

What can philosophy teach us about chemical reactions?

Dr Ross Stein



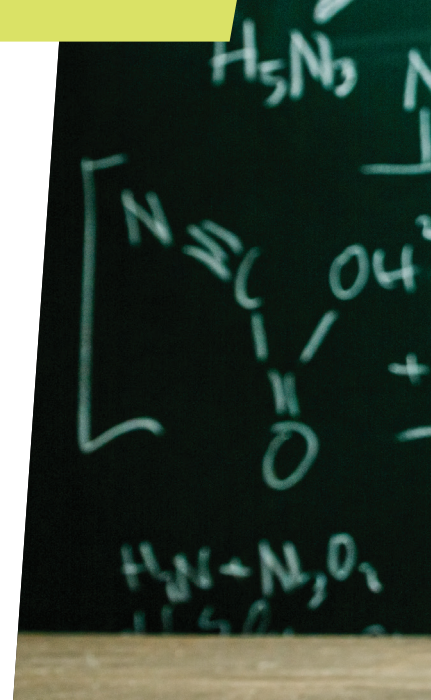
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What can philosophy teach us about chemical reactions?

Why do chemical reactions occur? Are molecules stable entities or constantly changing components in a dynamic system? These questions are best answered not by science, but by philosophy, says **Dr Ross Stein**. As an enzymologist, Ross studies chemical reactions with the aim of developing new drugs to treat diseases. And as a philosopher of science, he uses ideas from metaphysics to explore why these chemical reactions occur.



Dr Ross Stein

Independent scholar

Fields of research

Enzymology; philosophy of science

Research project

Exploring what metaphysics teaches us about chemical reactions

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Every second, countless chemical reactions take place inside your body. These reactions allow you to breathe, digest food, produce energy and fight disease. Understanding exactly how these reactions occur is essential for developing new medicines, but have you ever thought about why chemical reactions happen in the first place?

Dr Ross Stein is an enzymologist for a pharmaceutical company, where he investigates how enzymes speed up chemical reactions. Alongside his career in enzymology, Ross has a personal interest in philosophy. As an independent scholar, he explores metaphysics – the branch of philosophy concerned with the fundamental nature of reality – and applies this knowledge to understand more about chemical reactions.

How and why do scientists study chemical reactions?

“The chemical transformation of one molecule into another involves breaking chemical bonds between

Talk like a ...

philosopher of science

Chemical reaction — a process in which chemical bonds break and new bonds form, transforming one molecule into another

Enzyme — a protein that speeds up chemical reactions in living organisms without being used up itself

Metaphysics — the branch of philosophy that explores the fundamental nature of reality and asks why things happen

Philosophy of science — the study of how science works, including how scientific

knowledge is developed and how scientific explanations can be understood

Process metaphysics — the philosophical view that change is a fundamental feature of reality, so entities such as molecules are constantly changing rather than remaining fixed

Substance metaphysics — the philosophical view that entities such as molecules are naturally stable, with change occurring because of external influences

the atoms of a molecule and forming new bonds between these atoms to create new molecules,” explains Ross. For example, when methane burns in oxygen, the carbon-hydrogen bonds in methane molecules and oxygen-oxygen bonds in oxygen molecules break, before new carbon-oxygen bonds form to produce carbon dioxide and hydrogen-oxygen bonds form to produce water. For this transformation to occur, several conditions must be met. “A molecule must gain enough

energy, that energy must be directed towards specific chemical bonds, and the reacting molecules must be correctly positioned,” says Ross.

One of the main ways scientists investigate enzymes is by measuring how quickly they carry out chemical reactions and how factors such as temperature or pH affect these reaction rates. This knowledge is particularly valuable because many diseases involve enzymes that work



too quickly or too slowly, so drugs work by interacting with enzymes to change their rates in the body. Ross's work as an enzymologist is helping scientists to understand diseases and develop new drugs to treat them.

What is metaphysics?

Metaphysics is a branch of philosophy that asks fundamental questions about the basic nature of reality. Ross's interest in metaphysics complements his scientific research into enzymes. "While science investigates *how* a phenomenon occurs, metaphysics asks *why* it occurs," he explains. "For example, scientific studies explain how chemical reactions occur, while metaphysical investigations explain why. What must reality be like for the chemical transformation of molecules to occur?" To explore this question, Ross draws on two approaches to metaphysics: substance metaphysics and process metaphysics.

How does substance metaphysics explain chemical reactions?

The word 'substance' has a special meaning in philosophy that differs from its everyday use. It can be traced back to the ancient Greek philosopher Aristotle and his concept of *ousia*, a Greek word often translated as 'substance' but more accurately meaning 'entity'. According to substance metaphysics, entities such as atoms, molecules, cells and organisms are naturally stable, and change is something that happens to them because of external influences.

"Substance metaphysics views molecules as inherently static – much like the ball-and-

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While science investigates how a phenomenon occurs, metaphysics asks why it occurs.

