiefly Aristotle, their dictator. . . and knowing little history, either of nature or time, did, out of no great quantity of matter, and infinite agitation of wit, spin cobwebs of learning, admirable for the fineness of thread and work, but of no substance or profit.*"

After only 32 months at Cambridge, Bacon left the college at Christmas 1575, just before his 15th birthday. The nominal reason was the outbreak of plague, but as he later told his chaplain William Rawley (his first biographer) he was also glad to leave, heartily fed up with the academic life and with the central core of Aristotelian philosophy in the syllabus.

Bacon's first major setback occurred on 22 Feb 1579, when he was 18 yrs old, and his father died suddenly. Bacon was the 2nd son of a 2nd marriage by Sir Nicholas, who just before his death had arranged for parts of his estate to be given to his first 5 sons, but had yet to arrange for Francis. Francis suddenly found himself almost penniless, and in need of a career. This he achieved with remarkable success and speed; he trained as a lawyer, graduating from Grays Inn in 1582, becoming a reader (the equivalent of a lecturer) in 1588, and rising to the high position of Double Reader in 1600, a remarkable achievement at his age. At the same time he began a parliamentary career in 1581 at the age of 23, becoming member of parliament for Bossiney in Cornwall.

Bacon rapidly became one of the leading lawyers in England, thus eventually earning the queen's notice. However in 1593, while in a position to obtain high office under Queen Elizabeth, he criticized a taxation policy in Parliament, and opposed it in the vote. This destroyed any chance he might have had for either the position of Attorney General or Solicitor General under Elizabeth. Bacon was under the patronage of the Earl of Essex, who was for a time looked upon with favor by the queen (indeed, for a time was her lover). Essex was very well-disposed towards Bacon, even giving a substantial estate to his friend once he realised that Elisabeth still distrusted him. A few years later, fortunes reversed completely for Essex; he plotted against the Queen, was accused of going against her orders, and eventually was brought to trial and executed. In a remarkable *volte face*, Bacon acted as prosecutor, an action which earned him the lasting distrust of many of his contemporaries. Bacon later defended his own actions in "*An Apology in Certain Imputation Concerning the late Earl of Essex*".

With the death of Elizabeth in March 1603, and the succession of James I, Bacon's fortunes changed. He was quickly established as solicitor general, later achieved the position of attorney general, and eventually took over his father's old position of the Lord Keeper of the Great Seal. Bacon rose in rank again when a long time rival, Sir Edward Coke, was removed from his position after refusing to force a confession out of a prisoner and pronounce him

guilty. In 1602, Bacon was knighted, and in 1605 he married Alice Barnham, the daughter of a London alderman. In 1618 he was appointed as Lord Chancellor; and later that year, at the age of fifty-seven, he was ennobled as Baron Verulam. Finally, in 1621, he was made Viscount St. Albans. At this time Bacon, at the height of his powers, was widely admired for his legal skills, if not as a moral paragon. His reputation was that of a man with a remarkable mind, of forensic analytic and political skills, who was however content to act as a conscientious and deferential tool for his political masters.

Remarkably, the same year as he was made a baron, he was charged with accepting bribes, tried and found guilty. In reality Bacon's offense was small (he even found guilty the two men who had paid him off) but he ultimately became a scapegoat, sacrificed by King James and by Buckingham to appease a parliamentary opposition. His offices were taken from him and he was fined 40,000 pounds (a huge sum in those days), as well as being sentenced to imprisonment, expatriation from parliament and forbidden to come within twelve miles of the Chancery court. Ultimately the parliamentary sentence was not imposed, and James I remitted his fine; and in 1622, Bacon was even allowed to return to London and, eventually, to kiss the king's hand.

Nevertheless this whole episode was a huge shock to Bacon, and the disgrace forced him into political retirement. He devoted the remainder of his life to study and literary work, and nowadays it is the literary product of this period that he is chiefly remembered for - he wrote most of his great work during this time.

In March 1626, Bacon acquired a chicken, and, to see how long its flesh could be preserved by cold, he stuffed it with snow. In doing so he caught cold, and to recover he went to stay at the Earl of Arundel's house nearby. According to the story, Bacon preferred the nobleman's best room, where there was a damp bed, to a more modest room in which there was a dry bed. This led to bronchitis, and on April 9, 1626 Bacon died at Highgate, now in London, at the Earl of Arundel's house. He left behind him enormous debts, a reputation that was highly controversial and ambiguous, and a remarkable vision for the future of science and philosophy.

