Rationality and Knowledge in Complex Systems: The Case of Stanislaw Lem

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Summary

The article focuses on two "detective novels" by Stanislaw Lem, analysed in terms of chaos theory, which states that complex systems are not merely disorderly, but can generate a kind of order. Lem's fictions exemplify the failure of rationality to solve problems within the context of infinite networks of random variables. This, however, does not imply a rejection of rationality or objective knowledge as such; rationality and the quest for objective truth remain implicit to the detectives' investigations.

Opsomming

Die artikel is 'n analise van twee "speurverhale" deur Stanislaw Lem in terme van chaosteorie. Volgens chaosteorie is komplekse sisteme nie bloot ongeordend nie, maar kan hulle 'n soort orde genereer. Lem se verhale *illustreer die onvermoë* van rasionaliteit om tot 'n probleemoplossing te kom binne die konteks van oneindige netwerke van ewekansige veranderlikes. Dit impliseer egter nie die verwerping van rasionaliteit of objektiewe kennis as sodanig nie; rasionaliteit en die soeke na objektiewe waarheid bly onderliggend aan die speurders se ondersoeke.

In this article, chaos theory is used as conceptual framework for the analysis of Stanislaw Lem's detective novels *The Investigation* ([1959] 1974) and *Chain of Chance* ([1975] 1978). It is not suggested that the theory offers an analytical tool which can simply be applied to the text. The extent to which chaos theory can be used to typify the postmodern cultural context of the text and the question of whether Lem's novels are typically postmodernist writings, fall outside the scope of this article. Rather, it is contended that, in certain cases, chaos theory offers a viable alternative to acknowledged literary theories in that, like the above-mentioned texts, it deals explicitly with the investigation of random complexity.

In these texts, Lem develops a critique of cognitive rationality, that is, rationality as a tool for problemsolving (Spinner 1987: 29-30). The main focus of analysis will be to work through the argument on cognitive ration-

ality within random complex systems implicit in Lem's texts. It will be demonstrated that the failure of rational analysis in the detectives' investigations does not necessarily imply that rationality as such or the quest for objective knowledge should be discarded. Reason as ground for knowledge and truth becomes untenable in a random complex environment, yet chaos theory can be used to suggest an alternative conception of rationality.

Deterministic Chaos: A Brief Overview

Chaos theory studies dynamic systems which exhibit complex behaviour. Such systems are aperiodic, that is, their behaviour never reproduces itself within a given period of time; the opposite is true of periodic systems (Feigenbaum 1989: 50). Chaotic systems are unpredictable, since, "given infinitesimally different starting points, we often end up with wildly different outcomes" (Cvitanovic 1989: 3). Given two slightly different initial states of a complex dynamic system, its future behaviour will be unpredictable, as successive states may differ more and more widely, and the differences will be impossible to predict (cf. Lorenz 1989: 370). Moreover, the same system can exhibit both stable and complex behaviour at different times (Peitgen, Jürgens & Saupe 1993: 59).

In other words, aperiodic systems exhibit sensitive dependence on initial conditions, that is, small perturbations cascade upwards through the system (Gleick 1987: 22). They "blow up" and produce a chain of effects throughout the system which cannot be explained in terms of direct causality. Peitgen et al. (1993: 42-48) illustrate the concept by folllowing the iteration of the quadratic expression $p+rp(1-p)$, which is central to a well-known population dynamics model. Taking the constant $r=3$ and the initial value $p_0=0.01$, the iteration is, on the one hand, run without interruption; on the other, it is run until the 10th iteration, then the result is truncated after the third decimal place, and the iteration is continued as if the truncated result were the last output. After the 10th iteration, the results of the two processes predictably agree only in three decimal places. However, in the higher iterations, the results appear totally uncorrelated; the very small difference at the 10th iteration escalates quite unpredictably.

Edward Lorenz, the meteorologist who first theorized sensitive dependence on initial conditions, also described the so-called Lorenz attractor. He took a system of three equations for the rising of hot gas in liquid, known as convection, which he selected because their "solutions afford the simplest example of deterministic nonperiodic flow of which the writer is aware" (Lorenz 1989: 371). Lorenz used the changing numerical values of the three

equations' variables to construct a picture of the system's behaviour. Each set of three numbers was taken to establish coordinates which specified "the location of a point in three-dimensional space" (Gleick 1987: 30). The resulting picture showed that the system's behaviour never reproduced itself, but "traced a strange, distinctive shape, a kind of double spiral in three dimensions, like a butterfly with its two wings" (p. 30): the Lorenz attractor.

Ruelle and Takens proposed a related concept, namely, strange attractors (Gleick 1987: 133). The strange attractor is situated in phase space, "the totality of all possible states of a physical ... system", "a space ... the elements (phase points) of which ... represent the states of the system" (Anosov 1991: 150). In phase space, a point denotes the state of the system at a particular moment in time. The trajectory of the system's behaviour in time can be charted as a series of points, each representing a successive state of the system (Gleick 1987: 134-137). Thus, for example, the behaviour of a "rotor, a pendulum swinging through a full circle, driven by an energetic kick at regular intervals" can be plotted with the aid of a computer (p. 143). Eventually, the picture becomes impenetrably complex, almost amorphous. However, it can be simplified by constructing a Poincaré map, which involves converting it to two dimensions, sampling the system periodically, instead of continuously, and reducing the continuous line representing each swing to a point (Gleick 1987: 142; Hobbs 1991: 154). In other words, the system's trajectory is traced from an initial point p in a flat rectangle, until it re-enters the rectangle at a point T(p). By repeating the procedure, image points T(p) can be found for all the initial points p in the rectangle (Peitgen et al. 1993: 694-695). Thus, it can be shown that a pattern, a "trajectory towards which all trajectories converge" (Gleick 1987: 150) underlies the system's complex behaviour. The trajectory of a strange attractor never closes on itself; it is infinite and multidimensional (Cambel 1993: 70). At any given moment in time, the "system will be somewhere on the strange attractor, but one does not know where" (p. 73). Though infinitely complex and unpredictable, the strange attractor is not simply disorderly; it displays "an infinite regress of detail, a never-ending nesting of pattern within pattern" (Hoftstadter 1987: 384).

