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# A methodology for conducting interdisciplinary social research

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**Abstract**

The Vienna Circle idea that science is an interdisciplinary enterprise leads to the question of how the knowledge of the natural sciences can be used to further understanding in the social sciences. Analysis of the practice of social research shows there is no easy answer to this question. Ideologies colour the use of exact knowledge in social research methods; even in the natural sciences ideological misunderstandings seem inevitable in research practice. The concept of strangification is introduced to describe this situation and to give a framework for a methodology to handle this problem of scientific regression. It is applied to the problem how the mathematical theory of complexity can be used in the social sciences to understand complex social phenomena. 

*Keywords:* Complexity; Systems; Interdisciplinary; Social sciences; Methodology

## 1. A personal route to science

I began my academic career studying physics, because in my opinion that was the most challenging of disciplines. I was fascinated by the intellectual puzzles of modern physics and was comforted by the idea that the real world was its testing ground. The world of human beings also had its appeal for me and because I was a serious student I thought to become engaged in this world by joining a debating club. It was in this atmosphere of discussing with friends the problems of the world and the way that academics might be able to contribute to solving those problems that my second academic career started. We debated the Marxist view of science and society, we were tempted by the Freudian view, we discussed Popper's criticisms of Marx and Freud, we explored the work of the Vienna Circle (1929). In short, we debated all kinds of social views of science, thereby exploring the history of the development of modern social sciences. At the same time I was sparked by the enthusiasm of those members of the debating club who were studying social psychology; for them real life was the laboratory for testing social sciences. This seemed to me a sound basis for an empirical science, and, because their institute of social psychology was attempting to combine psychology with sociology, I applied to study this in-between-discipline in my spare time alongside my main study in physics. This was the start of my interdisciplinary career in science, and

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perhaps the subjective basis for a methodology for doing interdisciplinary research.

## 2. Interdisciplinary social research

In the natural sciences, it is taken for granted that the enterprise of science is an interdisciplinary one. A classic example is the interaction between physics and mathematics: physics cannot do without mathematics, mathematics cannot survive without physics. Sound mathematical (and logical) reasoning is also relevant to the conduct of social research in a proper and non-ideological way. At least, that was the argument, among others, of members of the Vienna Circle such as Carnap (1928) and of influential theorists of science such as Popper (1934). Early researchers who were influenced by those ideas and who tried to practice an interdisciplinary social science were associated with System Theory (von Bertafalany, 1932–1942; Lewin, 1948, Bateson, 1972).

As a (social) psychologist, Kurt Lewin used the ideas of natural scientists in a rather unproblematic way. Inspired by the motto of the mathematician Whitehead that "nothing was more practical than a good theory" he thought to combine in action-research highly abstract theories, such as his field theory, with the concrete practice of working with small minority groups of boys. In his field theory he used the mathematical idea of a topological structured space to develop a psychological counterpart of the field theory of physics.

Given my background as a physicist, it was no surprise that I was attracted by these ideas and that I, together with fellow students, began to practice action-research. Later on, when my enthusiasm for this kind of practice of social science had brought me a career as a researcher in the social sciences, I wrote articles and a book on action-research (van Dijkum, 1981).

However, I gradually discovered in such interdisciplinary practices two sides to the use of knowledge of one discipline for another discipline. Focusing on mathematics: at first I used mathematical reasoning in a fairly non-problematic and naive way, as a pure application of mathematical knowledge. However, such usage could lead to strange results. Lewin, for example, had the idea that psychological reality should be mapped out in a space with its own topology and its own problems of measurement, an idea that was realised and explored for example, in mathematical psychology (Roskam, 1981). But in the practice of social research, without further arguments, that knowledge was neglected and forgotten. The result is that nowadays almost all measuring instruments are based on a single topology, that of (a linearly structured) Euclidean space. Mathematical reasoning was limited to an arbitrary choice, not scientifically disputed. According to Holzkamp (1972), such use of mathematical knowledge was typical of psychological research. In his view, using such techniques as factor-analysis, mathematical concepts were used superficially to camouflage empty and often ideologically coloured research. In our practice of action-research, we did not use factor-analysis, but tried to use very different methods of quantitative multi-variate analysis, combined with qualitative analyses, in order to come to a convergence in conclusions. But was this enough to avoid Holzkamp criticism? In any case we needed to answer the question how knowledge from one discipline can be used in another discipline. Is such knowledge properly used or misused?

