What is the insight with which the scientist tries to see into nature? Can it indeed be called either imaginative or creative? To the literary man the question may seem merely silly. He has been taught that science is a large collection of facts; and if this is true, then the only seeing which scientists need do is, he supposes, seeing the facts. He pictures them, the colorless professionals of science, going off to work in the morning into the universe in a neutral, unexposed state. They then expose themselves like a photographic plate. And then in the darkroom or laboratory they develop the image, so that suddenly and startlingly it appears, printed in capital letters, as a new formula for atomic energy.

Men who have read Balzac and Zola are not deceived by the claims of these writers that they do no more than record the facts. The readers of Christopher Isherwood do not take him literally when he writes ‘I am a camera.’ Yet the same readers solemnly carry with them from their schooldays this foolish picture of the scientist fixing by some mechanical process the facts of nature. I have had of all people a historian tell me that science is a collection of facts, and his voice had not even the ironic rasp of one filing cabinet reproving another.

It seems impossible that this historian had ever studied the beginnings of a Scientific discovery. The Scientific Revolution can be held to begin in the year 1543 when there was brought to Copernicus, perhaps on his deathbed, the first printed copy of the book he had finished about a dozen years earlier. The thesis of this book is that the earth moves around the sun. When did Copernicus go out and record this fact with his camera? What appearance in nature prompted his outrageous guess? And in what odd sense is this guess to be called a neutral record of fact?

Less than a hundred years after Copernicus, Kepler published (between 1609 and 1619) the three laws which describe the paths of the planets. The work of Newton and with it most of our mechanics spring from these laws. They have a solid, matter of fact sound. For example, Kepler
says that if one squares the year of a planet, one gets a number which is proportional to the cube of its average distance from the sun. Does anyone think that such a law is found by taking enough readings and then squaring and cubing everything in sight? If he does, then as a scientist, he is doomed to a wasted life; he has as little prospect of making a scientific discovery as an electronic brain has.

It was not this way that Copernicus and Kepler thought, or that scientists think today. Copernicus found that the orbits of the planets would look simpler if they were looked at from the sun and not from the earth. But he did not in the first place find this by routine calculation. His first step was a leap of imagination to lift himself from the earth, and put himself wildly, speculatively into the sun.1 ‘The earth conceives from the sun,’ he wrote; and ‘the sun rules the family of stars.’ We catch in his mind an image, the gesture of the virile man standing the sun, with arms outstretched, overlooking the planets. Perhaps Copernicus took the picture from the drawings of the youth with outstretched arms which the Renaissance teachers put into their books on the proportions of the body. Perhaps he had seen Leonardo’s drawings of his loved pupil Salai. I do not know. To me, the gesture of Copernicus, the shining youth looking outward from the sun, is still vivid in a drawing which William Blake in 1780 based on all these: the drawing which is usually called Glad Day.2

Kepler’s mind, we know, was filled with just such fanciful analogies; and we know what they were. Kepler wanted to relate the speeds of the planets to the musical intervals. He tried to fit the five regular solids into their orbits. None of these likenesses worked, and they have been forgotten; yet they have been and they remain the stepping stones of every creative mind. Kepler felt for his laws by way of metaphors, he searched mystically for likenesses with what he knew in every strange corner of nature. And when among these guesses he hit upon his laws, he did not think of their numbers as the balancing of a cosmic bank account, but as a revelation of the unity of all nature. To us, the analogies by which Kepler listened for the movement of the planets in the music of the spheres are farfetched.3 Yet are they more so than the wild leap by which Rutherford and Bohr in our own century found a model for the atom in, of all places, the planetary system.

No scientific theory is a collection of facts. It will not even do to call a theory true or false in the simple sense in which every fact is either so or not so. The Epicureans held that matter is made of atoms two thousand years ago and we are now tempted to say that their theory was true. But if we do so we confuse their notion of matter with our own. John Dalton in 1808 first saw the structure of matter as we do today, and what he took from the ancients was not their theory but something richer, their image: the atom. Much of what was in Dalton’s mind was as vague as the Greek notion, and quite as mistaken. But he suddenly gave life to the new facts of chemistry and the ancient theory together, by fusing them to give what neither had: a coherent picture of how matter is linked and built up from different kinds of atoms. The act of fusion is the creative act.

