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Anatomy of the Unsought Finding. Serendipity: Origin, History, Domains, Traditions, Appearances, Patterns and Programmability

PEK VAN ANDEL*

ABSTRACT

I define serendipity as the art of making an unsought finding. And I propose an overview of my collection of serendipities, the largest yet assembled, chiefly in science and technology, but also in art, by giving a list of 'serendipity patterns'. Although my list of 'patterns' is just a list and not a classification, it serves to introduce a new and possibly stimulating perspective on the old subject of serendipity. Knowledge of these 'serendipity patterns' might help in expecting also the unexpected and in finding also the unsought.

- 1 *Origin*
- 2 *History*
- 3 *Chance*
- 4 *Unanticipated, Anomalous and Strategic*
- 5 *Abduction*
- 6 *Domains*
- 7 *Traditions*
- 8 *Appearances*
- 9 *Patterns*
- 10 *Conclusions*
- 11 *Epilogue*

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A *propos*: a travelling serendipity exhibition is available, also for 'new democracies': 'Freedom of opportunity as developed by democracy is the best human reaction to divergent phenomena. We may, in fact, define 'freedom' as 'the opportunity to profit from the unexpected.' (Langmuir [1956])

Unless you expect the unexpected you will never find [truth], for it is hard to discover and hard to attain. (Heraclitus, 540–480 BC)

(Socrates: 'I understand the point you would make, Meno. Do you see what a captious argument you are introducing—that, forsooth, a man cannot inquire either about what he knows or about what he does not know? For he cannot inquire about what he knows, because he knows it, and in that case is in no need of inquiry; nor again can he inquire about what he does not know, since he does not know about what he is to inquire.' Sophists, 500–300 BC, as cited by Socrates, who disagreed with it. (Plato)

I ORIGIN

Once upon a time the King of Serendip (a medieval Persian name for Sri Lanka) had three sons who refused to succeed their father after their education. The King banned them. The three Princes began to travel by foot to see the different countries and miracles of the world.

One day they walked along the track of a camel. The eldest brother saw that the grass on the left side of the track was grazed bare, while the sappy grass on the right was undisturbed. He concluded that the camel's right eye was blind. The middle brother observed in the left verge many plugs of chewed grass. That gave him the idea the camel might miss a tooth. The youngest brother inferred from the relative faint imprint that the left back leg of the camel was crippled. Further on, the eldest brother noticed on one side of the track over a distance of a mile an endless stream of ants consuming something and on the other side a vast mass of bees, flies and wasps nibbling a transparent sticky stuff. He gathered that the camel was loaded on one side with butter and with honey on the other. The second brother discovered traces indicating that the animal had kneeled. He also found there marks of small human feet and a wet spot. He touched it with his fingers and even before smelling them he felt a carnal temptation. He concluded that a woman sat on the camel. Handprints on both sides of the place where she had watered were noticed by the third brother. The woman had supported herself because of the size of her body and might be pregnant, he thought.

Later the three brothers met a camel driver, who missed one of his animals. Because they had seen so many tracks they joked that they had seen the camel and to make it credible they mentioned the seven marks, which all appeared right. Accused of theft the brothers were put in jail. But the unharmed camel was found and they were released.

After many other travels and adventures they succeeded their father in Serendip.

So far my summary of the first part of a long fairy tale in the American translation, edited by Remer [1965]. This text is based on the Italian *Peregrinaggio di tre figliuoli del re di Serendippo* [1557], the free adaptation by the Armenian Christopher from the *Hasht Bihisht* (*Eight Paradises* [1302])

of Khusrau, India's greatest Persian-language poet, who lived in Delhi. (Camman [1967])

The word 'serendipity' was coined and defined on 28 January 1754 by Horace Walpole, the 'genial dilettant', in one of his eighteen hundred letters to Horace Mann. He knew this British envoy in Florence from his *grand tour*:

This discovery indeed is almost of that kind which I call serendipity, a very expressive word, which as I have nothing better to tell you, I shall endeavour to explain to you: you will understand it better by the derivation than by the definition. I once read a silly fairy tale, called The Three Princes of Serendip: as their Highnesses travelled, they were always making discoveries, by accidents & sagacity, of things which they were not in quest of: for instance, one of them discovered that a mule blind in the right eye had travelled the same road lately, because the grass was eaten only on the left side, where it was worse than on the right—now do you understand serendipity? . . . (you must observe that no discovery of a thing you are looking for, comes under this description) . . .