This question became pressing when we used advanced scientific knowledge in the field of (computer) simulation and gaming. Computer models as operationalizations of differential equations were used in the practice of action research to simulate the essential quantitative aspect of problem situations and let stakeholders in the problem experiment with suitable interventions. Different quantitative methods were used to analyse the available empirical data and to arrive at a convergence in the description of the problem situation. In one example, different actors from the Dutch health care system were able to experiment with interventions to raise the quality of medical centres. The quantitative side of this experiment was represented in a computer model in which costs, quality of care and (quantifiable) interventions were programmed. This was used in a game in which an intervention became the model's input, the effect of that intervention the output, whereupon then a decision for the next intervention was made in a second round, and so on. The rules of the game made it possible for the subjective and qualitative side of the problem to be explored by the participants (van Dijkum and ten Brummeler, 1989; van Dijkum and Bunck, 1990).

Using computer simulation, quantitative explorations could be improved, alternative models as a follow-up of a game more easily programmed, while at the same time the reality behind these quantitative worlds could be discussed with new insights.

One of the questions raised was what quantitative data give an adequate view of the processes in the real world. In order to compare the simulated sequences of events and to have information about an intervention and its effect, longitudinal data are needed. Moreover, to analyse those data one has to identify time related sequences as causes and effects. In addition, the possibility of feedback between effect and cause has to be introduced, thus allowing causes to be influenced by effects. That is logically argued in system dynamics and, as a consequence, beautifully expressed in recursive differential equations (Forrester, 1971; Haefner, 1996). However, methods of research (collecting and analysing data) in social science are mostly fixed on static data and are not well suited to investigate feedback loops between causes and effects.

Wondering how that could happen we encountered practical arguments in the cost of longitudinal surveys. But most of all we were confronted with the doctrine that to be falsifiable, reasoning has to be very simple. The idea that there is a mutual interaction between cause and effect, i.e. causal recursion is considered too complicated and not a logically sound way of viewing causality. Besides that, why should one use such complicated tools as differential equations when there are more than enough simple (statistical) expressions to formulate relations between data?

Amazed by the lack of clear logical arguments for these opinions, I searched for the source of such misunderstandings. That was not so difficult to find, because most of the methodological literature, when it became too difficult to argue the simplicity of the opinions above cited, refers to Popper (1934) who seemed to be at the origin of all that wisdom.

It was true that Popper preferred simple logical reasoning. However, he based his arguments meticulously in (his view of) logic and mathematics. The only way to honour such a work of science was to analyse these arguments, to update them in the same way Popper himself did, and to ask oneself whether those updated arguments do indeed lead to the rules described.

## 3. A program of methodological research

This was the starting point of my systematic exploration of the question of how logic and mathematics is properly used in the social sciences.

### *3.1. The use of logic and mathematics in social science: A case*

At first I was interested in the question of how Popper's methodology was grounded in logic and mathematics. Although Popper clearly approved of the way the Vienna Circle tried to give social science a basis in logic and mathematics, he thought to correct certain "flaws" in Carnap's attempts to establish a logic of inductive probability. In Popper's view an inductive logic was not possible because it would have to be justified and gave rise to the following problem:

> ..To justify it, we should have to employ inductive inferences; and to justify these we should have to assume an inductive principle of a higher order; and so on. Thus the attempt to base the principle of induction on experience breaks down, since it must lead to infinite regress (Popper, 1959, p. 29)

In this frame of reference he rejected induction. In general Popper seemed to think that the only valid logic in science was a finite logic because of the problem of infinite regress. In order to avoid infinite regress one has to use the (finite) deductive logic of the "modus tollens"; a scientist has to look for facts which are in contradiction with the statement. One can then decide with certainty, via a finite number of steps, that a statement is untrue, i.e. falsify a statement. In his preference for finite simple logic Popper introduced the principle of simplicity: "Simple statements, if knowledge is our object, are to be prized more highly than the less simple ones because they tell us more; because their empirical content is greater; and because they are better testable" (Popper, 1959, p. 142).