All science is the search for unity in hidden likenesses. The search may be on a grand scale, as in the modern theories which try to link the fields of gravitation and electromagnetism. But we do not need to be browbeaten by the scale of science. There are discoveries to be made by snatching a small likeness from the air too, if it is bold enough. In 1935 the Japanese physicist Hideki Yukawa wrote a paper which can still give heart to a young scientist. He took as his
starting point the known fact that waves of light can sometimes behave as if they were separate pellets. From this he reasoned that the forces which held the nucleus of an atom together might sometimes also be observed as if they were solid pellets. A schoolboy can see how thin Yukawa’s analogy is, and his teacher would be severe with it. Yet Yukawa without a blush calculated the mass of the pellet he expected to see, and waited. He was right; his meson was found, and a range of other mesons, neither the existence nor the nature of which had been suspected before. The likeness had borne fruit.

The scientist looks for order in the appearance of nature by exploring such likenesses. For order does not display itself of itself; if it can be said to be there at all, it is not there for the mere looking. There is no way of pointing a finger or a camera at it; order must be discovered and, in a deep sense, it must be created. What we see, as we see it, is mere disorder.

This point has been put trenchantly in a fable by Karl Popper. Suppose that someone wished to give his whole life to science. Suppose that he therefore sat down, pencil in hand, and for the next twenty, thirty, forty years recorded in notebook after notebook everything that he could observe. He may be supposed to leave out nothing: today’s humidity, the racing results, the level of cosmic radiation and the stockmarket prices and the look of Mars, all would be there. He would have compiled the most careful record of nature that has ever been made; and, dying in the calm certainty of a life well spent, he would of course leave his notebooks to the Royal Society. Would the Royal Society thank him for the treasure of a lifetime of observation? It would not. The Royal Society would treat his notebooks exactly as the English bishops have treated Joanna Southcott’s box. It would refuse to open them at all, because it would know without looking that the notebooks contain only a jumble of disorderly and meaningless items.

Science finds order and meaning in our experience, and sets about this in quite a different way. It sets about it as Newton did in the story which he himself told in his old age, and of which the schoolbooks give only a caricature. In the year 1665, when Newton was twenty-two, the plague broke out in southern England, and the University of Cambridge was closed. Newton therefore spent the next eighteen months at home, removed from traditional learning, at a time when he was impatient for knowledge and, in his own phrase, ‘I was in the prime of my age for invention.’ In this eager, boyish mood, sitting one day in the garden of his widowed mother, he saw an apple fall. So far the books have the story right; we think we even know the kind of apple; tradition has it that it was a Flower of Kent. But now they miss the crux of the story. For what struck the young Newton at the sight was not the thought that the apple must be drawn to the earth by gravity; that conception was older than Newton. What struck him was the conjecture that the same force of gravity, which reaches to the top of the tree, might go on reaching out beyond the earth and its air, endlessly into space. Gravity might reach the moon: this was Newton’s new thought; and it might be gravity which holds the moon in her orbit. There and then he calculated what force from the earth (falling off as the square of the distance) would hold the moon, and compared it with the known force of gravity at tree height. The forces agreed; Newton says laconically, ‘I found them answer pretty nearly.’ Yet they agreed only nearly; the likeness and the approximation go together, for no likeness is exact. In Newton’s sentence modern science is full grown.
It grows from a comparison. It has seized a likeness between two unlike appearances; for the apple in the summer garden and the grave moon overhead are surely as unlike in their movements as two things can be. Newton traced in them two expressions of a single concept, gravitation: and the concept (and the unity) are in that sense his free creation. The progress of science is the discovery at each step of a new order which gives unity to what had long seemed unlike. Faraday did this when he closed the link between electricity and magnetism. Clerk Maxwell did it when he linked both with light. Einstein linked time with space, mass with energy, and the path of light past the sun with the flight of a bullet; and spent his dying years in trying to add to these likenesses another, which would find a single imaginative order between the equations of Clerk Maxwell and his own geometry of gravitation.

