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In 1877, Hermann Kolbe made scathing remarks about van 't Hoff's hypothesis, 'Arrangements of Atoms in Space'. When van 't Hoff was appointed in 1878 as full Professor of Chemistry, Mineralogy and Geology at the University of Amsterdam, he made use of the opportunity of giving an inaugural lecture, 'Imagination in Science', as a sort of reply to Kolbe's harsh criticism. In the words of George F Springer who translated the Dutch version of the lecture to English, "... presenting here a most unusual talk which should enable the reader to sit back and view his own efforts in the context of science and creative attempts as a whole. ... The inaugural talk shows the significance of imagination in all scientific achievements, and the fate which the new ideas may have, even if they are sound and judged by competent individuals. It also gives a glimpse at the singular mind of the twenty-six-year-old VAN 'T HOFF. ... VAN 'T HOFF examines the prerequisites for many of the really important discoveries and observes that they frequently were made by unusual minds creative also in arts, poetry, or philosophy". An excerpt from van 't Hoff's lecture* is reproduced below.

G Nagendrappa

Imagination in Science

Jacobus Henricus van 't Hoff

Science is practical in the highest sense of the word.

If the assignment consists of reaching a given aim, then it is sometimes easier to *circumvent* prevailing difficulties rather than to *attack* them; since the former is frequently possible when the latter exceeds our energy. Yet, we would be compelled to confine ourselves to direct confrontation if there were no connection between that which is occurring and that which will take place.

This connection is real; in its over-all effect it is termed the relation between cause and effect. It is the task of Science to elucidate this connection in all its details.

* Jacobus Henricus van 't Hoff, *Imagination in Science*, pp.8–18, Translated into English, with Notes and a General Introduction by Georg F Springer. Springer-Verlag New York Inc., 1967. With kind permission of Springer Science and Business Media.



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This is the reason why I called Science practical in the highest sense of the word; Science is the great expedient by which the environment is subjugated to our will.

With this we have more closely circumscribed the scope of our topic as: *The role of the imagination in investigating the connection between cause and effect.*

We will define imagination as the ability to visualize any object with all its properties so that one recognizes it with the same great certainty as by simple observation. There now remains only to describe the mechanism with which the connection between cause and effect can be investigated and to ascertain where the ability just mentioned plays a role. This mechanism is extraordinarily simple. It is composed of two parts:

1. By means of the first, observation, one tries to obtain accurate knowledge of our environment forthwith.
2. By means of the second, the causal connection in it is investigated.

1. While observation as such, the giving of an account to oneself of the impressions on our sensory tools, requires nothing but skill in their use and the ability to focus their attention, there are higher demands to be made of those qualities which alone give observation its high value, namely:

- a) the choice of the moment or the object of observation,
- b) the discretionary change of the observed,
- c) the finding of those expedients which facilitate the observation and even frequently are the only means which make it possible.

These are just as many prerequisites in which completely different faculties play a role rather than skilled sense organs and attention.

a) Choice of the moment or the object of observation: Shortly before his death the French astronomer LEVERRIER predicted the existence of a new planet in proximity to the sun. Several observatories at his urging searched for this planet at the instant when it was located between earth and sun and should be seen as a dark disk on the latter. These observations were not crowned by the results hoped for. An American chose a different moment; *the*



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thought occurred to his mind that this planet could be visible during an eclipse of the sun in the same way as the moon during the night. Indeed, Vulcan was observed on this occasion for the first time.⁶

This so-called *occurring to the mind results from a requisite survey of the possible cases in one's mind and a definite selection therefrom*⁷, i.e., combined efforts of imagination with the power of critical judgment are required.

b) Of even greater significance than the choice of the object or of the moment of observation is the discretionary alteration of the observed, for here the possibility of the acuteness of judgement is revealed. TYNDALL wanted to find out during his studies on fermentation what happens if the air, which comes in contact with the fermenting substance, is altered by freeing it from those floating small dust particles which can be shown in it by means of a light beam.. He removed the dust particles very simply by covering the inside surface of the box, in which he carried out the experiment, with glycerol. After some time even the smallest dust particles stuck to the wall, like flies on a tar-covered fence.