As Remer remarks in his book (with a photocopy of the original manuscript of this letter with Walpole's own underlinings as cited above), Walpole presumably believed that the discovery of the marks on the sand was accidental and that the interpretation of it was a sagacious act. This seems a tenuous rationale for Remer, who cites the correspondence of Walpole again to show Walpole's appreciation for the magnificent definition, that he had coined:

Nor is there any harm in starting new game to invention; many excellent discoveries have been made by men who were *à la chasse* of something very different. I am not quite sure that the art of making gold and of living forever have been yet found out—yet to how many noble discoveries has the pursuit of those nostrums given birth! Poor Chemistry, had she not had such glorious objects in view!

2 HISTORY

Merton and Barber [1958] wrote a draft typescript of 338 pages ('to be revised and perhaps extended'): *The Travels and Adventures of Serendipity, A Study in Historical Semantics and the Sociology of Science*. It is the best study on serendipity I ever read, but until now it has not been published, despite the interest recently expressed in it by the estimable publisher Norton. An ironic example of 'negative serendipity' or a missed opportunity. But Il Mulino (Bologna) is publishing an Italian edition of it. Merton and Barber mention in their *Begriffsgeschichte* that it took till 1833 before the word 'serendipity' was printed: the above cited crucial letter was then published in the Mann correspondence. And in 1875 'serendipity' was used for the first time in print by somebody else, namely the antiquarian, bibliophile and former chemist Solly in the periodical *Notes and Queries* and therewith launched into literary

circles. 'Serendipity' was to be used almost only by bibliomaniacs till the 1930s, when Cannon [1945], professor of physiology at Harvard Medical School, cultivated the word serendipity, that he later on also mentioned and illustrated with the chapter *Gains from Serendipity* in his book *The way of the investigator*.

According to Merton and Barber the word 'serendipity' was used by collectors, writers of fiction and non-fiction, literary scholars and lexicographers, medical humanists, social scientists, science writers and in applied research.

3 CHANCE

The notion that chance plays an important role in the process of discovery is much older than the coinage and the use of the word serendipity. To illustrate this Merton and Barber quote two notable English scientists, Hooke from his preface of his *Lectiones Cutlerianae* [1679]:

... (The greatest part of Invention being but a lucky bitt of chance, for the most part not in our own power, and like the wind, the Spirit of Invention bloweth where and when it listeth, and we scarce know whence it came or wether 'tis gone.) 'Twill be much better therefore to embrace the influence of Providence, and to be diligent in the inquiry of everything we meet with. For we shall quickly find that the number of considerable observations and Inventions this way collected will a hundred fold out-strip those that are found by Design.

and Priestley from his introduction of his *Experiments and Observations on Different Kinds of Air* [1775]:

The contents of this section will furnish striking illustration of the truth of a remark which I have more than once made in my philosophical writings, and which can hardly be too often repeated, as it tends greatly to encourage philosophical investigations; viz. that more is owing to what we call chance, that is, philosophically speaking, to the observation of events arising from unknown causes, than to any proper design, or preconceived theory in this business. This does not appear in the works of those who write synthetically upon these subjects; but would, I doubt not, appear very strikingly in those who are the most celebrated for their philosophical acumen, did they write analytically and ingeniously.

An often wrongly cited remark on the role of chance was made by the chemist and microbiologist Pasteur in 1854 in his opening speech as Dean of the new *Faculté des Sciences* at Lille:

It was in that memorable year 1822, Ørsted, a Danish physicist, kept in his hands a copper wire connected with its ends to the both poles of a pile of Volta. On his table was a magnetic needle, placed on its pivot, and he saw suddenly (by chance, you might say, but remember, that in the sciences of observation, chance favors

only prepared minds), he saw suddenly the needle move and taking a position very different from that given to it by the magnetism of the earth. A wire conducting an electric stream did change the position of an magnetic needle. Sirs, that was the birth of the actual telegraph.

I translated this quote directly from Pasteur's original manuscript send to me in copy by Grmek [1984], who remarked that Pasteur wrote: '*des esprits préparés*' ('prepared minds'), printed and mostly quoted as: '*les esprits préparés*' ('the prepared minds'). Above the entrance of Harvard Medical School it was 'quoted' as: 'Chance favors only the prepared mind.' Ørsted's discovery, that an electrified wire can induce motion in a magnet, is now regarded as an example of 'pseudoserendipity', see below Section 8.3).