Strange attraction does not always develop spontaneously, and there seems to be chaotic systems in which it does not occur (Gleick 1987: 307). Therefore, it cannot be regarded as a universal rule or fundamental structure.

The transition from stable to chaotic behaviour has been investigated mathematically by the theoretical physicist Mitchell Feigenbaum with reference to a variety of systems. The feature common to all these phenomena

is that their behaviour remains orderly within a certain range of values for an external parameter such as temperature; beyond that range, the behaviour becomes erratic (cf. Feigenbaum 1989: 50). Feigenbaum found that, for all systems following the period doubling route to chaos, there is a critical value of the external parameter, beyond which the systems' behaviour becomes erratic (Hofstadter 1987: 375; Feigenbaum 1989: 50).

A periodic system repeats itself at regular intervals. In period doubling, the system will first take double the initial period of time to repeat itself, then four times the period, and so on (cf. Gleick 1987: 206). For some values of the external parameter beyond the critical point, the system can become aperiodic; for most, it will be periodic, but the periodicity will be hard to detect (cf. Hofstadter 1987: 375). Most importantly, for all these systems, the rate of the onset of complex behaviour is predetermined at the value 4.6692016 ... (Feigenbaum 1989: 50). Thus, Feigenbaum discovered and precisely calculated certain universal constants in dynamic systems' transition from orderly to erratic behaviour. Like the Lorenz attractor and strange attractors, this indicates that the behaviour of chaotic systems can be regulated, though unpredictable.

While Feigenbaum and others revealed the hidden order underlying chaotic systems, the mathematician Benoit Mandelbrot demonstrated that simple processes can generate infinite complexity. This is exemplified by, amongst others, the Mandelbrot set, the "most complex object in mathematics" (Gleick 1987: 221). It is produced by the "iteration in the complex plane of the mapping" of a simple equation (p. 227). In the complex plane, the numbers from minus infinity to infinity "lie on a line stretching from the far west to the far east", while the imaginary numbers lie on a line which "stretches from infinity in the north and the south" (p. 215). The set contains an infinite variety of shapes, of shapes within shapes, repeating but not reproducing themselves (pp. 221-228). It is an example of a fractal. Fractals are a family of highly complex mathematical shapes introduced by Mandelbrot and anticipated by mathematicians such as Cantor and Sierpinski. Fractals are characterized, amongst others, by various degrees of self-similarity, that is, the smaller shapes generated through iteration repeat and sometimes reproduce the "original shape" (cf. Mandelbrot 1982: 1, 20; Dewdney 1985; Peitgen et al. 1993: 144-146).

It seems dubious to assert that, according to the theory, "chaos possesses a deep structure of order" (Hayles 1988: 307). The notion of deep structure suggests that chaos is generated by a fundamental algorithm. However, Chaitin (1975: 48) showed that this is not the case for random numerical systems, while the universal constants identified by Feigenbaum and the attractors theorized by Lorenz, Ruelle and others merely indicate that the

behaviour of chaotic systems can be regulated, that chaotic phenomena are never simply anarchic or irrational. Sensitive dependence on initial conditions indicates a diffuse, decentred causality which operates unpredictably within a network of relations and can result in ignorance instead of clarity: if the initial conditions are not precisely known, future knowledge of the system's behaviour is impossible (cf. Feigenbaum 1989: 76). Conversely, if only the effect of these complex relationships at a given point in time is known, it will be impossible to determine the initial conditions. This is especially relevant to the investigative process in Lem's detective novels.

Lem

The writings of Stanislaw Lem reflect his thorough grounding in mathematics, statistics and philosophy (cf. Lem 1984a: 255-260). The texts discussed here present a radical subversion of determinism. Events and actions in Lem's chaotic world have a certain probability, but it cannot be calculated precisely. As a result, the explanatory hypotheses proposed by Lem's detectives are undecidable in a sense loosely corresponding to Tarski's definition of undecidability in theories, according to which a theory is decidable "if the set of all its valid sentences is recursive", that is, if the set can be shown to apply to a series of related phenomena which would thus be compatible with and corroborate the theory (Tarski 1971: 12-14).

In *The Investigation* ([1959] 1974), for example, it is impossible to decide whether all the facts of the case can be integrated into the solution proposed at the end, and whether the possible alternatives would simply be an extension of the final hypothesis, that is, whether it would introduce certain variables, such as a different culprit, without invalidating the theory, or would necessarily imply alternative theories. In *Chain of Chance* ([1975] 1978), it is impossible to decide whether the solution proposed is fully compatible with the information concerning each case, and whether statements about similar phenomena could be integrated into the theory; if the series of events were to be continued, would the theory still be adequate, or would alternatives be required?