Popper rejected infinities because he was influenced by Hilbert's program of logic (Hilbert, 1904). If one analyses Popper's texts the following (idealised) principles of Hilbert's program can be distilled from them: (a) one can reduce mathematics to axioms of formal logic; (b) all the proofs of formal logic are finite (see van Dijkum 1991a). But at the same time that Popper was inspired by Hilbert's program it was also disputed. Gödel (1931) in particular explored the boundaries of Hilbert's program, attempting to push the principles of the program to the limit in order to demonstrate that the theorems of logic and mathematics could all be produced using finite mechanical procedures (algorithms). First he proved for a (simple) field of logic that all the statements could be produced in this way. Next, he reasoned that if it was possible to prove the theorems of mathematics in finite steps in this way, then of course it should be possible to prove all the theorems of arithmetic in a mechanical way. However, he failed in this and arrived at a paradoxical result. It was possible to formulate statements of which neither the negation nor the affirmation could be inferred from within the system of statements. One can make a statement about a system, from within a system, that the system is not provable. What this showed is that Hilbert's program must fail. If – even in arithmetic – statements existed which were true, but could not be formally proven, what would be the case with even more challenging branches of mathematics?

The logical base of Popper's program was consequently questionable: the "modus tollens" mechanism also allows the problem of infinite regress to arise (Popper, 1959; van Dijkum, 1988, 1991). Moreover, the principle of induction is still needed in science (Lakatos, 1978). When in his plea for an open mind, Popper (1982) later referred to the Austrian mathematician Gödel, he realised this, but was not sufficiently explicit to prevent his disciples believing in a simple falsificationism. According to Lakatos, Popper's followers misunderstood his carefully balanced ideas of objectivity, deduction and falsification; the dogmatic use of Popper's ideas was counterproductive.

Instead of a sophisticated falsificationism, a naive and dogmatic use of ideas of falsification developed within the scientific community (van Dijkum, 1993). As a consequence, many simplifications found their way into the methodology of the social sciences. For example, social research practice scarcely contains any models other than simple linear ones. The analysis of cause and effect relations is simplified to an analysis of the linear dependency of the effect on the cause, expressed as a linear correlation. Such practice was in fact not due to Popper, but the result of another simplification that Reichenbach (1956) introduced in (social) science. This simplification can also be falsified and exchanged for the idea of causal recursion (Maruyama, 1963; Blalock, 1969; Aulin, 1990; van der Zouwen and van Dijkum, 1998).

I conclude that when knowledge from logic and mathematics is used in social science the consequence can be most strange. That could be a reason to correct and update the methodology of the social sciences.

### *3.2. The use of advanced mathematics in the social sciences: Another case*

This did not, however, change my optimism about the use of logic and mathematics, and prevent me becoming involved in a group of natural scientists in the Netherlands (Verhulst and Broer, 1990; Tennekes, 1990; Verhulst, 1996) who, with the aid of non-linear (computer) models, were exploring previously phenomena of chaos and order in nature. Inspired by this work we set up a group of authors from fields such as physics, medicine, geography, psychology, sociology and organisational theory to analyse the use of non-linear (computer) models for empirical research in the social sciences. The result was a book (van Dijkum and DeTombe, 1992) which explored the use of non-linear (computer) models in these social sciences.

Several conclusions could be drawn from this book. First, that non-linear (computer) models can be used to describe social phenomena. The book gave examples such as the functioning of the heart, the description of eye movements in the reading process, processes of migration in a small village, the (abrupt) change of opinions in our society. Further, chaos and order were already described before in the social sciences, for example in classical works of organisational theory, but in a rather vague and metaphorical way. With mathematically formulated non-linear (computer) models those intuitions could be sharpened and the boundaries of such metaphors investigated. The question was then how far it was possible to go in the quantitative description of phenomena which had initially been described qualitatively. It was for this theme that social scientists could refer to a similar question in the natural sciences. Mathematicians have concluded that not all mathematical knowledge can be set out in quantities. The output of non-linear models are indeed quantities, but (graphic) patterns in that stream of output have to be described by qualitative concepts, such as "strange attractors", "fractals" and "penrose figures". A discipline like topology in which the interrelationship of quantities is studied is consequently an important part of the theory of non-linear (dynamic) models. The conclusion for social scientists may be that qualitative descriptions of chaos and order are essential to explore those phenomena. In addition, this should enhance the value of the original contributions of social researchers as Lewin in which the connectness of the psychological space was a theme for qualitative reflection.