Eleven years later Bernard [1865], the father of experimental physiology in France, wrote in his classic *Introduction à l'étude de la médecine expérimentale*:

Experimental ideas are often born by chance, with the help of some casual observation. Nothing is more common; and this is really the simplest way of beginning a piece of scientific work. We take a walk, so to speak, in the realm of science, and we pursue what happens to present itself to our eyes. Bacon compares scientific investigation with hunting; the observations that present themselves are the game. Keeping the same simile, we may add that, if the game presents itself when we are looking for it, it may also present itself when we are not looking for it, or when we are looking for game of another kind.

4 UNANTICIPATED, ANOMALOUS AND STRATEGIC

Merton [1957] remarked that empirical facts aid in the initiation of theory:

The serendipity pattern refers to the fairly common experience of observing an *unanticipated, anomalous and strategic* datum which becomes the occasion for developing a new theory or for extending an existing theory. Each of these elements of the pattern can be readily described. The datum is, first of all, unanticipated. A research directed toward the test of one hypothesis yields a fortuitous by-product, an unexpected observation which bears upon theories not in question when the research was begun.

Secondly, the observation is anomalous, surprising, either because it seems inconsistent with prevailing theory or with other established facts. In either case, the seeming inconsistency provokes curiosity; it stimulates the investigator to 'make sense of the datum', to fit it into a broader frame of knowledge. (. . .)

And thirdly, in noting that the unexpected fact must be strategic, *i.e.*, that it must permit of implications which bear upon generalized theory, we are, of course, referring rather to what the observer brings to the datum than to the datum itself. For it obviously requires a theoretically sensitized observer to detect the universal in the particular.

5 ABDUCTION

Merton [1957] described serendipity as an observation of a surprising fact

followed by a correct 'abduction'. To distinguish *abduction* from deduction and induction I quote Peirce [1965] (who according to Deely [1982] re-discovered *abduction* around 1866, as Poinset had done in 1631):

There are in science three fundamentally different kinds of reasoning. Deduction (called by Aristotle *συναγωγή* or *ἀναγωγή*), Induction (Aristotle's and Plato's *ἐπαγωγή*), and Retrodution (Aristotle's *ἀπαγωγή*, but misunderstood because of corrupt text, and, as misunderstood, usually translated *abduction*). Besides these three, Analogy (Aristotle's *παράδειγμα*) combines the characters of Induction and Retrodution. [a]

Peirce regarded *abduction* (he used as synonyms *retrodution*, *hypothesis* and *presumption*) as the only form of reasoning to discover something new:

It [induction] never can originate any idea whatever. No more can deduction. All the ideas of science come to it by abduction. Abduction consists in studying facts and devising a theory to explain them. [b]

Abduction is the process of forming an explanatory hypothesis. It is the only logical operation which introduces any new idea; for induction does nothing but determine a value, and deduction merely evolves the necessary consequences of a pure hypothesis. Deduction proves that something *must* be; Induction shows that something *actually* is operative; Abduction merely suggests that something *may* be. Its only justification is that from its suggestion deduction can draw a prediction which can be tested by induction, and that, if we are ever to learn anything or to understand phenomena at all, it must be by abduction that this is to be brought about. [c]

The first starting of a hypothesis and the entertaining of it, whether as a simple interrogation or with any degree of confidence, is an inferential step which I propose to call *abduction*. [d]

Eco [1983] described three levels of abduction:

(1) *Overcoded abduction*: from a surprising fact to another fact, based on a given rule, for example: Horace Walpole was 'the youngest son' of the first and great British prime minister: latterly Sir Robert Walpole. But he looked in every respect like Carr Lord Elvey, a known flame of his mother (also their memoirs are remarkably alike). Walpole, a keen observer, might have abducted his spurious parentage this way. He must have known it, but there is no evidence that it crossed his mind. (Cunningham [1891]) or is his letter, partly quoted in section 1, also an allusion to it?

I cannot free myself from my guessed link between the wellknown 'unintended?' fathering of Walpole and the fact that he, of all people, created this rhythmic and impossible word. Was he the personification of serendipity?

In the English translation of *The Three Princes of Serendip* of Kushrau, by Habib [1927], one of the princes discovered that a king had 'a butler's blood in his veins'. The king interrogated his mother, the queen, who confessed:

For years I have kept my secret undisclosed, but you shall hear my story, if your ears can stand the shock. It was the season of the spring. The king had gone out

hunting. I had been sleeping alone in my chamber, when on opening my eyes I saw a butler enter the door with my food on a tray. I was young, in the vigour of my health and the blossom of my beauty; inspired by a passion that vanquished my self-control, I flew at him like one drunk and would let him not go till he had done my bidding. From that union, you, my son, were born. It had been so inscribed in the book of my fate.