The Investigation ([1959] 1974)

The case presented in *The Investigation* ([1959] 1974) concerns the mysterious movements of a number of corpses in a certain geographic area of England. Initially, the corpses seem to be moved around at night, but the

matter is not taken further. The police intervene when several corpses disappear from the mortuaries in which they have been lying.

The text opens with a résumé of the problem presented by two of the detectives, Gregory and Farquart. This is followed by a second résumé, presented by the unofficial investigator, the statistician Sciss, who states that, in this instance, "the classical methods of investigation - the collection of evidence and the search for motives - have failed completely" (Lem 1974: 15). A considerable amount of meticulously recorded data is available, yet no plausible theory has been put forward to explain them. The police's dilemma is expressed by Gregory: "until you have a specific theoretical structure to fit the facts into, there's no point in collecting evidence". (p. 139). This is in line with the notion that observation can only be meaningful if it is linked to a particular problem or hypothesis (Popper 1979: 259). In the words of Darwin, quoted by Popper: "how odd it is that anyone should not see that observation must be for or against some view" (p. 259).

Sciss proposes to solve the dilemma through the "statistical method of investigation" (Lem 1974: 15). This involves the precise ordering of objective data according to statistical principles, and the partial substitution of traditional methods of investigation with abstract conjecture. Sciss does not propose hypothetical explanations for the events, but aims to achieve an exact, objectively verifiable "structural" analysis of the data according to statistical principles. He proceeds non-intuitively, identifying those elements "that are common to all the incidents, or at any rate to a substantial majority of incidents" (p. 16). He uses the "time elapsed between any two incidents", the "distance separating any two consecutive disappearing-body sites from the center" and the "differential between the prevailing temperatures at both sites" to calculate a constant, which is used to determine the location of the "causal factor of these phenomena" as well as their "geometric center" (p. 19). His calculations are motivated by the principle that, "regardless of the degree of difficulty, there is always a definite correlation, a valid basis for a discussion of causes and effects" (p. 20).

The assumption implicit to Sciss's reasoning is that the world can be rendered intelligible through an objective analysis of quantifiable relations between events or phenomena. In the initial stages of the investigation, however, his theorizing does not advance the police's understanding of the problem, but merely demonstrates the possibility of such correlations.

The greater part of the text focuses mainly on the investigation of a single further instance of attempted corpse removal (Lem 1974: 67 *et seq*). After the initial report (p. 67), the journey to the scene of the crime is described (pp. 68-72). Gregory's initial interrogation of the policeman on duty (Lem

1974: 73-75) is followed by an examination of the scene of the crime (pp. 75-77). The investigation *in loco* is continued through alternate interrogation and observation of physical detail (pp. 78-87).

Gregory's investigation is aimed at collecting accurate data (cf. Lem 1974: 73 *et seq.*). The first batch of data is consolidated in a detailed report presented to the Chief Inspector (pp. 99-101). It is a detailed presentation of the facts of the case already established and not in dispute. The writing subject intervenes twice, providing pointers for the reader, and is once implied by the qualifier "probably" (p. 100). Once, its presence becomes manifest - "we found stone fragments" (p. 101). For the rest, it is suppressed, to allow the facts to speak for themselves, and to de-emphasize the implicit presence of an observer and compiler.

The language of the report is terse, even elliptic, as if to minimize awareness of the medium. This conforms to "scientific objectivity", in terms of which language is used as a transparent medium, providing direct access to the "facts". The almost pedantic precision of the report is exemplified by sentences such as "Human footprints found ... at distances of 139, 133 and 123 feet respectively from mortuary" or "Distance from path ... measured in straight line at shortest point ... was 43 feet" and so on (Lem 1974: 100, 101).

Once the facts have been established, Gregory has to provide an explanatory hypothesis. The best hypothesis would combine maximum explanatory power with simplicity (Kahn 1990: 1856). It would only be acceptable if it could not be falsified by the data and if it stood up to critical examination and the competition of alternative hypotheses (Popper 1979: 143-144).

Gregory proposes two hypotheses, both taken apart by the Chief Inspector (Lem 1974: 102-105). The first is rejected as incompatible with the information about the scene of the crime and the behaviour of the constable on duty. It has insufficient explanatory power in that it fails to explain the constable's behaviour, and is rendered implausible, in some respects even falsified by the available data. The second hypothesis also falls short on explanatory power; it fails to clarify the reasons for the actions apparently carried out by the perpetrator.

Despite its almost exaggerated attention to minute detail and the exhaustive enumeration of data, Gregory's report does not provide the basis for a hypothesis which stands up to critical scrutiny. Thus, it subverts the idea that "objective" observation and a statement of the "facts" in transparent, impersonal language necessarily provide access to knowledge and understanding.

The Chief Inspector informs Gregory that, according to Sciss, "there won't be any more incidents"; "the series is over, indefinitely or ... for-

ever" (Lem 1974: 108). According to Sciss, the "case has nothing at all in common with criminology" in that "no offense of any kind was committed" (p. 116). Sciss is proposing the unthinkable, namely, a crime without a criminal or, worse still, a detective novel without a crime.

The precondition for any phenomenon to be explained, according to Sciss, is that "the structure of its events" should conform "to a regular pattern" (Lem 1974: 119). Such a pattern would suggest that the events are connected, and that an explanation could be found which would be valid both for individual events and for the series as a whole. In the absence of a pattern, only ad hoc explanations would be possible, that is, explanations which "are not testable independently of the effect to be explained" (Popper 1979: 15-16). Each explanation would only apply to a particular event and not be generalizable to the series as a whole.