It is Bacon's vision of science that had the greatest impact since his death. Bacon, on the other hand, thought of himself mainly as a political statesman and practical man, whose purpose was to mold the decisions of heads of state. William Rawley portrayed him as the glory of his age and nation; and the founders of the Royal Society, such as Hooke and Boyle, saw him as the pioneering inspiration of a new scientific way of life.

Later continental admirers included Descartes, Kant, and Leibniz; the latter declared that even a great genius like Descartes creeps on the ground compared to Bacon! Voltaire, who in France championed the English scientific contribution to the Enlightenment, called Bacon the father of experimental philosophy, and rated his literary talents very highly, describing his writing as elegant, instructive, and witty. Not everyone shared this opinion - the extreme rationalist philosopher Spinoza rejected Bacon's inductive ideas completely, and Hegel described Bacon as a "coiner of mottoes," of depraved character, whose ideas were mainly fit for "civil servants and shopkeepers.".

Perhaps the most important influence that Bacon had was on Newton, who saw his own work as the elaboration of the 'experimental philosophy' outlined by Bacon. We will come to this in more detail in the section on Newton's work.

DESCRIPTION of BACON'S WORK

Bacon's ideas for the reformulation of human thought started early - the influence of his university education ran very deep. In 1592, in a letter to his famous uncle, Lord Burghley (then first minister to Queen Elisabeth I), Bacon already described his plan for a full-scale reform and reorganization of human learning. This plan began with a reaction to his university training and to the Aristotelian ideas it was based on. This reaction to Aristotle was to be elaborated throughout his life; the following passage typifies it:

"*Some men become attached to particular sciences and contemplations, either from supposing themselves the authors and inventors of them, or from having bestowed the greatest pains upon such subjects, and thus become most committed to them. If men of this description apply themselves to philosophy and contemplations of a universal nature, they wrest and corrupt them by their preconceived fanciesof which Aristotle affords us a signal instance, who made his natural philosophy completely subservient to his logic, and thus rendered it little more than useless and disputatious*"

Bacon's early-stated intention was to devise a new framework for the investigation of the world. This was the "*Magna Instauratio*", discussed below. While he did not complete this ambitious project nor do any important scientific work himself, his formulation of the idea of a "scientific method", based on experiment, had a remarkably stimulating effect on the future development of science in England (and later on on the Continent). In what follows his key ideas are described, along with extracts from some of his work.

The "GREAT INSTAURATION"

In 1620, at the height of his political career, Bacon published the preliminary plan for an enormous work, dedicated to James, to be called "*Magna Instauratio*" (i.e., the Great edifice or "Instauration"), whose purview was to range across logic and epistemology as far as natural philosophy. This work was never finished; only the first two of six parts were completed. Part I, entitled "*De Dignitate et Augmentis Scientiarum*" (the Dignity and Advancement of Learning), was published in 1605. Its main aim was to identify obstacles to the advance and pursuit of knowledge, and to emphasize the value of such a pursuit. Part II, the "*Novum Organum*" (or *New Organon*, subtitled *True Directions concerning the Interpretation of Nature*, was published in 1620; it gives a detailed discussion of Bacon's methodology for investigating Nature. This methodology involved systematic observation and experiment, and the development of intermediate principles that could be built upon by the same experimental procedures to yield ever more basic principles. These two works outline the essential elements of Bacons philosophy, and in what follows I single out the most important ideas.

The "NEW ORGANON": The Greek word organon means "instrument" or "tool", and Bacon was referring back to Aristotle's Organon; his work was a "new instrument" designed to supercede the older one. (the frontispiece of the 1620 volume depicted a ship sailing out of the Mediterranean through the pillars of Hercules, which marked the end of the Ancient world). Bacon presented his ideas mostly as of a set of aphorisms, rather than in the form of a sustained discussion; nevertheless his basic ideas are rather clear. I present them briefly, starting with methodological questions, notably to do with induction, then moving onto more epistemological questions associated with the idea of experiments, and then finally a brief note on his idea of how science should be organised.

