

Robert Rosen: The Life of a Freethinker

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Robert Rosen (1934–1998) spent his working life on one question. What makes a living organism different from a machine?

His answer went against a belief that had carried biology since Descartes. The belief was simple. An organism is a mechanism. You can explain it from its parts. In principle, you can rebuild it on a computer.

Rosen disagreed on three points. A living cell makes its own working parts. An organism does not only react; it anticipates. And a model is something different from a simulation.

This essay follows his life, from Brooklyn to Chicago, Buffalo, Santa Barbara and Halifax. It then explains his main ideas in plain words. It ends with his place in *The Golden Thread*, a series of life stories of freethinkers that starts with Spinoza.

Every fact below was checked against at least two independent sources. Where sources disagree, the essay says so.

Brooklyn and Chicago, 1934–1964

Rosen was born on 27 June 1934 in Brownsville, a district of Brooklyn, New York. He grew up as the only child of a Jewish family. Sources say little about his schooling before Chicago.

In the same year, 1934, a Russian émigré started a weekly seminar at the University of Chicago. His name was Nicolas Rashevsky (1899–1972). He was a physicist who had fled the Russian civil war. He came to the United States via Constantinople and Prague. His plan was bold. He wanted to treat biology like physics, with mathematical models instead of microscopes.

Rashevsky called this *mathematical biophysics*. In 1939 he founded his own journal, the *Bulletin of Mathematical Biophysics*. Mainstream biology journals rarely took purely theoretical work. In 1947 his group became the Committee on Mathematical Biology.

The group was small but influential. In 1943 Warren McCulloch and Walter Pitts published their famous paper on neurons as logic switches in Rashevsky's *Bulletin*. It became a foundation of neural network theory. There is an irony here. The journal where Rosen would later argue that organisms are not machines was also the journal where the brain was first described as a computing machine.

Around 1950 Rashevsky reached an uncomfortable conclusion. Twenty years of models of single processes had not produced a picture of the living whole. In 1954 he changed course. He began to study the relations between the functions of an organism, whatever the matter that carried them. He called this *relational biology*.

The same years brought a crisis. In 1953–54 several members of the Committee were accused of communist sympathies. Rashevsky refused to dismiss them. The university cut his budget, and the group shrank from eight members to three.

Into this small group came Robert Rosen. Nadin dates his arrival to 1957; Louie places him there from the mid-1950s. In 1958 Rosen published two papers in the *Bulletin*. Together they hold the core of his life's work.

The first introduced *metabolism-repair systems*, or (M,R)-systems. The idea is easy to state. A cell takes in matter and turns it into other matter: that is metabolism. The enzymes that do this wear out and must be replaced: that is repair. But the repair parts also wear out. Follow this through, and you reach a loop. In an organism, everything that makes the organism work is made by the organism itself.

The second paper brought in a new kind of mathematics. Rosen used category theory, which Samuel Eilenberg and Saunders Mac Lane had introduced in 1945. Category theory describes objects and the arrows between them, without saying what the objects are made of. For Rosen, that was exactly the point.

In 1959 Rosen received his PhD under Rashevsky. He was twenty-five. He stayed in Chicago until 1964. In those years he wrote *Optimality Principles in Biology*, published in 1967 by Butterworths in London. Some sources date it to 1970; the publisher's page and library catalogues show 1967.

In 1964 the Committee fell apart. Rashevsky resigned in a conflict with the university and moved to Michigan. Rosen, now thirty, left for Buffalo. He took three things with him: Rashevsky's question, category theory as his language, and the experience of working against the current.

Buffalo and Santa Barbara, 1964–1975

In Buffalo, Rosen joined the State University of New York. He also had a joint appointment at the new Center for Theoretical Biology. The Center was led by the British cell biologist James Danielli, known for the Davson–Danielli model of the cell membrane.

His colleagues included Howard Pattee, a physicist who came in 1971. Pattee studied how symbols, such as the genetic code, relate to the matter that carries them. His idea of *semantic closure* looks much like Rosen's later *closure to efficient causation*. The sources do not show whether one influenced the other.

In 1969 Ludwig von Bertalanffy arrived in Buffalo. He was one of the founders of general systems theory. Systems science became Rosen's second home. His work would appear mostly in systems journals and series, and less in biology.

In Buffalo Rosen wrote textbooks. *Dynamical System Theory in Biology* appeared in 1970. He also edited *Foundations of Mathematical Biology*, three volumes, in 1972 and 1973. Rashevsky died in January 1972, while the volumes went to press.