Accordingly, Sciss primarily sets out to "connect" the events of the case "with other series of phenomena that was already familiar" (Lem 1974: 120). One such a phenomenon, which Sciss chooses at random, is death by cancer. Having analyzed the incidence of the mortality due to cancer in a particular region, he found that "Norfolk and its surrounding region ... constitutes an enclave with a relatively low cancer mortality" (p. 121). On the basis of the extent of bodily displacement in each case, Sciss is able to determine that "the rate of cancer mortality changes by an arithmetic rather than a geometric progression as we trace its passage from the enclave into the adjacent regions" (p. 122). There is a correlation between the geographical distribution of the rate of cancer mortality and the pattern according to which the phenomenon of corpse displacement spread.

Sciss, however, does not use this as the basis for inferences about the case. He seems to view his task as limited to the description of patterns; his primary aim is to achieve logical coherence. His statements are truthful in that they correspond to objective data, yet are not aimed at solving the case in terms of direct causality.

According to Sciss, it seems, knowledge and understanding are not attained simply by ascertaining the "facts", but by uncovering a pattern, a design, a certain coherence or correlation between phenomena. This ties in with a scientific paradigm according to which

> Eigentliche Gegenstand der Wissenschaft sind die mathematisch beschreibbaren Strukturen von und Beziehungen zwischen Elementen einer einheitlichen Natur. (Detel 1991: 182)

However, although the correlations Sciss describes are objectively truthful in themselves, there is no evidence that they are in fact relevant to the case.

It is therefore debatable whether Sciss actually promotes understanding, or merely demonstrates the logical consistence of his method.

In an attempt to break the impasse in which the investigation finds itself, Gregory proposes several "crazy" hypotheses which are not falsifiable in terms of the available knowledge, but cannot be rejected summarily, as it cannot be excluded that they might yet be corroborated (cf. Popper 1971: 212; Naess 1972: 76). The explanations he proposes are based on an elaborate analysis of Sciss's "statistical hypothesis" (Lem 1974: 136). However, he is forced to discard the hypotheses, because the assumptions on which they are based are completely improbable, even contradictory to the known laws of nature.

This failure moves Gregory to propose the theory of a random universe (Lem 1974: 204-205), in which the image of the world as a "jigsaw puzzle" is juxtaposed to that of a "soup with all kinds of things floating around in it", some of which "from time to time get stuck together to make some kind of whole". Perhaps, "everything that exists is fragmentary, incomplete, aborted, events with ends but no beginnings, events that only have middles" (p. 204); perhaps, events do not follow a linear progression from cause to effect.

In a random universe, "Perfection, fullness, excellence" would "occur only because there is such an excess, so unimaginably much of everything" (Lem 1974: 204). It would not be the result of deliberate actions or natural laws, but would occur because the probability of its occurrence is directly proportional to the number of phenomena involved. This recalls the findings concerning chaotic systems, in terms of which a large number of random events observed over a period of time can display a certain degree of order.

Gregory dismisses the orderly world constructed by reason as an illusion: "The only thing that really exists is statistics". The infinite possibilities of the world are regulated by probability; not all possibilities have equal probability (Kosko 1993: 47). This does not amount to "statistical determinism"; probabilities cannot be stated as universal rules which determine the outcome of events, since "nothing exists except blind chance, the eternal arrangement of fortuitous patterns" (Lem 1974: 205). If we flip a coin, the outcome is governed by chance, but the relative probability of heads and tails can be calculated for a number of flips over a period of time. In terms of fuzzy logic, however, the outcome does not even have to be either heads or tails, but can be both at the same time: heads to some extent, and tails to some (Kosko 1993: 94-97). This suggests that the concept of a random universe can be developed further, inasmuch as Gregory operates with discrete phenomena, while fuzzy thinking states that a phenomenon does not have to be either "a" or "not-a", but can lie on a continuum between the

two (Kosko 1993: 124-125). Because of sensitivity to initial conditions, even the tiniest difference between "a" and "nearly-a" can result in widely divergent and unpredictable outcomes.

In the end, the Chief Inspector proposes a solution which links the Mailer transport company to the crimes (Lem 1974: 206-214). The company, he argues, has 218 drivers, at least one of whom may be psychologically deviant, in terms of statistical probability (p. 210). In view of the gruelling work schedule of the drivers and the difficult conditions they had to cope with during the period when the crimes were committed (pp. 207-208), the mental condition of a driver who had been experiencing "visions, peculiar thoughts" and "hallucinations" for some time might begin to deteriorate (pp. 208-209). A "vision" may gradually rise to the surface of his consciousness "that becomes clearer and clearer, more and more consistent" until "finally, there comes a moment in which it becomes" so compelling, "so uncontrollable" that he knows "what has to be done" (p. 209).

Thus, mental delusion is proposed as the reason for the crimes. Furthermore, the Mailer truck drivers had both the means and the opportunity to commit the crimes: the routes they had to serve were situated in the geographical area where the corpse removals took place; their trips were undertaken at night, while "the incidents took place between midnight and dawn in small provincial mortuaries" (Lem 1974: 210); the perpetrator "must have known the topography of the whole region by memory"; "he knew exactly where all the cemeteries were located" (p. 211); so, probably, did the truck drivers; the trucks had ample space in which to hide the bodies; the guilty driver also had "plenty of opportunities" to "dump the evidence of his night of insanity" (p. 211).