In the Italian translation of 1557 this passage was already expurgated.

(2) *Undercoded abduction*: from a surprising fact to a possible rule, for example: Jenner practiced medicine in Berkeley in Gloucestershire. There, as in other counties of western England, was a local tradition that milkmaids, who had caught cowpox, were immune to smallpox. In 1796 Jenner inoculated a healthy boy with material from a blister of a milkmaid with cowpox. The boy developed cowpox. Jenner infected him then twice with smallpox: he appeared immune to smallpox or 'vaccinated'.

(3) *Creative abduction*: from a surprising fact to a new rule, that has to be invented, *f.e.* in 1910 the Russian painter Kandinski saw one of his works:

The painting had no subject at all, did not show any recognizable subject and consisted only out of clear fields of color. At last I came nearer and recognized it, for what it was—my own painting standing on its side on the easel . . . One thing became clear to me—that objectivity, the depicting of objects, was not necessary in my paintings and could indeed even harm them.

This way the father of abstract art gave his first impetus to it.

A meta-abduction is mostly a creative abduction, which leads to a change in paradigm (crucial in revolutionary scientific discoveries), *f.e.* Janski's invention of the radioastronomy, see below Section 9.12.

Eco illustrates his three levels of abduction with the text of the third chapter of *Zadig*. The text of Voltaire was written in 1747 and was inspired to such extent by a version of the *Peregrinaggio* (possibly *Les Soirées bretonnes*, a free French translation of Christopher by Gueulette in 1712), that Voltaire was in 1767 even (unjustly) accused of plagiarism. (Voltaire, [1748], Gueulette, [1786])

6 DOMAINS

My collection of more than one thousand examples of serendipity shows roughly four domains of serendipity (each followed by one or more examples):

(1) *Science*: X rays ('X' is of course the mathematical symbol for the unknown). Röntgen: 'I discovered by chance rays that penetrated black paper.' Years later, when asked, what he then thought: 'I didn't think; I experimented.' (Asimov [1976])

(2) *Technology*: Ktesibios, born in Alexandria, a son of a barber, had love and talent for mechanical things. When he hung a mirror in the shop of his father he made a construction by which the mirror could be moved up and down. A counter weight, a ball of lead, hanging invisibly in a pipe, was connected with a rope to the mirror via wheels. When the weight came down the air in the pipe compressed and escaped with a sound. Using this surprising finding Ktesibios was the first to construct hydraulic constructions like a cylinder with a piston. (Vitruvius [15 BC])

(3) *Art*: One day Picasso had only blue, no other colors. This inspired him to use only blue. The specific effect intrigued him enough to continue with what is now called his 'blue period'. Picasso described his own way of painting as: '*Je ne cherche pas, je trouve.*'

(4) *Daily life*: Honda introduced large motorcycles in the U.S.A. because analysis of the market had shown the demand for those. The salesmen travelled on small Honda motorcycles. Although the public in the U.S.A. showed a surprising interest in the small ones, it did not occur to the Honda people to sell them: a missed chance. But when the large motorcycles showed defects, the small motorcycles were offered for sale, with great success. Mintzberg [1967] calls this an 'emergent strategy'.

To fall in love with a surprising person. Do you agree that it is 'like looking for a needle in a haystack and rolling out with the farmer's daughter or son?' (The popular definition of serendipity!)

7 TRADITIONS

My files on serendipity show five ways by which a case can come to us, namely as:

(1) *Fairy tale*: The Chinese swineherd's son, Bo-Bo, stumbled upon the delicacy of roast pork when, playing with fire, he accidentally burnt down his father's cottage, and roasted thereby newly farrowed pigs. The art of roasting meat was invented this way in a story of the humorist Lamb. (Comroe [1977a]) (More humour? As a small child, playing with fire, I have really burned down my parental house unintentionally. I suppose that this was the germ of my pet sin to collect serendipities and my 'serendipitology'.)