(a) Obstacles in the way of Science: The "Idols": Before discussing the scientific method *per se*, Bacon felt that one had to deal first with some of the obstacles standing in the way of its application. In Book I of the New Organon (Aphorisms 39-68), he introduces his famous doctrine of the "idols." These are characteristic errors of the mind which prevent it attaining a complete and accurate picture of Nature. The idols stand in the same relation to the experimental study of Nature, as flawed arguments do to logical argumentation. Bacon uses the word "idol" (from the Greek eidolon, meaning "image" or "ghost") to mean a deception or misunderstanding, which obscures our knowledge of the real physical world.

There were 4 different kinds of idol, as follows:

1. *The Idols of the Tribe*: These are the "natural weaknesses and tendencies common to human nature". Because they are innate to humans, we are saddled with them, but they can be compensated for. Some of Bacons examples of these limitations or constraints are:

(i) Our tendency to imagine order in what we perceive, when it is not there, or more commonly to try and impose this order on the phenomena of which we are aware, when it may not be there. As Bacon remarks, we discern similarities or even identities between phenomena when they may be unrelated, and regularity where there is none. Bacon calls this a tendency towards wishful thinking, and such wishful thinking was far more prevalent then that it is now (although all modern scientists are familiar with the tendency of people to fasten on to almost any claimed underlying pattern to the world, particularly in the name of religion, or the paranormal).

(ii) The limitations of our senses which are "inherently dull and easily deceivable". To get around this, Bacon advocates the use of instruments, along with observations and experiments, to investigate and correct the misapprehensions of our senses.

According to Bacon, we have a natural tendency to believe or accept what we want to be true (and even try to prove it or at least demonstrate it to others). Our tendency is, in this view, to too easily to jump to conclusions, or to premature judgments, instead of following the Baconian line and gradually accumulate facts and evidence.

2. *The Idols of the Cave*: The idols of the Cave arise from our own presumptions and prejudices, which we bring to the table even when doing experiments. Unlike the Idols of the Tribe, which are common to all humans, idols of the cave vary from one person to another. They arise from the culture we are raised in, and are a product of the prejudices and beliefs that come from our different childhood and family backgrounds, education, religion, social milieu, etc. The most important of these for many people at that time was religion, which prevented most people from thinking along certain lines, and the pernicious influence of the Aristotelian doctrines on Nature and logic.

3. *The Idols of the Market Place*: These are the obstacles to knowledge that, according to Bacon, from the intercourse and association of men with each other. What Bacon was focussing on the necessity for critical thinking, and on the limitations on our thinking and understanding imposed by the language we use (particularly the specialised language used by intellectuals). Bacon argues that "the idols imposed by words on the understanding are of two

kinds", viz., that "they are either names of things that do not exist", or else misleading names for things that do exist (according to Bacon, secondary qualities and ethical or moral terms were particularly misleading here). Examples of the first kind are easy to think of - unicorns, hallucinations, or celestial spheres come to mind, along with the idea of a 'vital force' or 'vital substance'. As examples of the second kind, Bacon was particularly concerned with phenomena like colour or taste, which presented themselves to the senses but which clearly depended on particular aspects of those senses.

4. *The Idols of the Theatre*: These are idols which have their origin in the grand schemes or systems of philosophy. These give rise to unjustifiable philosophical prejudices and pre-conceptions. For Bacon these prejudices came particularly from three specific types of philosophy, viz:

Sophistical Philosophies: These are philosophies constructed largely in the absence of any empirical evidence, perhaps based on only a few observations of the world, and derived more from abstract argument. Bacon cites Scholasticism as an example of this - ie., the Aristotelian philosophy as re-interpreted in the late Middle Ages by the Scholastic philosophers.

Empirical Philosophies: This, for Bacon, was a philosophy erected on a base of in fact little empirical evidence, which was then extrapolated into a theory which claimed to explain a wide variety of phenomena. Bacon gave as a contemporary example the English scientist William Gilbert, whose experiments with lodestones led him to the conclusion that magnetism was the underlying explanation of a vast array of natural phenomena (an idea which later became quite popular).