Sheppard's reasoning is similar to Sciss's. Through an analysis of "certain unusual circumstances surrounding" the case, he identifies several constants: each "subsequent event" took "place farther and farther away from the center" of the geographical area concerned, because, as a result of weather conditions, "the average speed of the trucks was decreasing ...; consequently, it was taking them longer to cover the same distance" (Lem 1974: 210). The "resistance the driver" offered to the "two-hour fantasy-inducing period" was inversely proportionate to "the resistance the snow" offered to the "tires of the truck" (pp. 210-211). A constant is obtained by multiplying the "difference in temperature by the product of the time between two incidents and the distance from the center to the site of the incident" (p. 211). The constant identified arises from the interaction between the driver and his truck on the one hand, and between driver, truck and weather conditions on the other. Another constant is the "driver's work schedule" (p. 210) and the route he had to cover.

In Gregory's view, the identification of a deceased Mailer driver as the possible culprit is a convenient solution, "something to match the facts" to "give a semblance of order to this disorder and mark an open case closed with a nice sense of orderliness" (Lem 1974: 214). In terms of statistical probability, the possibility cannot be excluded that one or more of the drivers suffered from a mental delusion or was emotionally unstable, but it is equally probable that this was not the case. Further investigation might confirm that one of them was indeed the guilty party, yet that would involve the systematical examination of a very large number of random phenomena, the investigation of the "endless quantity of phenomena that can be fitted into the theory" (p. 213), in order to identify the most likely culprit. This might be neither practicable, nor entirely worthwhile, in that it would not necessarily lead to a solution better than the one proposed by Sheppard.

For this reason, the Chief Inspector decides that "the investigation is over now, except for a few technicalities" (Lem 1974: 215). Thus, the feasibility of an epistemology which equates "knowledge - episteme - with the proven" (Lakatos 1978: 129) is denied. In terms of Gregory's idea of a "random universe", it can be argued that, in an indeterministic world, correspondence of a hypothesis to the facts is the result of random statistical distributions, and therefore, does not support its claim to truthfulness by providing verification or proof beyond reasonable doubt; Sheppard's move - terminating the investigation - suggests that truthfulness itself is not required for a hypothesis to be acceptable, only plausibility, that is, a certain narrative coherence between the facts and the theory.

Sheppard's hypothesis seems a fairly plausible approximation, but remains inconclusive, as it cannot be shown that it truthfully accounts for the data. Statements about the individual events constituting the problem remain undecidable and ad hoc, in that they cannot be shown to fit into a general explanation (cf. Tarski 1971: 12-14). There is no conclusive evidence that accurate statements about aspects of the case can be integrated into a general hypothesis. As a result of the undecidability of Sheppard's hypothesis and the non-linearity of the problem, the number of possible hypotheses is potentially infinite. Therefore, Sheppard's arbitrary decision to close off the case is the way of least resistance, perhaps a choice for economy of effort.

Gregory's notion of a random universe is not presented as a general explanation for the facts of the case; it is simply yet another hypothesis. One should also bear in mind that the concept of randomness can only be used meaningfully if it is defined in terms of a particular context (cf. Ruelle 1991: 13). Chaos theory does not offer universal hypotheses, but always focuses on specific systems. Nevertheless, Gregory can be said to propose a radical departure from rationalist causality. In a random indeterministic

world, what is perceived as structure or design or causal relationships may simply be a result of the random coincidence of statistical distributions. For example, the "unusual circumstances" analysed by Sheppard (Lem 1974: 210-211) can be viewed as the trigger for the hypothetical driver's "mental delusion", and thus, as the possible "cause" of the crimes. Yet, the occurrence of these circumstances is regulated by statistical distribution. Their coincidence at certain timespace coordinates with a specific person, to whom a very large number of variables are attached, as well as the resulting interaction and its outcome are governed by chance. There is no particular reason for the coincidence; the initial conditions for the interaction are local and accidental, not governed by universal laws.

Given the randomness of the process, the probability of a particular outcome to the coincidence will be different every time the process is repeated. Over a period of time, the outcomes, represented as points, may not simply be scattered in a disorderly manner, but might form a strange attractor: the relationships of the elements of the process may be random, yet regulated.

The non-linear problem facing Lem's detectives can be viewed as part of a chaotic system, which displays sensitive dependence on initial conditions. Any change to the system will result in a different, unpredictable outcome. The series of crimes in *The Investigation* can be viewed as but one possible, entirely unpredictable outcome of a random, infinitely variable causal network. There is no general rule in terms of which any of the elements in the network can be predicted, and no way of establishing a direct linear relationship between "cause" and "effect". Against this background, Gregory's persistent search for a "perpetrator", dictated by the conventions of the detective novel, seems quite naive. *The Investigation* demonstrates that the usual cognitive tools of rational analysis, such as the collection of data and linear reasoning are unable to deal with random complexity.