When Coleridge tried to define beauty, he returned always to one deep thought: beauty, he said, is ‘unity in variety.’ Science is nothing else than the search to discover unity in the wild variety of nature — or more exactly, in the variety of our experience. Poetry, painting, the arts are the same search, in Coleridge’s phrase, for unity in variety. Each in his own way looks for likenesses under the variety of human experience. What is a poetic image but the seizing and the exploration of a hidden likeness, in holding together two parts of a comparison which are to give depth each to the other? When Romeo finds Juliet in the tomb, and thinks her dead, he uses in his heartbreaking speech the words,

Death that hath suckt the honey of thy breath.

The critic can only haltingly take to pieces the single shock which this image carries. The young Shakespeare admired Marlowe, and Marlowe’s Faustus had said of the ghostly kiss of Helen of Troy that it sucked forth his soul. But that is a pale image; what Shakespeare has done is to fire it with the single word honey. Death is a bee at the lips of Juliet, and the bee is an insect that stings; the sting of death was a commonplace phrase when Shakespeare wrote. The sting is there, under the image; Shakespeare has packed it into the word honey; but the very word rides powerfully over its own undertones. Death is a bee that stings other people, but it comes to Juliet as if she were a flower; this is the moving thought under the instant image. The creative mind speaks in such thoughts.

The poetic image here is also, and accidentally, heightened by the tenderness which town dwellers now feel for country ways. But it need not be; there are likenesses to conjure with, and images as powerful, within the man-made world. The poems of Alexander Pope belong to this world. They are not countrified, and therefore readers today find them unemotional and often artificial. Let me then quote Pope: here he is in a formal satire face to face, towards the end of his life, with his own gifts. In eight lines he looks poignantly forward towards death and back to the laborious years which made him famous.

Years foll’ring Years, steal something ev’ry day,
At last they steal us from our selves away;
In one our Frolicks, one Amusements end,
In one a Mistress drops, in one a Friend:
This subtle Thief of Life, this paltry Time,
What will it leave me, if it snatch my Rhime?
If ev’ry Wheel of that unweary’d Mill
That turn’d ten thousand Verses, now stands still.

The human mind had been compared to what the eighteenth century called a mill, that is to a machine, before, Pope’s own idol Bolingbroke had compared it to a clockwork. In these lines the likeness goes deeper, for Pope is thinking of the ten thousand Verses which he had translated from Homer: what he says is sad and just at the same time, because this really had been a mechanical and at times a grinding task. Yet the clockwork is present in the image too; when the wheels stand still, time for Pope will stand still for ever; we feel that we already hear, over the horizon, Faust’s defiant reply to Mephistopheles, which Goethe had not yet written – ‘let the clock strike and stop, let the hand fall, and let time be at an end.’

Werd ich zum Augenblicke sagen:
Verweile doch! du bist so schön!
Dann magst du mich in Fesseln schlagen,
Dann will ich gern zugrunde gehn!
Dann Mag die Totenglocke schallen,
Dann bist du deines Dienstes frei,
Die Uhr mag stehn, der Zeiger fallen,
Es sei die Zeit für mich vorbei!

I have quoted Pope and Goethe because their metaphor here is not poetic; it is rather a hand reaching straight into experience and arranging it with new meaning. Metaphors of this kind need not always be written in words. The most powerful of them all is simply the presence of King Lear and his Fool in the hovel of a man who is shamming madness, while lightning rages outside. Or let me quote another clash of two conceptions of life, from a modern poet. In his later poems W. B. Yeats was troubled by the feeling that in shutting himself up to write, he was missing the active pleasures of life; and yet it seemed to him certain that the man who lives for these pleasures will leave no lasting work behind him. He said this at times very simply, too:

The intellect of man is forced to choose
Perfection of the life, or of the work.

This problem, whether a man fulfills himself in work or in play, is of course more common than Yeats allowed; and it may be more commonplace. But it is given breadth and force by the images in which Yeats pondered it.

Get all the gold and silver that you can,
Satisfy ambition, or animate
The trivial days and ram them with the sun,
And yet upon these maxims meditate:
All women dote upon an idle man
Although their children need a rich estate:
No man has ever lived that had enough
Of children’s gratitude or woman’s love.