Superstitious Philosophies: Bacon was referring here to any philosophical system that depended on or was connected to a religious base. Like many of the Ancient Greeks, going back to Thales, Bacon felt that religion and science should not mix. Bacon himself gave as examples Pythagoras and Plato, of philosophers who fell into this error, and also cited examples in his own day, referring to efforts to connect theories of the world with passages in the Bible.

Here as elsewhere one is quite amazed at the skill with which Bacon was able to unearth and categorise the patterns of intellectual thought that he saw around him. This prepared the way for him to move to what he saw as new patterns of thought, to which we now turn.

(b) The Inductive Method: At the beginning of the Magna Instauratio and in Book II of the New Organon, Bacon introduces the method of "true and perfect Induction", to be regarded as the central core of any scientific method, and a necessary tool for the proper investigation of Nature. For Bacon, a correct inductive system differs not only from the deductive logic of the mediaeval Scholastic philosophers, but also from the classic induction of Aristotle, so we begin with this.

Bacon characterised Aristotelian induction as follows: it derives general propositions from a few observations of Nature, and then works backward (via deduction) to arrive at intermediate propositions. Thus, for example, from a multitude of observations one might arrive at the inductive conclusion that "all birds have wings" Suppose one now adopts this as a general truth, or 'axiom'. One can then proceed backward from this axiom to deduce such lower level corollaries such as "all crows have wings". These corollaries could be treated as axioms in themselves but in reality they would not need to be verified empirically, since their truth is logically guaranteed provided the original generalization (ie., the 'axiom' that "all birds have wings") is true.

Now a big problem with this Aristotelian inductive procedure, as Bacon forcefully argued, is that if the general axioms are actually false, then all the intermediate corollaries may be false as well (note that they do not *have* to be false - thus it is perfectly possible for all crows to have wings, but not all birds). In the Aristotelian procedure, all it needs is one exception to the rule (ie., a bird without wings) and, then, according to Bacon "*the whole edifice tumbles.*" Bacon therefore adopted a different scheme, in which one proceeds up the ladder of generalisations, going to ever broader inductions (what Bacon called the "ladder of intellect"). As Bacon puts it, one proceeds "*regularly and gradually from one axiom to another, so that the most general are not reached till the last*". At each step up this ladder, each 'axiom' is tested by observation and experiment.

In the case of the present example, little experiment is involved - one would proceed by a mere enumeration of examples, covering all the birds one found. Such a method is very tiresome and laborious, as Bacon acknowledged; but he argued that nevertheless it was more sure, and that it would eventually produce a more stable edifice of inductively established knowledge. Bacon recognised very clearly that no absolute truth could be attached to any of the axioms so derived. In fact, he argued that not only does a single negative result disconfirm the axiom, but that this was something to be welcomed on pragmatic grounds - the discovery of a false generalization saves the scientist all the time and labour that would be entailed in proceeding further along a false line of inquiry. Meanwhile the axiomatic structure that he has already built remains intact, insofar as it is independent of the axiom that has just been falsified.

Reading Bacon, one is fascinated by the piling up of particular results - of 'facts' and 'data'. Bacon was almost obsessed by this process, to the extent that it almost seems to become, not the first step in the process of establishing

general propositions about Nature, but the essence of the process itself. Thus observation and experiment becomes not just a means to an end (that of attaining knowledge), but an activity pursued as an end in itself. The ascent up the Baconian ladder begins to appear more like an climb without end, rather than a path to somewhere else. It is certainly the case that a few experimental scientists have more or less followed the Baconian inductive ideal. For example Tycho Brahe spent much of his time overseeing a team whose job was to observe and then record and organise huge masses of astronomical data; and his methods had a beneficial influence on Kepler, even though he went far beyond them. Certainly Aristotle's biological research, and that of many subsequent biologists and zoologists, contains a strong dose of Baconian methodology (and remarkably Darwin claimed that "The Origin of Species" was also based on Baconian principles.) However even in biology the heart of the subject consists in the great generalisations that Bacon talked about but never was able to grasp. The fame of Darwin rests not on his detailed comparison of species, but on his theoretical proposal of a mechanism, ie., evolution by natural selection, that explains the entire history and variety of these species.

Having said all this, it is interesting to see just what Bacon had to say on the more general epistemological aspects of his scheme, beyond the arid collecting of facts.