Again imagination was responsible that this *thought occurred to his mind*.

c) Thirdly, the expedients which facilitate the observation and frequently are the only means to make it feasible. There is a difficulty which makes it impossible to observe the retina through the pupil although the latter is completely translucent. The difficulty is that precisely during observation, as the idiom states, one stands in one's own light. A flame put between the observed and the observing eye would illuminate the former but make its observation impossible. *The thought occurred to HELMHOLTZ'S mind* to place between both eyes a small mirror with a small aperture in such a way that a lateral light beam would fall in the subject's eye which now can be observed through the aperture. This synergism of imagination and critical judgment resulted in the invention of the ophthalmoscope.

So much for the first part of the mechanism. The result of its application is accurate knowledge of our environment; but this knowledge relates to a complex whole, to conglomerations of causes and effects.

[6] This has not been confirmed.. Vulcan has never been found and the mathematical necessity for its existence was removed by Einstein's relativity theory (GFS).

[7] It does not always seem a necessary precondition "to survey the possible cases"; the correct answers may occur to the mind "suddenly and without warning" – see the last sentence of this brochure (GFS) .



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2. It is now our task to unravel from this relative chaos one by one the individual threads which join each cause with its corresponding effect.

The way in which this takes place can be *paraphrased by the following allegory*⁸.

Several musicians, A, B, C, etc., simultaneously play different instruments behind a curtain. We think of these musicians as a coherent whole of causes; the concert generated by them is the (harmonious) conglomerate of effects. The question as to the connection between each given cause and its effect then concerns knowledge of the instrument played by each musician. The simplest expedient would certainly be to ask all musicians to stop playing for a moment except one, for example, A. But this is not always possible and the musicians can only all together play a bit more softly or somewhat louder. Suppose, also, in another instance at which one must confine himself to have A stop or to let him change his manner of playing.

This example refers only to the simplest case, in which one can regulate the participation of the musicians as desired for the experiment. Yet, even in the most complicated cases, all depends upon the observation of agreement or difference in the playing of the individual instruments.

On preparing ammonium arsenate MITSCHERLICH was impressed by the similarity of this salt with the corresponding phosphoric acid derivative which he had in his hands a short while before. Continued investigation furnished proof that it is the conformity in the shape of the crystals which expresses itself in this fashion. This observation which led to the discovery of the connection between composition and crystal-form is comparable to the ability to discern the same instrument in two otherwise completely different orchestras. Imagination is needed for both observations; if MITSCHERLICH had not had a vivid recollection of the first compound when he studied the second one, he would not have noted the correspondence.

Admittedly, imagination is used here in order to recall earlier observations; nevertheless, it cannot be ranked at the same level as memory, since the former has about the same relation to the latter as has the ability to imagine a certain person with that to retain his name.

Not all means for the investigation of causal connections are exhausted with this. The ones discussed so far only apply to instances in which the line of descent, so to speak, is a straight

[8] MILL, J S: System of Logic I, 448.



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line: causes on the one side, effects on the other. It is just as likely that several observations together can be the effects of a common, unknown cause. The investigation of these proceeds in a different manner, in that one considers a series of possible causes (hypotheses) and compares their effects with the facts.

It will turn out that at first there are deviations and perhaps for a second and third time as well, until at last correspondence will be found; then this possible cause has become the probable.

KEPLER'S studies of the planets are excellent illustrations of the usefulness of this second aid in the elucidation of the causal connections, especially since he also made known in the publications of his discoveries the way in which he came to make them. It would lead us too far to discuss this in detail here; it may suffice to point out that KEPLER'S imagination gave him new clues throughout twenty-two years until at last he was able to pursue the track of the possible cause and find the laws which today bear his name. It need hardly be said that in this instance the above-mentioned capability plays a role.

In summary, it follows: in the mechanism of investigating a causal connection imagination is necessary in five operations.

1. In the choice of the moment or the object of observation.
2. In the discretionary alteration of the observed.
3. In the finding of aids, which facilitate observation, and frequently even are a prerequisite to make it possible.
4. In the observation of a correspondence or a dissimilarity.
5. In the setting up of an hypothesis.

This mechanism by itself is sterile. The individual who possesses all these qualifications required by this mechanism will nevertheless remain without any significance if he lacks the irresistible drive to make use of these abilities, and this compelling drive which manifests itself first as enthusiasm and subsequently as perseverance is frequently the pursuit of an idea which exists only in the mind of the investigator and consequently represents the result of imagination. Such creations of the imagination, they may be correct or erroneous, have brought about miracles: the firm belief in the influence of celestial bodies on the fate of mankind and also that in the philosopher's stone have served astronomy and chemistry inestimably. FARADAY, who believed in the connection between light and electricity, tried



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to track down this connection for twenty-three years; he found it in the influence of magnetism in polarized light. This fancy, at the time, had only very weak foundations and FARADAY accordingly says of himself in a letter to DE LA RIVE⁹: “Do not suppose that I was a very deep thinker, or was marked as a precocious person. I was a very lively imaginative person and could believe in the ‘Arabian Nights’ as easily as in the ‘Encyclopaedia’.”