Random Causality: *Chain of Chance* ([1975] 1978)

Lem's preoccupation with randomness recurs in *Chain of Chance*, first published in 1975. Like *The Investigation*, it has the format of a detective novel. The investigation in *Chain of Chance* concerns the deaths of a number of mostly middle-aged American bachelors who died while on a visit to Naples. All died in different ways, some of natural causes. No evidence of foul play was found in any of the cases, although there were a number of suspicious elements (Lem 1978: 62-63, 75, 77, 83-84). Only in two of the cases does there seem to have been a possible motive for murder

(Lem 1978: 84, 89). With reference to the first nine cases, the narrator-investigator states that all followed "the same mysterious pattern" and displayed an "all-too-obvious similarity", but concludes that

> there were still insufficient grounds for launching a criminal investigation aimed at prosecuting the guilty since there was not the slightest hint as to their whereabouts or whether in fact they even existed.
>
> (Lem 1978: 85)

The "pattern" to which the narrator refers consists in a number of generic similarities between the deceased, such as age and unmarried status, and certain unclarified aspects of the periods immediately preceding their deaths. There is, however, no prima facie evidence that a crime was indeed committed (cf. Schmidt 1989: 4), with the result that the justifiability of an investigation seems rather dubious. It also seems dubious whether the different cases should be treated as a single problem, since there is no apparent connection between them, apart from the generic similarities mentioned above. They do not seem to form a set of interrelated events, but appear as disconnected happenings which have been grouped together on the basis of superficial resemblances.

It is not the narrator's task to solve the problem itself, but simply to act out the role of a potential victim. The actual investigation is carried out by the "six-man team" who keeps him "under constant surveillance - two men to a shift, plus two technicians to monitor my blood, heart and lungs" (Lem 1978: 91). In Rome, he is awaited by a "specialist in forensic medicine", whose "job was to examine all the medical data recorded on the tapes" (p. 91).

The weight of scientific expertise brought to bear on the case is further increased through the involvement of the narrator's contact at the CNRS in Paris, "Dr Philippe Barth ... a well-known French computer scientist", heading a research team who is

> in the process of programming a computer capable of solving multifactorial problems in which the number of case-related facts far exceeded the storage capacity of the human memory.
>
> (Lem 1978: 60)

Despite all the expertise involved, the narrator's mission ends as a "complete flop" (Lem 1978: 91). It cannot be ascertained whether any of the deceased were in fact murdered. Barth ascribes the failure to the methodology used, and suggests that it would have been preferable to send "a whole group of similars down there. No fewer than five" (p. 92). Some of

the variables attached to either the "potential victim" himself, or to the environment in which the simulation was carried out, or both, may invalidate the simulation if it is conceived "in terms of a scientific experiment" (Lem 1978: 92), by rendering impossible a simulation exercise of which the inaccuracies are restricted to an acceptable level. Obviously, it would have been impossible to perform the experiment in a controlled environment. It is, therefore, quite possible that the environment was "deficient"; if the simulator was the deficient factor, then he "should have selected men having the same characteristic variability ratio as that exhibited by the victims" (p. 92).

Barth accepts the causal factor(s) of the incidents to be geographically determined, but states that one should think in terms of random causality, which "operates like a lottery, not like a machine" (Lem 1978: 93). He compares the environment in which the incidents occurred to a "firing zone", in which, whether one is killed "by someone aiming deliberately at you, or by the sheer density of the fire", the possibility of a crime cannot be excluded, in that "either way someone on the other end is anxious to see a lot of people dead" (p. 93). In such a setup, the number of victims is more or less determined by the ratio between the number of potential victims and the density of fire; the identity of the actual victims, by their presence - itself the result of numerous random variables - at certain timespace coordinates.

Barth organizes a party attended by, amongst others, doctors, mathematicians, lawyers and statisticians, at which various hypotheses concerning the events are generated and inconclusively debated (Lem 1978: 118-130). At the same occasion, the mathematician, Saussure, also proposes the idea of random causality, using the analogy of somebody trying to hit the nails on a table with drops from an eyedropper as against the nails being hit in "five minutes of a steady downpour" (p. 126). According to Saussure, on the basis of certain similarities, the investigating team constructed a set constituted by events which are not necessarily linked. In doing this, they implicitly assumed the existence of a rule for the construction of the set, based internally on specific common denominators and externally, on the presumed existence of one or more causal factors acting on all the victims in the same manner. However, the similarities between the victims could be the result of a statistical distribution, not of deliberate selection, and therefore, the events can be regarded as an arbitrary sample of an infinite chaotic series. Paraphrased thus, Saussure's remarks imply that the investigators inadvertently created a non-linear problem for themselves.

According to Barth, a further error committed by the investigators was that "the incidents were arbitrarily categorized as relevant or irrelevant"

(Lem 1978: 102). Barth asserts that death preceded by insanity was arbitrarily chosen as criterion for identifying the series of victims, "or at least insanity, even when the latter failed to result in death" (p. 102). Different criteria would result in a different series, change the problem, and would probably lead to different hypotheses.

Barth proposes that they should "turn to some of the discarded facts, to the false clues" (Lem 1978: 102). All the presumed victims suffered from baldness and made no effort to conceal it, while "the survivors included both those who were balding and those with a normal head of hair" (p. 111). Some of these, however, may have been wearing toupets. A tendency towards baldness, instead of insanity, is therefore identified as a possible link between the victims.