(2) *Aprocryphal story*: The famous legend about 'Kaldi and the Coffee Bean'. The goatherd Kaldi saw, to his surprise, that his goats became very active after eating violet berries. He told it to an Imam, who systematically experimented

with the berries: he parched and boiled them, drank the galenic extract and did not fall asleep when he prayed. Thus 'coffee' was born. (Berry [1989])

(3) *Fake, false or exaggerated serendipity*: Fiction seen as non-fiction, intentionally or not, known or not. The falling apple that led Newton to his revolutionary synthesis: The discovery of the universality of gravity. According to different sources Newton told this in his later years. As Valery commented: '*Il fallait être Newton pour apercevoir que la lune tombe, quand tout le monde, voit bien qu'elle ne tombe pas.*' (Lot [1956a])

(4) *Unknown, unpublished, hidden or denied serendipity*: 'Retrospective falsification' for example because of beliefs, traditions or dogmas about 'scientific methods', articles, editors, referees, journals, fund raising, careers and/or 'selfrespect'. McLean looking for blood clotting factors, discovered heparine as an anticoagulant (a factor preventing blood clotting), but didn't 'tell it like it was' until 41 years later (Comroe [1977b]):

I had in mind, of course, no thought of an anticoagulant, but the experimental fact was before me; and I retested again and again until I was satisfied (. . .)

(5) *Well-documented, authentic serendipity*: From laboratory diaries, notebooks with experimental results, scientific articles, textbooks, case histories, acceptance lectures of Nobel laureates, memoirs, autobiographies, informal talks, etc. The value of such sources is of course not absolute. The serendipitous discovery of X-rays and the 'pseudoserendipitous' discovery of penicillin (see below Section 8.3) are good examples of this category.

8 APPEARANCES

I discriminate three appearances of serendipity:

(1) *Positive serendipity* (Barber *et al.* [1958]): A surprising fact or relation is seen and followed by a correct abduction, Röntgen's discovery of X-rays, for example.

(2) *Negative serendipity* (Barber *et al., op. cit.*): A surprising fact or relation is seen but not (optimally) investigated by the discoverer, Columbus' 'New World', for example

(3) *Pseudoserendipity* (the term was coined by Roberts [1989d]): To discover, invent, create something you were looking for in a surprising way, Fleming discovered penicillin after he had discovered lysozyme:

It was (. . .) fortunate that (. . .) I was always on the lookout for new bacterial inhibitors, and when I noticed on a culture plate that the staphylococcal colonies

in the neighborhood of the mold faded away, I was sufficiently interested in the antibacterial substance produced by the mold to pursue the subject.

9 PATTERNS

Until now, I collected seventeen ways in which unsought findings have been made. Following Merton and Barber I call them 'serendipity patterns'. They can coexist, overlap and/or cooperate. I will illustrate each pattern with one or more cases of serendipity:

(1) *Analogy (the similarity, analogon or 'metaphor' comes from the same or from a totally different context):* Laënnec invented the stethoscope after seeing children playing. They scratched with pins on one end of a piece of wood and listened with their ears on the other end.

Biological analogy (copied from living nature: 'bionics') The entomologist De Réaumur wrote in 1719 to the French Royal Academy that wood pulp like that used by wasps to build their nests might offer a remedy for the growing shortage of rag papers in the increasingly literate Europe. The fabrication of the paper you are reading now was thus inspired by wasps.

Personal analogy: Archimedes identified himself with the 'golden' crown to such an extent that he discovered a way to measure its volume, after stepping into a bath. (Vitruvius [15 BC])

(2) *One surprising observation:* Blass, an Israeli water engineer, in the thirties, happened to pass a row of trees. He noticed that one of the trees was much taller than the others. On investigation he found that, although the soil around the tree was dry, water was continually dripping from a nearby leaking connection in a water pipe. This gave him the idea of an irrigation method supplying plants with small and steady amounts of water for a period time. He designed a suitable moulded dripper and 'trickle irrigation' was soon shown to be an important method. (Badger [1973])

(3) *Repetition of a surprising observation:* AIDS, as a rare syndrome of rare symptoms, was found by a 'heaping' of cases.

(4) *Successful error:* The 'bad and discarded' glue, the 'temporarily permanent' adhesive on removable self-stick 3M post-it notes, was unintentionally invented at 3M. (Roberts [1989a])

If it is an assistant that makes the successful error he is normally gratefully 'credited' by the boss: *f.e.* 'Ringer's solution' as an essential reagent in the everyday use for the maintenance of living cells. Because Ringer's laboratory boy, one Fielder, had used ordinary tap water instead of distilled water ('limited

sloppiness') to make a solution of table salt in a concentration found in frog's blood, that Ringer normally used for experiments on the hearts of frogs outside their body. Tap water contains calcium and potassium ions which regulate heart muscle performance. (Kohn [1989])