However, when considering the question of how chaos and order can be investigated empirically, one is again confronted with the regression of Popper's program Instead of using computers to explore the boundaries of quantitative descriptions, social scientists considered the finite logic of falsification to be best supervised by a computer. There is then only the algorithm in which the output is determined by the input in a number of finite steps and no possibility of intervention by the subjective human mind. This is science freed from the ideology of human beings, and rid of qualitative explorations. The methodology is aimed at a knowledge which is as little as possible affected by the researcher or the instrument of research. Objective knowledge would be possible if all the choices of researchers could be translated into a computer program (Swanborn, 1987).

With such ideas, non-linear models were hardly used or accepted in the social sciences. The surprising and sometimes uncontrollable nature of these models was at odds with such thoughts. Simple models are difficult enough and they also give more information than complex models. Similarly simple models do not require differential equations, certainly not non-linear differential equations. Non-linear models were seen as artefacts of no use in the practice of social research. In short, in this case too, I came to the conclusion that the standard methodology of the social sciences functioned more as an impediment than as a framework to guide the growth of scientific knowledge.

### *3.3. Stagnation in science?*

Such a conclusion is in the long run not only valid for the social sciences; one has to remember that the natural sciences were also dominated over a long time by a language in which there was a fixation on linear phenomena. Facts which nowadays are interpreted as non-linear were denied, seen as a disturbance or simply corrupted. With new hardware and software, however, mathematicians and computer scientists could go beyond this position and explore non-linear models. To answer the question of why linear models have dominated natural sciences for such a long time, mathematicians sometimes refer to Laplace's deterministic view of the world (see Verhulst and Broer, 1990). Laplace believed in a world in which the future was determined by laws, which could be calculated by an almighty intelligence (God):

> Given for one instant an intelligence which could comprehend all the forces by which nature is animated and the respective situation

> of the beings who compose it – an intelligence sufficiently vast to submit these data to analysis – it would embrace in the same formula the movements of the greatest bodies of the universe and those of the lightest atom; for it, nothing would be uncertain and the future, as the past, would be present to its eyes. (Laplace, 1814; English translation p. 1301, Newmann, 1988)

This idea was challenged by Poincaré in his age:

> But that is not always the case; it may happen that slight differences in the initial conditions produce very great differences in the final phenomena; a slight error in the former would make an enormous error in the latter. Prediction becomes impossible and we have the fortuitous phenomenon. (Poincaré, 1908; English translation p. 1361, Newmann, 1988)

In modern natural science, Poincaré's intuition can be verified by computer experiments and Laplace's determinism can at last be falsified. According to analysts of science (Böhme et al., 1978) the maturity of the natural sciences makes it possible to overcome ideological regressions, but the social sciences, lagging behind are not yet sufficiently mature. That is perhaps why most social scientists still use a deterministic world view.

## 4. A methodology for interdisciplinary research into complexity

### 4.1. The emergency of complexity

Such an outdated view is no longer tenable because, not only the natural sciences, but also society is confronted with problems that cannot be fully comprehended by the simple deterministic view. We are faced with a dynamic world which changes faster and faster. We also now understand that organisations are not machines but are adaptive and unpredictable (DeTombe and van Dijkum, 1996). Scientific knowledge is needed to survive in the midst of this uncertain world, but one needs a methodology to handle this knowledge adequately.

The natural sciences have introduced the concept of complexity to shape this methodology (Prigogine, 1980; Casti, 1994). That methodology first introduces the idea that knowledge is no longer simple. One needs to combine different kinds of knowledge or different points of view to describe a phenomenon. Different disciplines have to work together to outline objects in a scientific way. In addition, a phenomenon has to be seen as a whole whose parts work together to constitute the whole. The phenomenon has to be seen as a system in which causes and effects are regulated by feedback cycles. Dynamic system theory states that such causal systems themselves evolve and cannot simply be seen as constants. This description of a system evolving over a period of time is one aspect of the idea of complexity. However, there is something else which is essential for a complex (non-linear) dynamic system. That is outlined in the following definition of a complex system:

> A complex system is an evolution generated by simple mathematical rules or physical principles that exhibits complicated, unpredictable behaviour. (Griffeath, 1992)

This is the essence of a complex system. Although the evolution is generated by simple mathematical rules, the outcome is unpredictable. Moreover, a computer, which is normally thought of as a perfectly deterministic entity, can produce unpredictable behaviour.