(c) The Experimental Philosophy: Certainly Bacon's scheme was not wholly centred on dry methodological questions. The whole idea of basing our understanding of Nature on inductive generalisation from experiments meant that experimentation occupied a critical role in his philosophy. It also meant that he had to address a very important epistemological question, viz: What kind of knowledge does experiment give us?

To understand his point of view one has to recall the enormous influence of Aristotle, which was still prevalent throughout Europe at that time. Bacon entirely rejected the Aristotelian prejudice that an experiment was an interference with the natural course of Nature. Bacon argued instead in something that has been called Immaculate Perception, viz., that

"*all depends on keeping the eye steadily fixed upon the facts of nature and so receiving their images simply as they are.*"

in this way of looking at things, everything about Nature was a set of facts, whether or not these occurred in an experiment or elsewhere. To put it another way, Bacon held that

"*One method of delivery alone remains to us which is simply this: we must lead men to the particulars themselves, and their series and order; while men on their side must force themselves for a while to lay their notions by and begin to familiarize themselves with facts*"

Up to this point his ideas seem very naive - there is no acknowledgement that we ourselves, the observers, are also part of Nature, and are moreover flawed observers of Nature. However Bacon was still sufficiently under the thrall of Plato and Aristotle to realise that our ideas about Nature, even if derived from 'facts', still depended on our own perceptual apparatus and our particular mental capacities. This he notes that

"*Human understanding is like a false mirror, which, receiving rays irregularly, distorts and discolours the nature of things by mingling its own nature with it*".

This leaves him with the rather difficult task of explaining which parts of our understanding really do reflect facts about Nature, and which are simply artefacts of our own senses, or of our minds, or imperfect versions of what is really "out there". One can clearly either accept blindly what our senses give us and argue that everything we know comes form induction, or take the other extreme and argue that everything could be illusory. To answer this Bacon preferred to take refuge in analogy, rather than really addressing the problem. He remarks that our way of assimilating facts about Nature, and then coming up with some interpretive scheme for them, is rather like the way a bee proceeds in its peregrinations:

"*But the bee takes a middle course: it gathers its material from the flowers of the garden and of the field, but transforms and digests it by a power of its own. Not unlike this is the true business of philosophy; for it neither relies solely or chiefly on the powers of the mind, nor does it take the matter which it gathers from natural history and mechanical experiments and lay it up in the memory whole, as it finds it, but lays it up in the understanding altered and digested. Therefore from a closer and purer league between these two faculties, the experimental and the rational (such as has never yet been made), much may be hoped.*"

It is interesting that although Bacon clearly vastly under-estimated the importance of purely theoretical speculation in his philosophy, he nevertheless understood from a *purely philosophical point of view* that all experiments involved some sort of interpretive theoretical component. This point was largely lost in the later ideas of the British empiricist philosophers, and had to be reintroduced by Kant. It returned with a vengeance in 20th century physics, as we will see.

From a historical point of view, Bacon's emphasis on experiments was of real importance for subsequent British scientists. Bacon's rejection of the Aristotelian idea, that experiments were an artificial interference with Nature, in

effect sanctioned all future interference of this kind. Subsequent physicists and medical researchers in England would still run into sharp prejudice against the use of experimental methods to investigate Nature (particularly where it involved experiments on humans). But when Boyle and Newton were carrying out experiments on gases, and on chemical reactions (then called 'alchemy') - and these experiments were often conducted in some secrecy - they did so with the blessing of Bacon.

It is not clear how much Bacon's ideas on experiment were influenced by the ideas of Galileo. It is quite remarkable that at virtually the same time as Galileo was bringing to fruition the whole new 'experimental philosophy' in a practical way, by doing experiments to uncover previously hidden truths about Nature, Bacon was formulating a philosophic system to try and justify this. This is not to say that Galileo did not attempt a philosophical justification of his procedure - like Bacon, he was strongly opposed to anything Aristotelian, and already in 1623, in his work 'the Assayer' ("*Il Saggiatore*"), Galileo discussed the proper and improper ways to do and interpret experiments, as well as the proper use of language in their description and in the formulation of more general truths, notably in the distinction between primary and secondary qualities (later to be taken up by Locke). But it seems that Bacon and Galileo were largely unaware of each other. Bacon was less interested in what was actually being done with experiments in his day than in formulating a general methodology - something which Galileo was also doing in a much more dramatic and successful way, and in a way which had a much larger impact on his contemporaries. It is a pity that Bacon did not pay more attention to the way that the interplay between experiment and theory really produces new ideas. This is something that Galileo understood very well, since this is exactly what he did, amalgamating experiment with theoretical ideas, formulated mathematically where possible.