(5) *From side-effect to main effect*: In 1945 Huant gave nicotinamide to patients undergoing radiation therapy to lessen nausea, vomiting and skin damage. He noticed that it worked also as a drug against tuberculosis. Many derivatives of nicotinamide were tested, and isoniazid was found for the treatment of tuberculosis. (Comroe [1977c]) Another derivative, iproniazide, gave as a by-effect a good mood to patients with tuberculosis. It became a drug against depression. (Jeste *et al.* [1979])

(6) *From by-product to main product ('spin-off')* Perkin tried to make quinine artificially from toluidine, derived from coal tar, a cheap byproduct of the steel industry. He failed. He got a black solid. Examining it, before throwing it away, Perkin noticed, washing out the solid, that the flask turned purple. This unexpected result fascinated him. He found out that it could dye cloth. This 'mauve' was the first successful synthetic dye and the unintended birth of organic chemistry. (Roberts [1989b])

(7) *Wrong hypothesis*: The Australian psychiatrist Cade reasoned that mania might be caused by a substance in the body fluids. He began a search for such a hypothetical compound by injecting urine of manic patients and of normal people in the abdominal cavity of guinea pigs. He also investigated the effect of uric acid, because of its high concentrations in urine. He therefore worked with lithium urate, which is more soluble than other salts of uric acid. As a control for the effects of lithium as opposed to effects of lithium urate he injected a solution of lithium carbonate into other guinea pigs. To his surprise these animals became lethargic. Cade speculated that the calming effect of lithium might have a therapeutic effect in manic patients. Lithium carbonate is now the treatment of choice for mania. (Cade [1949])

(8) *No hypothesis*: Hahn and Strassmann bombarded uranium with neutrons and found some barium, an element about half the size of uranium. Because there had been no barium in the bombarded sample, they could not understand the unexpected result. At last they had to conclude that some uranium with a nuclear charge of 92 had been cut in two, because barium had a nuclear charge of 56 and crypton, which they also found, a nuclear charge of 36. Hahn:

The total breakdown of uranium was regarded impossible. And it is exactly that what really happens with uranium. Actually without willing it Strassmann and I arrived in the autumn of 1938 at conclusions which went straight against the

views of the physicists. (. . .) We were long convinced that there was a mistake here in our experiments.

Meitner, Frisch and Bohr heard about it and called it 'nuclear fission'. (Roberts [1989c])

(9) *Inversion*: McLean (see above, Section 7.4).

(10) *Testing of a popular 'belief'*: Jenner (see above, Section 5.2).

(11) *Child, student or outsider*: Rubella during pregnancy as a cause of congenital cataract was suggested to the Australian ophthalmologist Gregg by a mother whose child had the defect. (Beveridge [1980])

(12) *Disturbance*: Radio-astronomy was, with the help of the physicist Janski, born out of the 'noise' in transatlantic telephone calls, that showed a periodicity of 23 hours and 56 minutes. (Kellerman [1983])

(13) *Scarcity*: The cigarette is an improvisation of a beggar of Seville using tobacco from discarded cigar butts.

(14) *Interruption of work*: Glycogenesis (sugar-metabolism) in the liver was discovered by Bernard, who measured *in duplo*, with many hours in between, because he was '*pressé par le temps*', two very different concentrations of sugar in the liver. (Lot [1956b])

Lot [1956c] distinguishes between '*le hasard extérieur*' which intervened '*ad oculos*' of the observer in the fourteen patterns above and '*le hasard intime*' which intervened during intellectual operations, as in the following three patterns:

(15) *Playing*: The first 'impossible tribar' was in 1934 to his surprise created by Reutersvärd, who, bored at school, drew first six and then three cubicles around a star of David. (Ernst [1989])

(16) *Joke*: A practical joke, like Vernes' travel to the moon. And the Walkman (that electronic solution for 'autism') was inspired by an employee of Sony carrying a heavy tape recorder. 'Serendipity-prone' people, as Merton [1958] calls them, are known because of their sense of humour, which is not surprising as sense of humour and sense of serendipity have a lot in common. I refer to Koestler's [1964] chapter *From humour to discovery*.

(17) *Dream or 'forgetting-hypothesis'*: Descartes' dream in 1619 about a world ruled by mathematics, where everything could be explained and calculated

logically. Poincaré [1909] emphasized the combination of the specially esthetic sensibility (*'la sensibilité esthétique spéciale'*) and the anarchy (*'le désordre né du hasard'*) of the unconsciousness (*'le moi subliminal'*) in his elegant model of preparation, incubation, illumination and verification. This model is sometimes referred to as his 'forgetting hypothesis'.