The love of women, the gratitude of children: the images fix two philosophies as nothing else can. They are tools of creative thought, as coherent and as exact as the conceptual images with which science works: as time and space, or as the proton and the neutron.
9

The discoveries of science, the works of art are explorations—more, are explosions, of a hidden likeness. The discoverer or the artist presents in them two aspects of nature and fuses them into one. This is the act of creation, in which an original thought is born, and it is the same act in original science and original art. But it is not therefore the monopoly of the man who wrote the poem or who made the discovery. On the contrary, I believe this view of the creative act to be right because it alone gives a meaning to the act of appreciation. The poem or the discovery exists in two moments of vision: the moment of appreciation as much as that of creation; for the appreciator must see the movement, wake to the echo which was started in the creation of the work. In the moment of appreciation we live again the moment when the creator saw and held the hidden likeness. When a simile takes us aback and persuades us together, when we find a juxtaposition in a picture both odd and intriguing, when a theory is at once fresh and convincing, we do not merely nod over someone else’s work. We re-enact the creative act, and we ourselves make the discovery again. At bottom, there is no unifying likeness there until we too have seized it, we too have made it for ourselves.

How slipshod by comparison is the notion that either art or science sets out to copy nature. If the task of the painter were to copy for men what they see, the critic could make only a single judgment: either that the copy is right or that it is wrong. And if science were a copy of fact, then every theory would be either right or wrong, and would be so for ever. There would be nothing left for us to say but this is so, or is not so. No one who has read a page by a good critic or a speculative scientist can ever again think that this barren choice of yes or no is all that the mind offers.

Reality is not an exhibit for man’s inspection, labeled ‘Do not touch.’ There are no appearances to be photographed, no experiences to be copied, in which we do not take part. Science, like art, is not a copy of nature but a re-creation of her. We re-make nature by the act of discovery, in the poem or in the theorem. And the great poem and the deep theorem are new to every reader, and yet are his own experiences, because he himself re-creates them. They are the mark of unity in variety; and in the instant when the mind seizes this for itself, in art or in science, the heart misses a beat.

NOTES
1. This has now been admirably documented by Thomas S. Kuhn in The Copernican Revolution (Harvard, 1957). As he shows, from the Neoplatonist elements in the new humanism ‘some Renaissance scientists, like Copernicus, Galileo, and Kepler, seem to have drawn two decidedly un-Aristotelian ideas: a new belief in the possibility and importance of discovering simple arithmetic and geometric regularities in nature, and a new view of the sun as the source of all vital principles and forces in the universe.’ Kuhn draws particular attention to the influence of the ‘symbolic identification of the sun and God’ in the Liber de Sole of Marsilia Ficino, a central figure (with Pico della Mirandola, who wrote the famous De Hominis Dignitate) in the humanist and Neoplatonist academy of Florence in the fifteenth century. This has been elaborated by A. Koyré in La révolution astronomique (Paris, 1961). In 1960 Robert McNulty discovered an eyewitness account of Giordano Bruno’s lectures on
Copernicus at Osford in 1583 which shows that Bruno drew heavily on Ficino’s *De vita coelitus comparanto*; this is discussed by Frances A. Yates in *Giordano Bruno and the Hermetic Tradition* (London, 1964). The general subject has also been attractively discussed recently by Arthur Koestler in *The Sleepwalkers* (London, 1959), and earlier in Pauli’s essay on the mystic images in Kepler’s science in *Naturerklärung und Psyche* by C. G. Jung and W. Pauli (Zurich, 1952).

2. The derivation of Blake’s drawing from the Renaissance studies, by Leonardo and others, of the Vitruvian proportions and mathematical harmonies of the human figure is also discussed by Sir Kenneth Clark in *The Nude* (London, 1956). It was first remarked by Sir Anthony Blunt in the *Journal of the Warburg Institute* in 1938.

3. The music of the spheres was itself a mathematical conception, which had been invented by Pythagoras in the sixth century B.C. Pythagoras taught that the distances between the heavenly bodies match the lengths of the strings that sound the different musical notes. It was deduced that the spheres that carry the heavenly bodies make music as they turn.