This brings me to history. The conviction just developed that imagination plays a role both in the ability to do scientific research as well as in the urge to exploit this capability, has prompted me to investigate whether or not this ability also manifests itself in famous scientists in ways other than their researches. A study of more than two hundred biographies showed that this was indeed the case and in large measure.

I consider artistic inclinations a healthy expression of imagination. I give here a few quotes so that everyone may judge the reasons upon which I have based my conclusion that this aptitude was present. The quotes are taken from the biographies in question:

1. NEWTON (ARAGO. Oeuvres. III. 324): “It was towards the end of his stay at Grantham that, besides a marked success in painting, he developed a remarkable poetic talent. Several productions from that time are carefully preserved by connoisseurs.”

2. HAÛY (BUCKLE. Miscellaneous Works. I. 10): “He was essentially a poet, and his great delight was to wander in the Jardin du Roi, observing nature, not as a physical philosopher, but as a poet. Though his understanding was strong, his imagination was stronger.”

3. MALUS (ARAGO. Oeuvres. III. 114): “I found, among his papers, two stanzas of an epic poem entitled The Creation of France or la Thémelie and two completed tragedies, one concerns the capture of Utica and the death of CATON, the other, which is entitled, ‘Elektra’, recounts the horrible vicissitudes of the house of Atreus. Beautiful verse and interesting situations, etc.”

4. LALANDE (YOUNG. Works. II. 596): “His earliest taste seems to have been for romantic tales, and he was fond of making little stories with the materials that he possessed, but their subjects were chiefly religious. Having been sent to Lyon, to continue his studies under the Jesuits there, he acquired a taste for poetry and eloquence, and was then inclined to devote himself to literature and to the bar; but an eclipse of the sun recalled his attention to astronomy.”

[9] TYNDALL, FARADAY as a Discoverer, p.7.



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5. GALILEI (ARAGO. Oeuvres. III. 260 and 286): “In his youth he was a great admirer of ARIOSIO; he knew the entire Orlando furioso by heart. During his time a dispute arose in Italy over the comparative merits of ARIOSIO and TASSO, a dispute in which he took part vehemently. Age did not weaken his art of expression nor the fluency of his poetry which distinguished the productions of his youth.”

6. POISSON (ARAGO. Oeuvres. II. 590 and 602): “He had striking success at Fontainebleau in his literary studies as well as in mathematics. He had a genuine passion for the theatre; this entertainment was expensive, but he paid for it by depriving himself of dinner every fifth and tenth day. He knew MOLIERE, CORNEILLE and above all the tragedies by RACINE by heart.” – “Thus he became a friend of DUCIS the poet, GERARD the painter and TALMA the tragedian.”

7. LACEPEDE (CUVIER. Eloges historiques. II. 375): “BUFFON was among those authors whom he was allowed to read at an early age; he carried his books with him on his walks. It was in the heart of the most beautiful country in the world, along the fertile valley of the Garonne, facing the rich hills and the view which the peaks of the Pyrenees terminate so majestically, that he was absorbed in the eloquent descriptions of this great naturalistic writer. Thus his love for the beauties of nature began at the same time as his admiration for the great painter to whom he owed the supreme enjoyment of nature. Both feelings remained united in his soul forever. Meanwhile, circumstances awoke an additional interest, not less suitable for a young, southern and imaginative mind: that of music. His father, his tutor, and nearly all his relatives were musicians. They met frequently to perform concerts. The young LACEPEDE listened to them with indescribable pleasure, and soon music became his second language which he wrote and in which he conversed with equal facility. One liked to sing his melodies and hear him play the piano or the organ. The entire city of Agen applauded the motifs that he had composed on request for a church ceremony. Thus, from success to success, he had advanced to the stage of writing a score for Armide when he found in the newspaper that GLUCK was also working on this opera. This made him withdraw from this venture. He could not resist, however, the temptation to show his outline to the great composer, who paid him the greatest compliment: GLUCK found that the young amateur had more than once fallen in with his own ideas.”