A further line of investigation is suggested by Superintendent Leclerc via Inspector Pingaud, the "Sûreté's liaison with the Barth team" (Lem 1978: 136). Pingaud summarizes the case of one Dieudonné Proque (pp. 133-148), who, for no apparent reason, began to experience fits of hysteria, during which he became aggressive and destructive. As a result of one of these fits, he was involved in a car accident, which landed him in hospital. There, he died of heart failure, ascribed to a "reactive psychosis" (p. 141). A connection was established between Proque and a Doctor Dunnant, who was busy developing "psychotropic depressants" for the French government (p. 144). Proque had to repair the Doctor's glasses. During his first visit, Proque told him about an attack which "sounded like an acute depression caused by a chemically induced psychosis, very similar, in fact, to the symptoms produced by the compound x he had been working on" (p. 146). Dunnant formed the hypothesis that small quantities of the compound, present on his glasses, reacted with something in Proque's workshop, "and that the resulting catalytic reaction made the chemical's effect a million times more powerful" (p. 147). After Proque's death, Dunnant tested all the reagents in the workshop for their effect on compound x, but failed to corroborate his theory. In addition, after Madame Proque's death, Dunnant took samples of all the materials in the abandoned workshop, but still failed to corroborate his theory.

Leclerc suggests an analogy between this case and the Naples mystery, without specifying what he has in mind. The dissimilarities between Proque and the series of victims are such that the analogy seems dubious, yet Barth does not question the existence of compound x, and advances the hypothesis that this is the causal factor which precipitated the emotional crises suffered by the victims prior to their deaths (Lem 1978: 150).

The denouement is sparked off by the narrator's decisions to enter a barbershop and order "the works" (Lem 1978: 158), and to purchase a

"bronze-colored Vesuvius covered with roasted almonds" (Lem 1978: 153). This produces the very effect which the simulation exercise failed to. Eventually, it is found that a hormone ointment, which the barber probably applied to the narrator's scalp, combined with a certain medication used for allergies, can form compound x. As a result of a number of almond factories in Naples having been treated with a disinfectant containing sulphur, a chemical substance is found in the almonds which caused them to act as a catalyst capable of increasing "the psychotropic toxity" of compound x "a million times" (pp. 171-172).

"Proque also fell into the trap, but by a different route" (Lem 1978: 172): he, too, absorbed the substances which caused the reactions experienced by the narrator and the other victims, but via different sources. The "missing link", the vital clue linking Proque to the narrator was the almonds found with the latter's "notes on the table" (p. 173). A further important detail is that "cyanogen sulphide" introduced into the body by itself "is incapable of having a catalytic effect on compound x; ionic sulphur must also be present in the reacting bodies" (p. 172). Most of the victims probably absorbed this from the mineral baths they used (p. 172). Proque inhaled "sulphur dioxide from hypo used in developing photos" (pp. 172-173). The ionic sulphur found in the narrator's blood possibly came "from wine that had been allowed to sulphurize" (p. 173), which he probably drank "at Barth's place", since he "never ate any meals out" (p. 173).

The narrator's "accidental success" is the result of a series of interconnected chance events (Lem 1978: 177). The events are interconnected in that one led to the other, not in the sense of direct causality, but in the sense that the successive events are interdependent. Saussure points out that each of the events was a vital link in the "chain of chance" (p. 179). This remark can only be made a posteriori: the chain of events constitutes a chaotic series, and therefore, their sequence cannot be predicted. At any point in the chain, future knowledge of the series is impossible. Because the series is erratic and unpredictable, the problem could not be solved through rational analysis and experiment. Yet, to the extent that the trajectory of the series is regulated by specifiable parameters, it does not constitute a denial of reason as such; indeterminism and randomness are not incompatible with rationality.

According to Saussure, the "Naples mystery was the result of a random causality" (Lem 1978: 179), which can be described as the coincidental intersection of a number of factors, unrelated in themselves, which acted together to produce certain effects. Similarly, "it was the same random causality that solved it" (p. 179), through the narrator's accidental involvement in a series of unrelated but interdependent events. The events

are not inherently interdependent, yet all of them had to occur to produce the solution; this does not imply the existence of a rule for the construction of the solution, as it could have been reached via a different series of events.

There was a random probability that, sooner or later, the intersection of a certain combination of events and a specific set of personal attributes would create conditions favourable to the reactivation of the causal factors. The timespace coordinates of the intersection could not be predicted, and the favourable conditions could not be specified in advance, but their occurrence was inevitable. In this sense, the "chain of chance" can be described as a self-organizing system, that is, its internal dynamics produces a certain directedness (cf. Gleick 1987: 55, 252; Cambel 1993: 19-20). In this context, the role of cognitive rationality is limited to the formulation and testing of hypotheses as they erratically present themselves, and to the a posteriori description of the chain of events.

Saussure's explanation for the random complexity of the process is that

> Mankind has multiplied to such an extent that it's now starting to be governed by atomic laws. The movement of gas atoms is chaotic, but out of the chaos are born such things as stable pressure, temperature, specific gravity and so on.
> (Lem 1978: 176-177)

The investigators' initial attempts at systematic analysis and their simulation experiment fail, because a chaotic system such as the one constituted by the victims and their circumstances and environment cannot be reconstructed with absolute reliability; the initial conditions are not exactly known. It is therefore unavoidable that there will be errors in the experimental set-up. Even the slightest deviation from the "original" system will blow up and lead to erratic results.

The World as Chaos

Saussure's notions of random causality and of human behaviour functioning according to atomic laws (Lem 1978: 176) and Gregory's idea of a random universe (Lem 1974: 204-205) are compatible with the theories of deterministic chaos, according to which the trajectories of chaotic systems cannot be described or predicted in terms of fixed general rules, but are somehow regulated.

In the sense that the causal relationships identified are governed by chance, they contradict the idea, postulated by classical reason, of a stable,

inherently orderly world. At the same time, deterministic chaos implies a kind of order of which the parameters can be approximately specified, but not predicted; though unstable, the parameters can converge to recognizable patterns.