The year in Santa Barbara

The turning point of his career did not happen in Buffalo. It happened at a think tank in California that had nothing to do with biology.

The Center for the Study of Democratic Institutions was founded in 1959 by Robert Maynard Hutchins. Hutchins had led the University of Chicago from 1929 to 1951. Like Rosen, he was born in Brooklyn. At his Center, fellows met daily to discuss the big questions of society: technology, ecology, media, civil rights, peace.

Rosen went there as a visiting fellow. The sources disagree on the year. Rosenlife.org and Wikipedia say 1970. Nadin and Louie say the academic year 1971–72. The papers Rosen wrote there were submitted on 18 October 1972. That detail points to 1971–72.

Rosen came to talk about planning and policy. He noticed something. A society that plans makes a picture of its future. It then acts now according to that picture. He saw the same pattern in organisms. And he saw that science had no concept for it.

In the preface to *Anticipatory Systems*, Rosen owed as much to Hutchins and his Center as to his teacher Rashevsky. It was there, he wrote, that he first had to face the nature of anticipatory behaviour.

What an anticipatory system is

Four papers came out of that year. The best known is "Planning, management, policies and strategies: four fuzzy concepts". It appeared in 1974 in the first volume of the *International Journal of General Systems*, edited by George Klir. According to Louie, Rosen used the term *anticipatory system* there for the first time.

Physics since Newton describes systems that react. The state now, plus the forces acting now, decides the state later. Causes come before effects. A system that steers by something that has not yet happened seems to chase a goal. And goals, or final causes, had been banned from science since the seventeenth century.

Rosen found a way out. A system can steer by the future without the future acting on the present. It only needs a model inside that runs faster than reality. Louie sums up the definition. An anticipatory system contains a predictive model of itself and its environment. It uses that model to change its state now, according to what the model predicts for later.

The difference with a reactive system is not the direction of cause and effect. It is what the system carries inside: a model that runs ahead, and a way to act on its outcome.

In 1975 Rosen left Buffalo. The same year, Pattee moved to Binghamton. Rosen accepted a post at Dalhousie University in Halifax, Nova Scotia.

Halifax, 1975–1998

In 1975 Rosen became Killam Research Professor in the Department of Physiology and Biophysics at Dalhousie University. He was forty-one. The post freed him from teaching. It gave him what his work needed most: time. In the preface to *Anticipatory Systems* he thanked Dalhousie as a place where thinking was still valued.

Halifax lay far from the centres of American biology. For Rosen, that was no loss. He had never worked in a large laboratory.

Three books

The first book from Halifax was *Fundamentals of Measurement and Representation of Natural Systems* (North-Holland, 1978). It asks what happens when a natural system is measured. A measurement turns a state into a number. Numbers become a description. A description becomes a model. Rosen asked what is lost on the way, and what is needed to get back from the model to the system.

Between January and June 1979 he wrote *Anticipatory Systems*. The book did not appear until 1985, from Pergamon Press in Oxford. The preface blames the delay on "external reasons" without saying more. The book first explains the modelling relation. It then works out the anticipatory system. His daughter Judith Rosen regards it as the most important part of his work.

The third book made him known. *Life Itself* appeared in 1991 from Columbia University Press. It takes up the question Erwin Schrödinger asked in 1944: what is life? Rosen held that the question, in that form, was badly posed. Donald Mikulecky summed up the better question: how do organisms differ from machines?

Rosen planned *Life Itself* as the first part of a larger work. A second part, on the ontology and synthesis of organisms, was never finished.

Student and society

In 1979 Aloisius Louie came to Halifax as his doctoral student. He started just as Rosen finished the first draft of *Anticipatory Systems*. Louie received his PhD in 1981 with a thesis on *Categorical System Theory*. He would become the main interpreter of Rosen's mathematics.

In 1980 Rosen was president of the Society for General Systems Research. Bertalanffy, Rapoport, Boulding and Gerard had conceived that society in 1954. His successor in 1981 was George Klir. Around 1984 Rosen visited Ei Teramoto's group in mathematical biology at Kyoto University.

The pattern was now fixed. In systems science Rosen was an established figure. In biology he remained an outsider.

The end

Rosen worked at Dalhousie until his retirement. Louie and Mikulecky both report a long illness in his last years.