### 4.2. The understanding of complexity in an interdisciplinary enterprise

One can use mathematics to explain what complexity is, but to determine the complexity of a system is a task which has to be achieved through the co-operation of different disciplines, for example between mathematics and physics. This is not a simple matter and requires considerable effort to escape the ideology of a deterministic world view outlined above.

Why this world view should have dominated scientific thoughts so long can perhaps be understood by reference to the function of ideology. Ideology functions as an instrument to preserve the interest of a ruling group (Rein, 1976). It is possible that the scientists in power were more concerned with retaining that power than on the progress of science? It may be that science was thus turned by a power elite into a bureaucracy in which "the facts could not speak for themselves", a bureaucracy producing ideology rather than theory which alienated scientists from their scientific aims. This is the kind of analysis open to a sociologist of science.

In trying to understand these phenomena, the philosopher of science Wallner and Peschl (1990, 1991) employs the concept of 'strangification'. Strangification is a kind of alienation in our own time, which arises through interdisciplinary efforts to understand the world. Disciplines have to work together in order to understand the complexity of the world, yet the language each discipline uses is different. In the process of translation between the disciplines therefore strange things can happen. The mathematician does not understand how his concept of complexity is used in biology, the biologist does not understand how in computer science the concept of a living organism is used by programmers. It seems inevitable that in the use of knowledge from one discipline by another small but essential discrepancies or shift in the meaning of concepts arise. Wallner calls this strangification. The question is whether these shifts in concepts can be used positively in the development of science.

### 4.3. Analysing complexity

With this concept the main theme of my method, i.e. methodological program of research can be spelled out more explicitly. I focus on the question of how the complexity of the social world can be understood in an interdisciplinary analysis. For the social sciences the question becomes: how can the knowledge of the mathematical theory of complexity help the social sciences to understand the complexity of social phenomena?

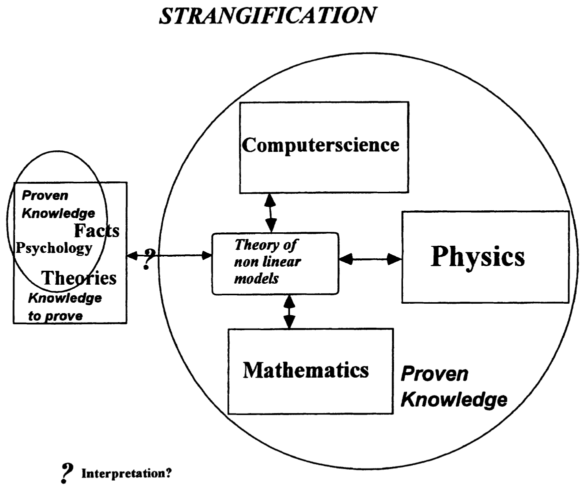


Fig. 1. The transfer of knowledge (strangification).

Schematically:

The question can be reformulated: how can the strangification of the theory of complexity, from the natural sciences to the domain of the social sciences (for example psychology), be used to develop valid knowledge about the complexity of social phenomena? (see Fig. 1).

For the social sciences, the strangification of natural scientific research into complexity is not at all easy and implies fundamental methodological problems. Nevertheless that enterprise has been started by a number of scientists and the attempt to lead the social sciences on the scientific road of complexity is being taken seriously (see for example: Goerner, 1994; DeTombe, 1994; van Dijkum, 1997). In this literature, the challenges are made quite clear and a base for our next step in a methodology of interdisciplinary co-operation designed to handle complexity.

### 4.4. The strangification of complexity: A methodology and methods

So far, we have laid a minimal methodological base to handle complexity in the social sciences. This base implies the reformulation of a number of original, logical questions and subsequently the (re)formulation of methods which are essential to conduct social research according to the latest advances in the (natural) science. First of all this means that Popper's original search for the logic of science is restored to his essence. The negative strangification of logic and mathematical concepts which introduced regression into social science research is reversed into a basis for positive strangification. That is one of the elements of our methodology.