We see that in many ways Bacon's methodology got in the way of his epistemology. The Baconian inductive procedure, on its own, does not lead clearly to any general propositions, since one can amass facts without any such propositions forcing themselves upon the investigator. At what point is the Baconian experimenter supposed to jump from collecting observed particulars, to making universal generalizations? Bacons inductive method says nothing about this - he clearly felt that this was a matter of creative instinct. One still finds this today - a tendency in some pseudo-sciences to a relentless investigation and collection of data (what Rutherford later characterised as 'stamp collecting'). But what Bacon wanted to obtain from the inductive method was scientific principles or theoretical statements that we can accept as universally true.

Thus there was at least some hesitance amongst scientists of Bacon's day about his scheme. William Harvey, who knew Bacon personally (he was personal physician to James I), and is best known for his discovery of the circulation of the blood, remarked that Bacon wrote of natural philosophy "like a Lord Chancellor". Certainly Kepler, Galileo, Harvey, and and other pioneering scientists at this time were not using Bacon's methodology. However we shall see that for an important period his ideas had a powerful grip on the idealogy (if not so much on the methodology) of scientists as creative as Newton; and his vision of the elaboration of his 'experimental philosophy' in institutes designed for that purpose is alive and well today. Bacon himself, by his own admission, did not see himself as a pioneer, but rather as the Buccinator, or "trumpeter", of the new science, and of a new world that would result from it. To this vision we turn now.

The Organisation of Experimental Philosophy: the "NEW ATLANTIS"

A remarkable product of Bacon's final years, published in 1624, was the *New Atlantis*, a work of narrative fiction. It describes a voyage in whihc the seafarers get lost and are eventually received in an unknown country, which Bacon intended to be a kind of Utopia. In this Utopia the explorers have the chance to visit what Bacon considered to be his ideal of an institute devoted to scientific research and the interpretation of Nature. According to Bacons first biographer William Rawley, the novel is just the first part of what was to have been a longer and more detailed work describing the entire legal and political organization of his Utopia.

As with many other writers who have resorted to fiction to get their philosophical ideas across, the story is insubstantial, no more than a vehicle for the elaborate description of Salomons House, a research institute where trained teams of investigators worked in an organised fashion to do experiments and collect data, and then applied the knowledge they gain to produce "things of use and practice for mans life". The institute was organised in a way that modern scientists will recognise, with central control. Moreover, as Bacon saw it, the developments coming out of this institute would eventually be shared with the rest of the world, although much of it was to be kept secret in the short term.

The detailed description of Salomon's house is quite fascinating. He describes a facility in which great caves have been built, deep underground, as well as towers half a mile high, built on top of mountains so that their tops are 3 miles above sea level; the caves are in some cases 3 miles deep. Saltwater and freshwater lakes are prepared, as well as fountains, wells, and pools, baths, and great enclosures for parks and gardens; and finally "great and spacious houses". These houses were of considerable variety - there were "brew-houses, bake-houses, and kitchens", which made "diverse

drinks, breads, and meats, of rare and special effects". There were "dispensatories, or shops of medicine", along with houses for the preparation of "papers, linen, silks, and tissues", and perfume houses, "wherewith we also join practises of taste", and houses for precious stones, crystals, fossils and minerals, and "glasses of diverse kinds, amongst them some of metals vitrificated, and other minerals besides those of which you make glass"; and there were hosues with 'furnaces of great varieties".

On the more scientific side Bacon described "perspective houses", for the study and use of colour and light; "engines houses, where are prepared engines and instruments for all sorts of motion" (this included naturally "instruments of war", as well as "ships and boats for going under water"). There were also "sound-houses, where we practise and demonstrate all sounds, and their generation"; and "houses of deceits of the senses, where we represent all manner of feats of juggling, false apparitions, impostures and illusions, and their fallacies". Finally, Bacon devotes a single sentence to describe "a mathematical house, where are represented all instruments, as well of geometry and astronomy, exquisitely made".