He died at the end of December 1998, aged sixty-four. The sources disagree on the day and the place. Rosenlife.org and Wikipedia give 28 December. Louie writes "Wednesday, 30 December 1998, in Halifax". We checked: 30 December 1998 was indeed a Wednesday. Wikipedia names Rochester, New York, as the place of death.

He left a wife and children, among them his daughter Judith. She became the keeper of his legacy. She founded Rosen Enterprises in Rochester, publisher and archive of his work. His *Essays on Life Itself* appeared in 2000. In 2012 Springer published a second edition of *Anticipatory Systems*, with contributions by Judith Rosen, John Kineman and Mihai Nadin.

The ideas in plain words

Rosen's work rests on three ideas. Each one breaks a part of the machine picture of life.

1. Closure to efficient causation

Rosen borrowed an old tool: the four causes of Aristotle. A thing has a material cause (what it is made of), a formal cause (its form), an efficient cause (what makes it) and a final cause (what it is for).

In a machine, the efficient causes come from outside. A factory builds the machine. A mechanic repairs it. In an organism, Rosen argued, every efficient cause is made inside the organism itself. He called this *closure to efficient causation*.

His (M,R)-system makes the idea exact. Think of three steps.

1. Metabolism (f) turns food into products.
2. Repair (Φ) uses those products to rebuild the metabolism.
3. Replication (β) rebuilds the repair. And β is itself one of the products of metabolism.

The loop closes. Every maker in the system is made within the system. Matter still comes from outside: the cell must eat. But the working causes do not.

2. The modelling relation

What does it mean that one system is a model of another? Rosen gave a precise answer.

A natural system changes by its own causes. A formal system, such as a set of equations, changes by logical inference. You *encode* a state of the natural system into the formal one. You infer. You *decode* the result back. If you land where nature itself would have gone, the formal system is a model.

This leads to a sharp distinction. A *simulation* only copies the outcomes. A *model* also mirrors the structure of cause and effect. Louie put it briefly: a simulation describes, a model explains.

3. Anticipation

The third idea joins the first two. An organism carries a model of its world inside it. That model runs faster than the world. The organism acts now on what the model predicts for later. Goals and purposes, banned from science since the seventeenth century, thus get a precise meaning. All causes still lie in the present.

The big claim, and the debate

From these ideas Rosen drew his boldest conclusion. A system closed to efficient causation cannot be fully captured by any computable model. In other words: life cannot be simulated on a Turing machine.

This claim set off a long debate after his death.

Yea	Who	What they argued
2002	Landauer and Bellman	Parts of Rosen's mathematics, especially the construction of β ,
2003	Letelier, Marín and	Every autopoietic system (Maturana and Varela) is an (M,R)-
2006	Letelier, Soto-Andrade, Guíñez, Cornish-Bowden	A first worked example in which β exists, using arithmetic on a twelve-hour clock.
2006–	Chu and Ho	Rosen's central proof against artificial life is incorrect. Louie replied.
2007	Wolkenhauer and Hofmeyr	A self-organising cell needs a special kind of mathematics (a cartesian closed category); ordinary simulations can imitate life
2009	Mossio, Longo and Stewart	Closure can be written in Church's lambda calculus, so there is

2010	Cárdenas, Letelier and others; Piedrafita and	Closure is now widely accepted; a simple self-maintaining metabolism was built and simulated.
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The state of play is mixed. Closure to efficient causation has become a standard idea in theoretical biology. The claim that it cannot be simulated is still disputed.

The circle around Rosen

Rosen had few doctoral students and no school in the usual sense. He ran no large laboratory. Yet a circle formed around his work, and it grew larger after his death. It has three rings.

Those who kept and explained the work

- **Aloisius Louie**, his student, became his main interpreter. He settled in Ottawa. His three books give Rosen's mathematics one continuous frame: *More Than Life Itself* (2009), *The Reflection of Life* (2013) and *Intangible Life* (2017). He defended Rosen's claim that life cannot be computed.
- **Judith Rosen**, his daughter, holds the rights to his books and runs Rosen Enterprises. In talks and articles she stresses one distinction: reactive versus anticipatory systems. Science, she argues, quietly assumes that all systems behave like machines.
- **Donald Mikulecky**, a physiologist at Virginia Commonwealth University, was not a student but a reader whose own work changed through Rosen. In 2001 he called Rosen "biology's Newton".

