

Could mathematics help to better treat cancer?

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The development and survival of living beings are linked to the ability of their cells to perceive and respond correctly to their environment. To do this, cells communicate through chemical signal systems, called

signalling pathways, which regulate and coordinate cellular activity. However, impaired information processing may prevent cells from perceiving their environment correctly; they then start acting in an uncontrolled way and this can lead to the development of cancer. To better understand how impaired information transmission influences the activity of diseased cells, researchers at the University of Geneva (UNIGE), Switzerland, are going beyond the field of biology. They propose to examine cellular communication in the light of information theory, a mathematical theory more commonly used in computer science. This work, to be discovered in the journal *Trends in Cell Biology*, offers a radically new approach to oncology.

"In a way, cancer can be viewed as an information disease," says Karolina Zielińska, a researcher at the Translational Research in Onco-haematology (CCTOH) at UNIGE Faculty of Medicine and first author of this work. "But while the oncogenic power of over- or under-activated signalling pathways is becoming well known, the exact mechanisms remain quite mysterious." How, indeed, do cells make their decisions based on the information they perceive—or no longer perceive? "Sometimes biology alone is not enough to decipher everything," explains Vladimir Katanaev, a professor at CCTOH, who led the research.

Measuring uncertainty

In the late 1940s, American mathematician Claude Shannon developed a probabilistic [theory](#) to quantify the information transmitted in a set of messages over a noisy communication channel. This theory has enabled the development of modern communication systems and computers. It is also the basis for a multitude of applications such as data compression and transmission, cryptography and artificial intelligence. "But curiously, Shannon's theory has not much been applied in the field of cell signalling," says Karolina Zielińska, who is both a mathematician and a

biologist. "Our idea is to use this powerful tool to examine the decisions made by diseased cells and compare them to those made by [healthy cells](#)."

Information theory uses probability theory as a fundamental tool. Its main concept, called [entropy](#), aims to measure the uncertainty of random variables. "If, for example, we flip a coin, the coin may randomly fall on heads or tails, so the result is uncertain. Now imagine a coin with two identical faces: the result is certain, and the entropy is nil. Entropy thus evaluates the degree of uncertainty of a random variable. When applied to communication, entropy indicates the amount of information necessary for the receiver to determine unambiguously what the source has transmitted."-

From mathematics to biology

Applied to cell signalling, information theory allows studying how cells process the information they receive from their environment. When a cell receives a stimulus—an information—from its environment, what concentrations of information can the cell process without error?

Knowing a cell response, can we distinguish between different stimuli to evaluate which one triggered this particular response? These questions are essential in the field of cancer. Indeed, cancer cells may be unable to process information from the environment as well as healthy cells, and start to proliferate and divide when it is not necessary to do so.

Researchers will now test the validity of their approach by studying how breast and lung cancer [cells](#) process information from their environment. Indeed, current treatments generally aim to remove or completely extinguish certain signalling pathways, despite significant side effects.

"The new approach we are proposing is not aimed at shutting down the signalling pathways, but rather at restoring their proper activity," says Vladimir Katanaev. "By applying pure mathematical concepts to biology,

we hope to identify information transmission failures that need to be fixed to correct them."

More information: K.A. Zielińska et al, Information Theory: New Look at Oncogenic Signaling Pathways, *Trends in Cell Biology* (2019). DOI: [10.1016/j.tcb.2019.08.005](https://doi.org/10.1016/j.tcb.2019.08.005)

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