8. WATT (ARAGO. Oeuvres. I.376): “The anecdotic wit which our colleague showed with so much charm among his friends for more than half a century developed early in his life. Proof of it can be found for this in some unedited lines, which I have translated. They were written



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in 1798 by Mrs. MARION CAMPBELL, companion and childhood friend of the famous engineer:

During a journey to Glasgow Mrs. WATT entrusted her young son JAMES to one of her friends. She returned a few weeks later to see him, certainly not expecting the most peculiar reception awaiting her. “My dear lady,” said her friend, as soon as she saw her, “please hurry and take JAMES back to Greenock. I can no longer stand the excitation into which he puts me: I am completely exhausted by lack of sleep. Each night, when the regular hour of retirement of my family approaches, your son succeeds ingeniously to start a discussion during which he always finds the opportunity to introduce a story which then leads to a second and a third and so on. These stories, which may be moving or ludicrous, are so interesting and have so much charm that my entire family listens to them with such attention that one could hear a fly moving. One hour follows the other without us noticing it, but the next morning I am dead tired. Therefore, Madame, I beg you to take your son home.” – (*ibid.* 472): Here are the terms in which Sir WALTER SCOTT speaks about his countryman in the foreword of *Monastère*: “We eventually found out that no frivolous novel escaped his attention, and the passion of the illustrious scholar for this kind of literature was as lively as that of the young eighteen-year old milliners.”

Our colleague would have made himself a name among the romance writers, if he had wished to do so; in private company he rarely failed to outdo terrible, touching or funny anecdotes which he heard being told. The smallest details of his stories, the proper names with which he studded them, the technical descriptions of the castles, of the country mansions, of the forests, and of the retreats where the action was successively moved, gave his extemporaneous talks such a great air of truth that one would have reproached oneself for even the slightest feeling of mistrust. On a certain day, nevertheless, WATT entangled himself and was sorely tried in attempting to extricate his characters from the maze in which he had thrown them incautiously. One of his friends noticed the unusual number of pinches of snuff which the narrator took in order to legitimate his frequent interruptions and give himself time for reflection. Therefore he asked him the indiscreet question: “Have you, by any chance, told us a story which you made up?” – “This doubt amazes” me retorted the old man naively, “during the twenty years in which I had the good fortune to pass my evenings with you, I have not done anything else.”

9. DAVY (CUVIER. *Eloges historiques*, III. 118): “Left to himself, he hunted, fished and ran in every direction through the picturesque countryside. He tried already to praise its beauty,



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because almost from infancy he had been an orator and a poet. His impressions were woven into his speeches: Whenever he came to school he was surrounded by his little playmates: they crowded one another and forgot everything else to hear his stories. His reading excited him as much as his observations; as soon as a translation of HOMER fell in his hands, he wrote an épopée off which DIOMEDES was the subject; it was a composition full of life and of varied incidents where a richness of invention and a freedom in execution were revealed which clearly showed a true poet.” – (*ibid.* 119): “As he wandered through the fertile countryside of Cornouaillés, he recited aloud verses by HORACE or by himself, as he had already written a large number. From this time dates his ode to mount Saint-Michel and his poem about Mounts-Bay, two of his most beautiful poems.”

10. AMPERE (ARAGO. Oeuvres. II. 11): “At the same time AMPERE saw by chance an open volume with verses addressed by HORACE to LICINIUS. Our friend, who so far had understood just as much Latin as he needed to comprehend mathematical reports, did not understand the verses, but was captivated by their rhythm. From this time on, he proved a rare exception to the general rule of moralistic ethics, namely that the human heart is unfit to harbor more than one ardent passion at a time. He devoted himself with infinite fervor to the simultaneous study of plants and of the poets of AUGUSTUS’ time. A volume of the *Corpus poetarum latinorum* accompanied him on his botanical excursions in the same way as the work by LINNE. The nearby hills of Poleymieux rang daily with some passages from HORACE, VIRGIL, LUCRECIUS or more often from LUCIAN between the meticulous dissections of a flower leaf or a fruit.”