Those who built on it

- **Mihai Nadin** came to anticipation by his own route. His book *MIND – Anticipation and Chaos* appeared in 1991. He later wrote the long introduction to the 2012 edition of *Anticipatory Systems*. No collaboration with Rosen is documented. Nadin himself mentions an exchange of letters in 1995 and says they never met.
- **John Kineman** wrote a new chapter on the ontology of anticipation for that edition. He sees Rosen's relational approach as a basis for a science of nature as a whole.
- **George Klir, Howard Pattee and George Kampis** carried his work into systems science.
- The **Chilean–French group** of Letelier, Soto-Andrade, Cárdenas and Cornish-Bowden rewrote the (M,R)-systems in clear algebra.
- **Jan-Hendrik Hofmeyr** in Stellenbosch built a model of the self-making cell on Rosen's version of Aristotle's four causes.

Those who checked the proofs

Rosen's claims were big. His proofs were short and written in his own notation. After his death, others had to work out what he had actually proved. Landauer and Bellman (2002) and Chu and Ho (2006) found gaps or errors. Mossio, Longo and Stewart (2009) showed that closure itself can be computed. Louie disagreed with them, and the question is still open.

After Rosen: anticipation as a field

In the quarter century since his death, anticipation has become a research field of its own. Springer publishes a book series called *Anticipation Science*, edited by Roberto Poli. *A Handbook of Anticipation* appeared in 2019. Louie wrote its chapter on the mathematical foundations.

So Rosen's work lives on along two roads. One is mathematical: making relational biology rigorous. The other is broader: using anticipation to understand people, organisations and societies. That second road leads back to where the idea began, at Hutchins' Center in Santa Barbara.

Rosen and The Golden Thread

The Golden Thread is a series of life stories of freethinkers. It starts with Spinoza; the first volume, *On the Way with Spinoza*, is online at maze.swarp.nl/spinoza. Each story follows one person, their places and their connections. Shared people and places are the knots that tie the stories together.

In this series a freethinker is not simply someone who rejects authority. A freethinker sees a shared expectation of their time fail, before the rest do. They name the failure. And they offer a new picture of the whole. Resistance often follows, but it is a result, not the test.

The expectation that failed

For Rosen, the expectation was this: an organism is a mechanism. It can be explained from its parts. In principle, it can be rebuilt on a machine.

That expectation had a long history. It goes back to Descartes, who saw animals as machines, and to the success of Newton's mechanics. In the twentieth century it gained new strength from cybernetics, computing and molecular biology. It still drives the dream of the "virtual cell".

Rosen saw it fail in three places:

1. **Organisation.** A cell makes its own working parts. A machine has its makers outside.
2. **Time.** Organisms do not only react to the past. They act on a model of the future.
3. **Science itself.** A model must mirror the causes, not only copy the outcomes. Simple systems, where every model can be simulated, become a special case. Life becomes the general case.

His new picture is the organism as a relational organisation. It makes and maintains itself. It carries a model of its future. It is known by its relations, not by its matter.

The knots

Rosen's story shares people with Spinoza's. Those shared people are where the two stories tie together.

Person	Link to Rosen	Kind and
Aristotle	Rosen built closure on Aristotle's four causes, above all in <i>Life Itself</i> (1991).	Trace, docum
Descartes	Rosen named the Cartesian picture of the organism as machine as the view he opposed.	Trace, docum
Spinoza	Spinoza called final causes a human invention (<i>Ethics</i> I, Appendix). Rosen gave goals a precise, causal meaning through anticipation. No source shows that	Echo, hypoth
Church, Gödel,	Rosen wrote on Church's thesis (1962) and Turing's morphogens (1968), and saw Gödel's results as a symptom of the limits of formal systems.	Trace, docum
Eilenberg and Mac	Rosen applied their category theory (1945) to biology in 1958.	Trace, docum

A *trace* is documented contact. An *echo* is a shared form without proven transfer.

One more echo points forward. Roger Schank's *Dynamic Memory* (1982) made the *expectation failure* the engine of learning. An inner script predicts; when it fails, memory reorganises. Rosen's anticipatory system also carries an inner model whose failure matters. No contact between the two men has been found. In this series the link counts as an echo, with the status of a hypothesis. It is also the root of the series' own definition: a paradigm shift is a collective expectation failure.

Rosen asked what life is, what a model is, and what a machine cannot do. These questions are now taken seriously. The answers are still open. That is what makes him a freethinker.

Annotated references

All links below were opened during the research. The full source notes are in the Dutch package *Op weg met Robert Rosen*, chapters 1–12.

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