4. In one of the places in which Coleridge put forward this definition, the essays *On Principles of Genial Criticism* (which Coleridge thought ‘the best things he had ever written’), he traced it back to Pythagoras: ‘The safest definition, then, of Beauty, as well as the oldest, is that of Pythagoras: THE REDUCTION OF MANY TO ONE.’

5. Pope was near the end of his career, and his friends Gay and Arbuthnot were already dead, when he published these lines in 1737. (They expand a thought from Horace, and his surviving friend Swift was particularly moved by them.) Twenty-five years earlier, as a young man in *The Rape of the Lock*, Pope had pictured the mill as a happy symbol in the ritual of the coffee-table.

   For lo! the Board with Cups and Spoons is crown’d,
   The Berries crackle, and the Mill turns round.

As the eighteenth century moved on, the image of the mill become more menacing the minds of poets, until Blake in 1804 wrote of ‘dark Satanic Mills.’ In part the change kept step with the progress of the Industrial Revolution, which Blake, for example, felt very sensitively. But in the main what the romantic poets feared was the new vision of nature as a machine, which Newton’s great reputation had imposed. Blake meant by the Satanic Mills not a factor but the imperturbable cosmic mechanism which was now imagined to drive the planets round their orbits. Blake used the words abstract, Newtonian and Satanic with the same meaning, to describe a machinery that seemed to him opposed to organic life. (so John Constable said of a painting which he despised, ‘Such things are marvelous and so is watchmaking.’) Goethe, who did original work in biology, also disliked Newton’s view of science; like other poets of the time, he felt that it turned the world into a clockwork. Yet at the same time religious apologists like William Paley in his *Evidences of Christianity* were using the same analogy to prove that the world, like a clock, must have an intelligent designer. Thus the symbol of the clockwork, and as T. S. Ashton has pointed out) a new sense of time in general, were critical in the thought of those who lived through the Industrial Revolution.

6. A literal translation is:

   If ever I say to the present moment:
   “Please stay! You are so beautiful!”
Then you may cast me in fetters,
Then I will gladly perish!
Then let the death bell toll,
Then you are released from your service.
Let the clock stop, let the hand fall,
Let time be at an end for me!

The greatest satire of the First World War, Karl Kraus’s *Die Letaten Tage der Menschheit*, contains a moving echo of these lines, which bears on what I have written in the preceding note. In one poem Kraus describes the machine-made murders of modern war as observed by a man *Mit der Uhr in der Hand*—that is, watch in hand. I quote two verses.

> Dort ist ein Mörser. Ihm entrinnt der arme Mann,
> der ihn erfand. Er schützt sich in dem Graben.
> Weil Zwerge Riesen überwältigt haben,
> sehst her die Uhr die Zeit zum Stehem bringen kann!
> Wie viel war’s an der Zeit, also jenes jetzt geschah?
> Schlecht sieht das Aug, das giftige Fase beizen.
> Doch hört das Ohr, die Uhr schlug eben dreizehn.
> Unsichtig Wetter kommt, der Untergang ist nah.

A literal translation is:

> There is a mortar, From it escapes the writeched man
> who invented it. He takes refuge in the trench.
> Because dwarfs have overpowered giants,
> behold, the clock can bring time to a stop!
> What time was it when this was happening now?
> The eye sees poorly that is etched by poison gases.
> But the ear hears, the clock just struck thirteen.
> Misty weather is coming, destruction is near.

The same image of the ticking clockwork haunted me when I visited refugee camps after another war, in 1947; and I wrote,

> The voice of God that spoke and struck
> Was the cuckoo in the clock.
> The exiles in the garden heard
> The engine tremble in the bid,
> Sobbing throat and iron bill:
> Time on his springy wheel stood still.
> Time began and time runs down.
> The voices in the garden drown.
> No God from his machine unhands
> The exile with a mouth of sand.
> The clockwork cuckoo on the hill,
> Abrupt and wheeling, stoops to kill.
7. This verse comes from the poem ‘Vacillation,’ and I have quoted it as Yeats first printed it, for example in *The Winding Stair and other poems*. In his *Collected Poems* soon after, Yeats left out the word *or* in the second line. No doubt the change improves the meter; but since I am here concerned with the contrast between the two images in Yeats’s mind, I have given his original text.