Out afield, in the gardens and parks, Bacon describes what would now be understood as zoos, botanical gardens, and the perfection of new medicines and plants, as well as the breeding of new species; he describes how they would "make a number of kinds of serpents, worms, flies, fishes, of putrefaction; whereof some are advanced to be perfect creatures, like birds or beasts, and have sexes, and propagate. Neither do we do this by chance, but we know beforehand of what matter and co-mixture what kind of those creatures will arise". And in the great caves there would be study of "coagulations, indurations, refrigerations, and conservation of bodies", as well as mines. The high towers would be used for "insolation, refrigeration, and conservation", as well as for the observation of meteors and the weather. The wells and lakes would be used for "fish and fowl", for the study of putrefaction, and for the "infusion of many things, where the waters take the virtue quicker and better than in vessels or basins."

The researchers would be called "fellows", and their activities would be divided into 3 kinds. There were 12 fellows that "sailed to foreign countries, under the names of other countries (for our own we conceal)"; their task was to bring back books and results of experiments done elsewhere - these 12 were called "Merchants of Light". Then there were 3 fellows involved in the process of finding general truths from experiments. These three, who were doing what would now be called theoretical work, were called the "Interpreters of Nature"; their job was to "raise the discoveries by experiments into greater observations, axioms, and aphorisms". Finally, and for Bacon by far the most important component of the institute, were the fellows involved in experimental work. These comprised 21 fellows, wose activities were divided into 7 groups of three. There were the "Depredators", who collected all the experiments in books; the "Mystery-Men", who collected all the experimental results; the "Pioneers" (or "Miners") who tried new experiments; the "Compilers", who collected the results of the preceding groups into "titles and tables, to give the better light for the drawing of observations and axioms out of them"; the "benefactors", who looked at the results of all the experiments and attempted to develop from them things of practical use; and the "Lamps", who examine the results of all the experiments, and then "take care, out of them, to direct new experiments, of a higher light, more penetrating into Nature than the former". Then there were the "Inoculators" who "execute the experiments so directed". All of this experimental activity was then handed over to the "Interpreters of Nature", for them to work their theoretical magic.

This whole band of fellows also had their apprentices, plus "a great number of servants and attendants, men and women". And finally, lest we fail to understand the importance of all this, Bacon describes how "we have consultations", to decide "which of the inventions and experiences which we have discovered shall be published, and which not; and take all an oath of secrecy, for the concealing of those which we think fit to keep secret; though some of those we do reveal sometimes to the state, and some not".

Bacon's book is quite startling in its vision of organised research - it could have only been written by someone who had himself been involved for most of his life in politics and in the organisation of affairs of the state, and who was also a lawyer. As fiction, the *New Atlantis* is rather lifeless, about as exciting as a re-organization plan for local government. The vision did not inspire Bacon's political masters - his attempts to get James I to back his plan to set up such an institute fell on deaf ears. But the plans outlined in the novel (as well as in his earlier work) later had a crucial impact on the development of science as an organised discipline. They served not only as an effective inspiration and model for the Royal Society, founded in 1660 and supported by the Crown, and organised into "Fellows of the Royal Society", but also exercised a strong influence on the subsequent organisation of research institutes, and ultimately of the scientific community.

Bacon's vision was very broad - he imagined a synergy between what we now call pure and applied science, as well as between science and technology. This is astonishing. Consider that the idea of a scientist did not yet even exist in his time (for Bacon and his contemporaries, all of this activity fell under the heading of "Natural Philosophy"); that the invention of Physics as a separate discipline from the rest of Natural Philosophy was only just beginning, under the stimulus of Galileo, and that Physics would not be recognised as such for over a century; and that technological development would not be allied with pure and applied science in any meaningful way until the late 19th century. In

this light Bacon's vision seems almost clairvoyant. Even though there has never really been an institute quite so broad in its scope as the one Bacon imagined, there have been centres of research that approached it. For example, the Manhattan project organised by the US government to build the atomic bomb was similar in many respects, and many modern 'industrial parks', situated on university campuses or in large research centres, with funding coming from government and private companies, are even closer. What Bacon did not imagine was that science would become so central to the economic activity of most countries that *whole scientific communities* would organise themselves along the lines he described.