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stick models of molecules used in chemistry classes," says Ross. "This is at odds with what chemistry actually teaches us." Substance metaphysics states that as energy is added (e.g., if the temperature is increased), a molecule will transform into another stable molecule. According to Ross, this view does not fully reflect what modern chemistry tells us because it treats chemical reactions as something that happen to molecules, rather than as part of their natural behaviour.

How does process metaphysics explain chemical reactions?

Process metaphysics can be traced back to the ancient Greek philosopher Heraclitus, who famously said that you can never step into the same river twice because it is constantly changing. Rather than seeing stability as the natural state, process metaphysics argues that entities are always changing and that stability is only temporary.

"Process metaphysics views molecules as inherently dynamic, with continuous internal motions that include rotations around chemical bonds, and torsions and vibrations of these bonds," says Ross. "The structure

of the molecule is not fixed but comprises an ensemble of many structures." Process metaphysics views molecules as part of a larger reacting system that includes the solvent and other molecules in solution. It states that as energy is added, internal motions in the molecules become more pronounced until the reacting system progresses to a new state.

Ross believes that this dynamic view is more consistent with what contemporary chemistry teaches because it sees chemical reactions as part of the ongoing behaviour of the reacting system. "I view the chemical transformation of molecules from the point of view of process metaphysics, where the molecule is part of a chemical reactive system which includes the molecule, solvent and other molecules in solution," he says.

How has philosophy influenced Ross's science?

Although Ross's study of philosophy is separate from his day job as an enzymologist, it has influenced the way he approaches his scientific research. His knowledge of process metaphysics helps him understand why chemical reactions depend on the dynamic nature of enzymes. "My study of philosophy has made me a more critical thinker and made my scientific writing clearer and more precise," he says. "Philosophy stresses sound and logical arguments to support a specific position, which has carried over into how I think about scientific problems."

As the study of knowledge and existence, philosophy helps us ask deeper questions about why the world works the way it does. How could you benefit from an understanding of philosophy?

About *philosophy of science*

“Philosophy of science is the branch of philosophy that investigates the foundations, methods and purpose of science,” says Ross. “Rather than doing science, it steps back to ask what science actually is, how it works and whether it reveals the true nature of reality.”

Philosophers of science explore questions about how scientific knowledge is developed, how scientists investigate the world and how we understand scientific explanations. “Topics include the scientific method

(How is science done?), questions about realism (Are molecules real? How can we know they exist?), and ideas about the laws of nature,” says Ross.

For Ross, science and philosophy provide two ways of understanding the same reality. Science helps explain how phenomena occur, while philosophy helps us think about why they occur and what reality must be like for them to happen. “The sort of metaphysics I practise insists that whatever philosophical stance I take,

it must be consistent with the findings of science,” he says.

Studying philosophy can also help scientists develop important skills in critical thinking. Philosophy encourages people to question their assumptions and clearly explain why they believe what they believe. “The chief skill lies in being able to propose an explanation for something and then defend the explanation with clarity, backing up every assumption with sound arguments,” says Ross.

Pathway from school to *philosophy of science*

At school, build a strong foundation in science subjects such as physics, chemistry and biology. Ross also recommends developing a broad education in subjects such as history and literature, as philosophy is focused on ideas and these subjects will help you explore how ideas develop and influence the world.

Some universities offer undergraduate programmes in philosophy of science. If this is not available, you could study a degree in philosophy while taking science courses, or vice versa.

Ross recommends gaining experience in philosophy of science by conducting research projects with professors in the field.

Explore careers in *philosophy of science*

Many philosophers of science are academic researchers who work at universities to philosophically study scientific questions while also teaching students.

You could work as a scientist for a company, like Ross, and apply your knowledge of philosophy to your scientific research.

Learn more about careers in the field from the Philosophy of Science Association: **philsci.org**



The ancient Greek philosopher Aristotle developed the concept of substance metaphysics. © thelefty/Shutterstock.com



Meet Ross

I've been interested in science and math for as long as I can remember. As a teenager, my other main interests were music (I played the trumpet in the school band and a rock group, and I had a pretty good album collection) and reading science fiction. I didn't do organised sports, but I played baseball and football with my friends.

My inspiration to become an enzymologist came from the biochemistry course I took during my junior year of college. The course was taught by an enzymologist, and I was lucky enough to work as a technician in his lab during my junior and senior years. This experience, along with his encouragement, set me on the course to become a scientist.

I've always been of a philosophical bent; I had considered studying philosophy in college. But it wasn't until 25 years later, when I found a copy of *The Reenchantment of Science* by process philosopher David Griffin in a used-book store, that my interest in philosophy was fully awoken. I bought the book, read it, and was hooked!