The preceding serves to define what we mean by the presence of an artistic inclination. Following are the names of those among the two hundred famous scientists, chosen at random, where it has been found:

AMPERE, BAILLY, BONAFOUS, BORDA, BOYLE, CASSINI, DE LA CONDAMINE, COPERNICUS, DAVY, DELESSERI, DUPASQUIER, DESCARTES, EBN-JOUNIS, FARADAY, FLAMSTEED, GALILEI, GESNER, GOETHE, HAILE, VON HAILER, HALLEY, HAÛY, the two HERSCHELS, INGEN-HOUSS, KANT, KEPLER, VON KOBELL, LACEPEDE, LAGNY, LALANDE, LEIBNIZ, LEMERY, LEONARDO DA VINCI, LINNAEUS, MALUS, MILLER, NEWTON, PAISSY, PASCAL, POISSON, RAMOND, ROUSSEAU, RUMFORD, SCHIEDEN, SCILLA, SCHOPENHAUER, SMITHSON, TENNANI, TYCHO-BRAHE, VOLTA, VOLTAIRE, WATT¹⁰:

[10] This study is far from being exhaustive and immediately after the lecture I was given the names of: CARUS, CHAMISSO and EULER.



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These are all together fifty-two names, i.e., 26 per cent. The following fact is offered as proof that this high percentage is not the consequence of an *arbitrary* choice of biographies: ARAGO has handed down to us details of the lives of twenty-nine famous astronomers¹¹; twelve of these, i.e., more than 40 per cent, comply with the requirements described earlier¹². Remarkably, one finds among these the best names: COPERNICUS, TYCHO-BRAHE, KEPLER, GALILEI and NEWTON.

So much for the healthy expression of a vivid imagination. In the second line we want to turn to the diseased imagination, since it has come to my attention that examples of the most bizarre imagination, superstition, spiritualism, hallucinations, even insanity, occur not infrequently in the examined biographies. NEWTON always was afraid that an accident would befall him in a carriage and thus held himself onto the door. KEPLER's conception of the universe was most peculiar; he seriously believed the earth to be a reptile and that the planets which surround the earth produced a melodious chord by their movement (Jupiter and Saturn form the bass, Mars the tenor, and so on).

DAVY describes in his, "Consolations in Travel or the Last Days of a Philosopher", (page 44) a visit to Saturn with the following words:

"Looking through the atmosphere towards the heavens, I saw brilliant opaque clouds of an azure color, that reflected the light of the sun, which had to my eyes an entirely new aspect, and appeared smaller, as if seen through a dense blue mist. I saw moving on the surface below me immense masses, the forms of which I find it impossible to describe; they had systems for locomotion similar to those of the morse or sea-horse, but I saw with great surprise that they moved from place to place by six extremely thin membranes, which they used as wings. Their colors were varied and beautiful, but principally azure and rose-color. I saw numerous convolutions of tubes, more analogous to the trunk of an elephant than to anything else I can imagine, occupying what I supposed to be the upper parts of the body, and my feeling of astonishment almost became one of disgust, from the peculiar character of the organs of these singular beings; and it was with a species of terror that I saw one of

[11] *Hipparchus*, PTOLEMY, AI-MAMOUN, ALBAIEGNIUS, ABOUL-WIFA, *Ebn-Jounis*, ALPHONSE, REGIOMONIANUS, *Copernicus*, *Tycho-Brahe*, GUILLAUME, *Kepler*, *Galilei*, *Descartes*, HEVELIUS, PICARD, *Cassini*, HUYGENS, *Newton*, ROEMER, *F'lamsteed*, *Halley*, BRADLEY, DOLLOND, LACAILLE, *Herschel*, BRINKLEY, GAMBARI, LAPLACE.

[12] Those whose names are printed in italics.



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them mounting upwards, apparently flying toward those opaque clouds which I have before mentioned.”

PRIESTLEY had his own special religion which he defended in innumerable articles. CUVIER remarks about this as follows (Eloges historiques I, 118): “His dissenting activities showed no limits, he compulsively fought alike atheists, deists, jews, arians, quakers, methodists, calvinists, anglicans and catholics. There are books by him against each of these creeds separately and I would have difficulties to finish even if I wanted only to list the titles. Proof that all this was done in the best of faith is that he believed in his ability to predict from the Bible events which were to occur. Those prophets who are not convinced make only prophecies far in advance, that they may not be contradicted during their lifetime. PRIESTLEY was more certain of his mission; in 1799 he published a document addressed to the jews in which, according to the revelation of DANIEL and ST. JOHN, he predicted to them their approaching reestablishment in Palestine, the reconciliation of all faiths and the establishment of the kingdom of heaven.”