The convergence of the statistical distributions of the elements constituting the "chain of chance" can be imagined to repeat itself at certain timespace intervals, which would be predictable, provided that the distributions remain consistent. In this instance, the system would become locked into periodic behaviour, certain events reproducing themselves at regular intervals. Lem's text, however, suggests that the distributions would be erratic, and their convergence unpredictable. Moreover, the distributions which have to be taken into account do not remain the same: part of the investigators' problem in *Chain of Chance* is that the selection of the causal factors' agents is governed by chance; the effects they are investigating could be produced through any of a large number of randomly variable agents.

The subversion of linear, deterministic causality and the resultant problematization of cognitive rationality as instrument for objective knowledge and understanding are central both to *The Investigation* and *Chain of Chance*. Lem's texts implicitly reject the possibility of a general explanation for any series of events in the world as chaotic system and suggest that, for such a system, all hypotheses beyond the level of the ad hoc and contingent are inconclusive. This does not imply a rejection of cognitive rationality as such, or a denial of the possibility of objective knowledge:

> The ironic postmodern detective story properly corrodes the naive rationalism of classical detection. But the popular form recurs because against the nihilism or at least radical scepticism of most postmodern fictions it images intellectual and moral truth ... or at least the desire for all these.
>
> (Steiner 1983: 462)

The process of investigation in itself implies the tacit assumption that rationality is the only suitable instrument for knowledge and understanding. In this context, a radically scepticist view of rationality would be selfcontradictory. Although the texts reject the rationalist assumption that there is a natural connection between rationality and objective truth, an intrinsic correspondence between reason and the true state of affairs, they support the notion of objective truth as regulative principle; they do not suggest that the only route left to cognitive rationality in an indeterministic world is to retreat into epistemological defeatism, the generation of arbitrary fictions. In this sense, they contradict Nietzsche's idea of truth as fiction:

> Ja, was zwingt uns überhaupt zur Annahme, das es einen wesenhaften Gegensatz von "wahr" und "falsch" gibt? Warum dürfte die Welt, die uns etwas angeht, nicht eine Fiktion sein?
>
> (Nietzsche 1964: 46)

The ideas expressed by Gregory and Saussure do not equate randomness with mere disorder; in this respect, Lem echoes the findings of contemporary science. It is possible for random sequences to have a non-random cross-correlation; the statistical distribution of a number of random individual events can be non-random and stable (Pagels 1983: 109, 112-114). Similarly, the long-term behaviour of a deterministic aperiodic system does not simply oscillate wildly between different states, but is to some extent stable and regulated, as illustrated by the theory of strange attractors. Randomness and order, chaos and rationality are not mutually exclusive, but co-exist; can in fact be interdependent, as in the case of Saussure's "random causality". This is neither compatible with optimistic rationalism, nor with radical scepticism.

Saussure compares human actions and events with the "movement of gas atoms" (Lem 1978: 176). According to Boltzmann, the "behaviour of a gas could be explained ... by the random motions of very many molecules" (Gribbin 1986: 368). Although the movements and interactions of the atoms occur in a random fashion, "the rules that describe such a system are very accurate and reliable" (p. 368). In other words, the internal mechanism of the system can be known, but the trajectory of its successive states is erratic and unpredictable.

Boltzmann's equations also allow the possibility of non-common-sense events, such as an ice cube in a liquid getting colder and the liquid around it beginning to boil, but state that such occurrences are extremely improbable (Gribbin 1986: 368-369). The problem of the moving corpses in *The Investigation* can be viewed as such a possible, but extremely improbable series of events. Deterministic causality cannot accommodate this, as it focuses on events with maximum probability, events which can be predicted and explained in terms of fixed general rules (cf. Kosko 1993: 47). As it cannot deal with a world of infinite possibilities, deterministic causality has to accept an approximate picture of reality; it creates order by suppressing multidimensional complexity. In the traditional detective novel, this approximate, simplified picture of the world is presented as objectively truthful and as validation of optimistic rationalism. Lem's texts refute this claim by highlighting infinite random complexity and illustrating the interdependence of order and chaos in complex systems.

Lem concedes elsewhere that problemsolving in terms of a coherent, com-

prehensive worldview has become impossible (Lem 1984b: 23). As a result, a hypothesis could be rational, that is, consistent, logically coherent, derived from empirical data and falsifiable, without providing access to objective truth and understanding. Rationality no longer affirms its supremacy by demonstrating the law and order presumed to be inherent to reality.

Instead, Lem's texts suggest that there is no solution to the riddle of the world, no decidable general hypothesis about objective realities, only the formulation of conjectures and the opening up of new areas of investigation. Thus, within the context of random complexity, cognitive rationality does not focus primarily on problemsolving, on providing answers, on the creation of a coherent picture of the whole, but on formulating the questions we should ask of the world, ad infinitum. Only thus can it come to terms with objective reality as an infinite proliferation of possibilities.

Within the context of random complexity, the quest for clear-cut solutions has to be abandoned in favour of radical open-endedness, even though the regulatedness of chaotic systems implies that objective knowledge and problemsolving remain a distinct possibility. The defeat of rationality as a tool for problemsolving in its struggle with complexity does not result in mere arbitrariness, the acceptance of truth as a fiction, a narrative, since objective truth as regulative principle is not discarded. The fractal complexity of the world is mirrored by the infinite proliferation of hypotheses within the horizon of the quest for objective knowledge and rational understanding.

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