IO CONCLUSIONS

If I define true serendipity as the art of making an 'unsought finding', what do I mean by a 'finding'? I speak of a 'finding' when two or more elements (observations, hypotheses, ideas, facts, relations or insights) are combined originally, for the finder or anybody, to something new and true (science), new and useful (technology), or new and fascinating (arts). The Latin verb *'cogito'* for 'I think' means literally 'I shake together', and one of the possible translations for *'intelligo'* is 'I choose', as has been remarked by Augustinus. The 'unsought' is related to the finder or anybody, and does not exclude that the finder sought something else when he found the 'unsought' finding (in fact this is mostly the case). In science we deal with 'discoveries' of 'phenomena' which already 'exist', like the 'universality of gravity' for example. In technology with inventions (*'in-veno'* = 'I come on' [something]) of things which did not yet exist, like the stethoscope. In art with creations more or less strongly linked to persons, like Chaplin.

When something 'new' is found it often takes years before we know how new and true, useful or fascinating it really is. If we then look back on how the finding was done, the possibility for forming a legend is there. The serendipity of it can easily become underestimated and even denied or overestimated and even invented. In practice it appears that, when serendipity plays a role, this role is normally secondary but essential. The discovery by Columbus is a beautiful example. Ironically enough, if the 'New World' had not been there, would I have known his name?

The evolution of genes illustrates the role of serendipity. Every mutation of a gene is a random and unsought ('blind') event. When the mutation, whether 'dull' or 'surprising', is tested, this happens also 'blindly'. And only then it appears whether there is a 'problem' for which it is an 'answer' and, if so, then it remains to be seen, whether the mutated gene has more survival value than the pre-existing gene.

In culture (culture defined as transferable knowledge) evolution mostly goes in an inverse way: The question exists before the answer. We go from problem to solution. But apart from that, serendipity does play a role in culture also. Several studies indicate that commercially successful innovations for example are for about eighty percent answers to an already pre-existing and known problem, like 'the pill', but in the remaining twenty percent, it appears that something was discovered before there was a demand for it, like X-rays.

By reading and studying my serendipities the following eight points emerged:

(1) Serendipity does exist. It is arrogant to think that 'God's will', an (un-)conscious mind, a plan, strategy, ideology, research-proposal or -project, (computer) program or expert system can intentionally anticipate unknown, unforeseeable, unpredictable, contra-intuitive, surprising facts or relations. That is by definition and logically impossible. A computer program cannot foresee or operationalize the unforeseen and can thus not improvise ('*imprévu*' = 'unforeseen'). It cannot be surprised or astonished, and has no sense for humor, curiosity or oddity. Because we do not always realize all the implications of our theses, when we put them into our computer, the results can be surprising for us, whether trivial or not. And why should we give programmes to a computer which can as well, or better, or even only be done by human beings? When our computer is master, we reach disaster faster. There is still enough unemployed human intellect.

(2) In strongly empirical fields such as astronomy, chemistry, medicine and technology, serendipitous findings appear to be the most frequent. In those fields it is easier to see and test whether a finding is a finding or not (no joke!).

(3) Serendipity plays a supporting but essential role, that should not be underestimated or exaggerated. Harwit, for example, looked at observational discoveries of 43 cosmic phenomena, and found that *about half* of them took place in a serendipitous manner (Kellermann [1983]):

(. . .) this does put into some doubt the normal criteria of the peer review (. . .), because the normal criteria do tend to request a theoretical justification for the work that you are going to be doing. Whether you're asking for telescope time or whatever you're going to do.

(4) Systematic, directed (re)search and serendipity do not exclude each other, but conversely, they complement and even reinforce each other. In practice it is not by design *or* by serendipity, but rather by design *and* by serendipity, and/*or vice versa*.

(5) In general the role of serendipity in science, technology and art is underestimated. This is mainly and unintentionally caused by the way we rationalize *a posteriori* about theoretical and experimental research and its results, when we publish. The not strictly rational, chronological or searched components (like chance, fortuitous, accidental, surprising, unsought, (n)ever dreamt of, unknown, *etc.*), which have led to these results are therefore underestimated and sometimes even banned from the theater and totally hidden behind the *décor*. The next step is that pure rationality becomes the

norm, not only regarding the results, but also regarding everything that has led to these results. Scientists then report their results as following directly and logically from their initial hypothesis, omitting possibly crucial (pseudo)serendipitous events. Reading and interpreting such articles as 'the inside story' about the discovery, can unwillingly brainwash the researcher in such a way and to such an extent that he neglects during his own research the flowers along the road that can form a nicer bouquet than those he is looking for. This can cause a loss of serendipity: the aim and/or plan spoils the journey. A successful researcher or manager has one open eye for sought findings and another open eye for unsought findings. As Von Laue said: *'Es gibt manchmal Verdienst ohne Glück, aber niemals Glück ohne Verdienst.'*