The “Observations upon the Prophecies of Holy Writ, particularly the Prophecies of DANIEL and the Apocalypse of ST. JOHN” of a NEWTON; the theory of “Monades” of LEIBNIZ; the “Tourbillons” of DESCARTES; the “Mesmerism” of AMPERE and BAILLY; the “Spiritism” of CROOKES, WALLACE and SCHOPENHAUER; the “Hallucinations” of DESCARTES:

“He frequently had dreams which interpreted by him the next morning seemed proof of complete derangement of his intellect In one of these dreams he made the vow of a pilgrimage to Notre-Dame de Lorette.” (ARAGO. Oeuvres. III, 299.)

I mention all this in order to delineate what is to be understood by a deranged expression of fantasy. I found it among the following two hundred arbitrarily chosen famous scientists: *Ampère*, BAILLY, BONNET, *Boyle*, CROOKES, *Davy*, *Descartes*, *Flamsteed*, *Häüy*, *Leibniz*, *Newton*, PRIESTLEY, *Ramond*, *Schopenhauer*, WALLACE. Remarkably, eleven of these fifteen (those in italics) have already been named in the preceding category.

We have now pointed to the important role which falls to imagination among the abilities which contribute to form a productive researcher. We have also noted that imagination occupies the place in the history of Science which we suspected. We would now like to make one more remark, which relates to our time.



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The number of those who are engaged in scientific research increases; previously, only irrepressible drive and extraordinary talents were able to overcome all difficulties which stood in the way of a scientific career. Today this road is open and the path well-trodden.

But the consequence of just this is that with the increasing number the mean value of the contributions is lowered; the rare gifts, among these, imagination, fall into an unfavorable relationship with those gifts which are more commonly distributed. This has changed the ways and means by which the scientific mechanism operates.

If the diaphragm, which plays the predominant role in breathing, is artificially paralyzed, then the chest takes over for a while the work of the diaphragm as best it can. If imagination is lacking, then one tries by other means to compensate for this deficiency:

1. The careful choice of the object and the moment can be substituted by systematic observation of all phenomena at every moment; the firmament has been apportioned over the various observatories and there is little which can escape attention; what crystallizes is sent to Strasbourg¹³, measured and tabulated.
- 2, 3. The attainment of a result, which requires experimentation or refinement of the means of observation can be supported by groping and testing in all directions.
4. Discoveries can be facilitated if one expresses the observations in numbers and compares these with one another.
5. The hypothesis finally becomes so transparent through the innumerable observations, that only a small step is needed to formulate it.
6. Enthusiasm can be pretentious ambition.

Actually the requirements are satisfied herewith as the results prove. But scientific discovery has now become something different from what it was : It *resembles* the shooting down of a fortress from different sides, the cautious scaling of the ruins, and the battle to raise the flag on top after the arrival of all forces. Before, it *resembled* the simple advancement of a single battery like the one which NAPOLEON used to subdue the British

[13] P GROTH, an established crystallographer, taught at Strasbourg; VAN 't HOFF studied under him in the summer of 1878, *i.e.*, shortly before his inaugural lecture (GFS).



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navy at Toulon. Even though it is now possible to compensate for imagination with a great effort of work, imagination has not been excluded. The role which it plays is a different one, but not the role which it is capable of playing. Even today KEPLER would have been able to rise above his environment in the same way as he did in his time.

At the end of a biography, CUVIER once compared two great chemists, VAUQUELIN and DAVY; he expressed himself about as follows¹⁴: “Notwithstanding his innumerable investigations and in spite of the important and noteworthy observations with which VAUQUELIN enlarged the stock of scientific knowledge, he cannot be considered as of the same caliber as DAVY. The former put his name in the paragraphs; the latter in the titles of each chapter. In a completely unpretentious manner, the former observed with a lantern the smallest obscurities and penetrated into the darkest nooks; the latter ascended like an eagle and illuminated the large realm of physics and chemistry with a shining beacon.”

I make these words my own in order to describe what research is without imagination, and what it can be if one uses it in an admissible manner. VAUQUELIN did not appear in the two classifications above; DAVY, however, did in both as poet as well as visionary. His discoveries were the fruits of that great gift which BUCKLE¹⁵ describes: “There is a spiritual, a poetic, and for aught we know a spontaneous and uncaused element in the human mind, which ever and anon, suddenly and without warning, gives us a glimpse and a forecast of the future, and urges us to seize the truth as it were by anticipation.”

[14] *Eloges historiques*, III, 174.

[15] H T BUCKLE (1821–1862), English historian, author of *History of Civilization in England* and internationally famous chess player (GFS).