Through *The Reenchantment of Science*, I discovered process philosophy, with its emphasis on the centrality of change and flux in nature. I immediately saw how the metaphysical teachings of process thinkers might help me understand, at a deeper level, the mechanisms of chemical reactions. It seemed that process philosophy could allow me to move from understanding the *how* of chemical reactions to exploring the *why* – the metaphysical principles that underpin the chemical transformation of molecules.

Even after all these years, I still enjoy being in the lab doing experiments as an enzymologist. Part of what I enjoy about philosophy is the broad, open-ended problems and questions it presents. These broad ideas complement the more narrow, practical thinking of my role as an experimental scientist.

Without question, my favourite philosopher is Alfred North Whitehead, the 'father' of process philosophy. His writing can be very difficult, but it is worth the effort.

Outside of my work as an enzymologist, much of my free time is devoted to reading and writing philosophy. I also continue to play the trumpet in a community band and a small jazz combo. And whenever I can, I enjoy listening to live music.

Ross's top tips

Read constantly and broadly, and think critically by recognising and questioning every assumption.

Philosophy of science

with Dr Ross Stein

Talking points

Knowledge

1. What is an enzyme?

Comprehension

2. From a scientific perspective, how do chemical reactions occur?
3. Why is it important to understand chemical reactions in order to develop new medicines?
4. What are the differences in how substance metaphysics and process metaphysics explain why chemical reactions occur?
5. Why does Ross argue that process metaphysics is more consistent with modern chemistry than substance metaphysics?

Application

6. Modern chemistry describes molecules as constantly moving and interacting. How might this understanding influence the way scientists investigate enzymes or design medicines?
7. How has studying philosophy influenced Ross's approach to scientific research?

Evaluation

8. To what extent do you agree that philosophy can contribute to scientific progress, even though philosophers do not carry out experiments? Why?
9. Scientific discoveries often answer how something happens, while philosophy asks why it happens. To what extent do you agree that both types of questions are equally important? Why?

Activity

Philosophy and science have always been closely connected. While science investigates how the world works through observation, experiments and evidence, philosophy asks deeper questions about why things happen and what scientific explanations really mean. Many important scientific ideas have developed because researchers questioned existing assumptions and explored new ways of understanding the world.

Ross argues that philosophy can strengthen scientific thinking by encouraging researchers to examine the concepts behind their work. His interest in process metaphysics, for example, has influenced how he thinks about enzymes and chemical reactions, leading him to view molecules as dynamic, constantly changing systems rather than fixed entities. Although philosophy does not replace scientific experiments, it can help scientists interpret evidence, develop theories and ask better research questions.

Discussion

Work with a partner or in small groups to explore the role of philosophy in modern science by discussing the following questions:

- Why is it important for scientists to question assumptions rather than simply accepting existing ideas?
- How can philosophy encourage critical and creative thinking in scientific research?
- Can philosophical thinking contribute to scientific discoveries and technological innovation? Find real-world examples.
- How might philosophy improve communication between scientists and the wider public?
- Should philosophy be included as part of science education for all students? Why, or why not?

Case study

Choose a scientific discovery or theory (e.g. evolution, quantum mechanics, climate science) and investigate how scientific understanding of this topic has developed over time. Identify the assumptions that were challenged, the evidence that changed scientists' thinking, and how considering alternative explanations contributed to progress.

Reflection

Write a short essay (~500 words) answering the following question: "Can science continue to advance without philosophy, or does philosophical thinking play an essential role in scientific discovery?" Use examples from Ross's article and your own research to support your answer.

More resources

- The Philosophy Foundation provides educational resources about philosophy: philosophy-foundation.org/philosophy-for-children

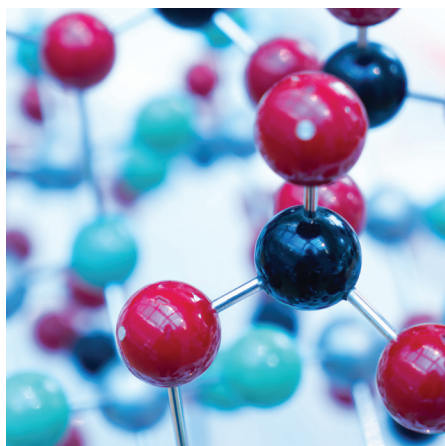


Photo montage

Top: The ancient Greek philosopher Heraclitus famously said that you can never step into the same river twice because it is constantly changing. © declarmat/Shutterstock.com

Middle row: Left: Ball-and-stick models are used to explain the structure of molecules, which assume that molecules are static entities, as taught by substance metaphysics. © alice-photo/Shutterstock.com

Centre: As a scientist, Ross investigates how chemical reactions occur. And as a philosopher, he asks why they occur. © Alexx60/Shutterstock.com

Right: Philosophers of science ask questions such as 'What is science?' © Triff/Shutterstock.com

Bottom: Ross works as an enzymologist to investigate how enzymes influence chemical reactions in the body, as this knowledge will help scientists develop new medicines. © THICHA SATAPITANON/Shutterstock.com