Beyond Popper, the emergence of the science of complexity gives rise to new concepts and a new approach of social phenomena. As has been demonstrated the source of these new concepts lies in mathematics and computer science. To grasp the essence of complexity, we experimented with non-linear models, beginning with the classical examples which lie on the border between the natural and social sciences (van Dijkum and De-Tombe, 1992). That was the method we started with. Pursuing a positive strangification of essential mathematical concepts, we continued to build specific recursive non-linear models of social phenomena as the next methodical step. We took the knowledge, skill and software (for example STELLA and POWERSIM) needed to construct these models from the field of system theory and system dynamics. To use the achievements of such solid cross-disciplines is another element in our methodical approach. Further, we collaborated with mathematicians and used tools such as Maple and Mathematica to ensure correct handling of mathematics. We used theories and results of empirical social science research, selecting this knowledge to suit to our (methodo)logic concepts of complexity. We selected theories in which causal recursion and non-linear feedback are described; and used data in which time-series were represented at the least. These selections were essential for our method to ensure a positive strangification of the theory of complexity to the social sciences.

As examples we developed complex (non-linear) models in two fields: psychology of health (van Kuijk et al., 1998; Mens-Verhulst et al., 1998) and criminology (van Dijkum and Landsheer, 1997). In both fields we work with longitudinal data and theories which: (a) are accepted by main stream researchers; (b) lead to non-linear models; (c) had not been modelled before. The resulting non-linear models proved to be as good or as better than competing linear models in explaining the empirical data, and generated typical non-linear phenomena such as patterns of bi-furcation. Moreover, in both fields we found researchers who were very interested in such patterns, in case of psychology of health field even by the originator of the used theory (Leventhal et al., 1984). A positive strangification of complexity into the empirical field of the socials sciences seems to be possible.

On the other hand, our positive strangification encountered a lack of any methods of validation for non-linear models. Our methodology is subsequently aimed at the development of a method of validation as a positive strangification of methods which can be found in the natural sciences, such as fingerprinting (Hegerl et al., 1994), or more in general, the use of Takens' projection thesis (1981). In addition, as a result of experience with these methods in the natural sciences, and guided by methods of social sciences, we will develop a method in which: (1) a quantitative comparison of the outcomes of the non-linear model with the data; (2) is related to a qualitative comparison of the patterns of outcome of the non-linear models (for example patterns of bifurcation in the development of a patient's complaints) with qualitative data (for example the variety in the own description of patients' complaints). From such related comparisons of model and data and interrelated to a comparison of an alternative model and data, a statement about the degree of (sophisticated) falsification will have to result. The concept of metaphor is used as a methodical device to supply a bridge between usable social scientific theories and the qualitative interpretation of the model and the data (see also: Verhulst, 1994).

In all these efforts, communication between the various disciplines is important. Strangification can be seen in a positive light and can be used as a method to translate a concept from one field to another in an exact way. However, still strange interpretations of concepts may result when research results are transferred from one field to another. It is known from anthropology and linguistics that a translation of even apparently straightforward concepts from one natural language to another can give rise to unexpected problems because of differences in cultural backgrounds (Ochoa, 1995). Science is a part of the society and will be influenced by values, belief systems, culture and power structures (Kuhn, 1962). Concerning those phenomena a more sociological interpretation of strangification as a consequence of ideologies and bureaucracy cannot be avoided. Even mathematics cannot completely escape from this influence (Fischer, 1995). In this situation the social sciences have developed specific methods to improve interdisciplinary communication. These methods are aimed at two aspects of the communication between disciplines. The first task is to enable the transfer of information and understanding between different disciplines. For this to be successful, the language of each discipline must be understood by every participant in the communication. This can be accomplished by translating the language of each discipline into an intermediary language, such as natural language, using metaphors and artificial languages such as mathematics, logic and systems theory. During the process another task arises: ensuring that different points of view are respected in the teamwork which develops among the participants of the interdisciplinary communication. For this one can refer to the observations of social scientists that such tasks are not automatically carried out by those participating, but with intelligent planning and a reasonable facilitator they can be managed. For this purpose, we employ social scientific knowledge of group communication, and the skills which have been developed for a modern group decision room (DeTombe and van Dijkum, 1996).

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