(6) As we also learned from Heraclitus, the sofists, Hooke and Priestley, the notion of 'accidental' or 'chance' discoveries or more precisely 'unsought' findings is of course much older than the surprising and comic word 'serendipity'. The Greek had even a god for the unknown. But then, according to the bible at least, the Christians came, saw and said that this Greek 'unknown' god was their God. Something went wrong there and then in history. Therefore I want to restore that intelligent Hellenistic god for the unknown.

(7) Most serendipitists are open-minded, perceptive, curious, intuitive, smart, flexible, artistic, humorous and diligent. I do agree with Pattle, as cited by Comroe [1967d]:

(. . .) some writers refer to a discovery based on observation of something which was not what was actually being investigated, as a 'chance' or 'accidental' discovery. This is *never* true. Observations are made because the observer is on the outlook of anything strange. The discovery of lung surfactant came about as the result of a peculiar concatenation of circumstances, but not as the product of chance or accident.

(8) If I define intuition ('*in-tueri*' = 'to look at') as an anticipation that can not be made explicit before or even afterwards, then serendipity starts by definition beyond intuition. But it is not that simple. In practice serendipity is nearly always 'intuition in the making' based on a more general orientation, experience or problem, than where the open-minded researcher is working on. That is where his mind is also 'prepared' for. His very general schematic anticipation is based on a specific problem-oriented and/or experience-based intuition. As soon as he observes a surprising fact he interrupts and sometimes even stops his 'normal' work or program for a certain period: to exploit and explain it himself by using his serendipity, intuition, knowledge, logic and/or experimental set up. Serendipity is the art of 'loose blinders'. Even a serendipitist needs blinders, whether he is searching, researching or manag-

ing, but he is able to put his blinders off, when he does a serendipitous observation, in order to make a right abduction or to find out an optimal emergent strategy. Typical for serendipity is what Selz [1924] calls the '*zufallsbedingte Mittelabstraction*' (= 'coincidental means abstraction'): the means abstracted from the incident is a means for something totally different from what he is doing:

Invariably, a present problem will lead either to the reproductive utilization of *earlier* observations as a solving method or, conversely, a *present* observation may lead one to discover the solution to an earlier problem. Whether the discovery has come about in one way or the other can no longer be deduced from the factual outcome. It can only be ascertained through self-observation or from a reconstruction of the external facts of the case, in particular the presence or absence of chance aids.

But a *present* observation can also lead one to discover the solution of a 'problem' that cannot be called 'an earlier problem'. The discoveries of the 'New World', heparine and nuclear fusion for example. In these cases of clearly pure serendipity it was documented that the discoverers resisted for a certain time against their own discovery and/or the *portée* of it: these findings did initially not fall within their very general schematic anticipation. In Columbus' case these anticipative elements were even so absent that he denied until his death that he had found an 'unsought' finding. We still speak of 'Indians'.

II EPILOGUE

I endorse Otto Selz's view, that sudden serendipitous findings and 'brainwaves' can be shown to be preceded by a very general schematic anticipation, whether actually present in the subject's mind or reawakened by an analogy in some outer event. Serendipitous luck may come unexpectedly, but it does so only in a mind 'prepared' by previous interest, thought and/or experience, as in the examples of pseudoserendipity, *e.g.*, Fleming.

After studying my cases of serendipity, this view, however, proved to be disputable for the examples of pure serendipity.

Like all intuitive operating, pure serendipity is not amenable to generation by a computer. The very moment I can plan or programme 'serendipity' it cannot be called serendipity anymore. All I can programme is, that, if the unforeseen happens, the system alerts the user and incites him to observe and act by himself by trying to make a correct abduction of the surprising fact or relation. And I can ask the programme to specify as far as possible the conditions of the unexpected fact or relation, for example: Is it incidental or structural? And which elements are involved? My cases of pure serendipity also seem to indicate that expert systems can assist, but not replace experts. Neither can I program or plan serendipity for myself. But I can and do wish my

reader and myself lots of serendipity, by definition, beyond our imagination and paradigms. As Selz wrote: 'The problems manifest themselves unsought during the elaboration in depth of the study.'

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