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# CHEMICAL BIOLOGY, SOCIAL CHEMISTRY

In recent years, chemical biology has played a crucial role in numerous medical breakthroughs, including research on proteases, which are among the most important regulators in the chemical biology of life. It is essential to ensure that this knowledge reaches a broad audience.

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In an era of rapid civilizational, technological, and environmental change, science is increasingly less an abstract construct confined within university walls. Its tangible presence in social life – from health policy to innovation ethics – requires deeper reflection. This is particularly evident in chemical biology, a discipline situated at the interface of life and matter, biology and chemistry, theory and practical application. At the microscopic scale of proteins, enzymes, and molecules, processes occur whose consequences extend to the macroscale of social discourse.

## Science as a Mechanism of Social Change

Let us begin with the fundamentals: science – conceived not merely as a system of knowledge but also as a cognitive process – is one of the most powerful drivers of civilization. Research in chemical biology is no exception. These studies have enabled us to understand the mechanisms of inheritance, develop modern diagnostic methods and targeted therapies, and design life-saving drugs. The social impact of such research

extends far beyond the laboratory. It is crucial for public health, quality of life, life expectancy, food safety, and environmental protection.

Biochemistry should therefore not be regarded merely as a “science for scholars.” Its outcomes contribute to healthcare systems, the pharmaceutical industry, biotechnology, diagnostics, and numerous other sectors that underpin social well-being. One could argue that modern society cannot progress without the contributions of scientists studying the molecular foundations of life.

## The Pandemic as Evidence

Until recently, chemical biology – like many basic sciences – was often perceived by the public as somewhat abstract field. The COVID-19 pandemic dramatically challenged this perception. Suddenly, scientists who routinely analyze viral protein structures or optimize mRNA vaccines became central figures in public debate. Research in chemical biology provided the foundation for vaccines, therapies, and diagnostic tests, all of which were crucial in addressing the global health crisis.

Among the most remarkable achievements of chemical biology during the pandemic was the development of Paxlovid, the first orally administered SARS-CoV-2 protease inhibitor to receive FDA approval for the treatment of COVID-19. In this context, my research group, in collaboration with Prof. Rolf Hilgenfeld's team, made a significant contribution to its development. At the very beginning of the pandemic, we mapped the activity of the SARS-CoV-2 Mpro



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protease – the enzyme essential for viral replication – and described its “enzymatic fingerprint.”

This work enabled the rapid identification of sites that could be chemically targeted to inhibit viral replication. Importantly, these data were made freely available to the global scientific community in the spirit of open science. As a result, Pfizer was able to design and test the protease inhibitor nirmatrelvir in record time, which, in combination with ritonavir, forms the drug now known as Paxlovid.

Paxlovid not only shortens the duration of illness but, more importantly, reduces the risk of hospitalization and death among high-risk individuals. It is available in numerous countries and contributes to saving lives on a daily basis. All of this began with fundamental research: the analysis of viral enzymes in the chemical biology laboratory at Wrocław University of Science and Technology.

This example illustrates how seemingly distant academic research can have a direct impact on public health on a global scale. It also shows that the

scientist’s social responsibility extends beyond the acquisition of knowledge to include its dissemination to other researchers, companies, institutions, and society at large.

## Proteases: Enzymes That Change the World

Although the term may sound technical, proteases are among the most crucial players in the chemical biology of life. They are present both in the human body and in pathogens, and their activity underlies many essential processes – from digestion and cell-cycle regulation to viral infections. It is therefore unsurprising that proteases have been the focus of intensive research by both academic scientists and drug developers for decades.

One of the most significant milestones in protease research was the discovery and therapeutic application of HIV protease inhibitors. In the 1990s, during the AIDS epidemic – which was taking a devastating toll

On June 4, 2025, the new laboratory building at IPC PAS was inaugurated, housing research teams carrying out projects under the ERA Chairs *Perfection* program and the Teaming for Excellence *TRIO-VI (CoE)* ICTER program

– scientists identified HIV protease as a key enzyme responsible for processing the proteins required for the formation of new virions. Inhibition of this protease effectively prevents viral replication.

In 1995, the first HIV protease inhibitors, including saquinavir and zidovudine, were introduced, fundamentally transforming the course of the disease. AIDS shifted from being a fatal disease to a chronic condition, giving millions of people worldwide renewed hope for life. To this day, protease inhibitors remain a cornerstone of antiretroviral therapy.

A similar scenario unfolded in the case of hepatitis C virus (HCV). Early therapies were largely ineffective and often associated with severe adverse effects.

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The breakthrough came with the discovery of the NS3/4A protease, which proved to be essential for HCV replication. Drugs targeting this protease revolutionized hepatitis C treatment, achieving cure rates approaching 100 percent.

Beyond viral diseases, research on proteases has also opened new avenues in anticancer therapies. Many cancers exploit proteases to facilitate tissue

invasion by degrading the extracellular matrix and promoting metastasis. Inhibiting these enzymes can slow disease progression and improve therapeutic outcomes.

Modern chemical biology increasingly views proteases not only as therapeutic targets but also as disease biomarkers. Their presence, concentration, or enzymatic activity may indicate cancer, neurodegenerative diseases, infections, or autoimmune disorders. This approach opens the door to precision medicine, tailored to the individual biochemical profile of each patient.

Consequently, research on proteases – their structure, function, and mechanisms of action – should be regarded not as an expense, but as a strategic investment in public health. A society that invests in science simultaneously invests in its own well-being.

## Public Trust and Scientific Responsibility

On the one hand, science provides tangible solutions. On the other, society does not always know how to make use of this knowledge. The challenge of communicating complex molecular processes and interpreting research findings often places chemical biology behind a wall of misunderstanding, and, at times, mistrust. This challenge must be addressed not only by society, but also by the scientific community itself.

Science must learn to speak the language of society. A text such as this is one way to initiate dialogue between scientists and the broader public. Transparency and accountability are equally essential. Researchers should not limit themselves to publishing results in specialized journals accessible primarily to their peers, but should also shape public discourse – by explaining, inspiring, and educating.

In this context, the idea of open science deserves special attention, as it is emerging as a cornerstone of contemporary research ethics. Accordingly, research results – including those in chemical biology – should be publicly accessible so that they can serve the common good. This represents a fundamental shift in the approach to knowledge, from elitism to inclusivity.

Naturally, every form of power carries the risk of misuse. By virtue of its capacity to intervene in the fundamental structures of life, chemical biology operates at the boundary between immense potential and equally profound risks. Genetic manipulation, the design of drugs that affect the psyche, and research on artificial DNA or proteins are all areas that raise ethical concerns.

The social role of science also lies in identifying these boundaries and respecting them. What is needed is an ethical framework for molecular research that is not merely a set of prohibitions, but a living system of

Peptide synthesizer



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reflection – one that includes both the scientific community and society at large. This is one of the central challenges of the 21st century: how can we conduct research without causing harm; how to make discoveries without manipulation; how to create without dehumanizing.

## Education as the Foundation of Trust

The social role of biological chemistry does not end with the laboratory, a publication, or the implementation of an invention. Its full realization occurs when knowledge becomes an educational tool. Schools, universities, science museums, and the media all play a crucial role in popularizing an understanding of life functions at the molecular level.

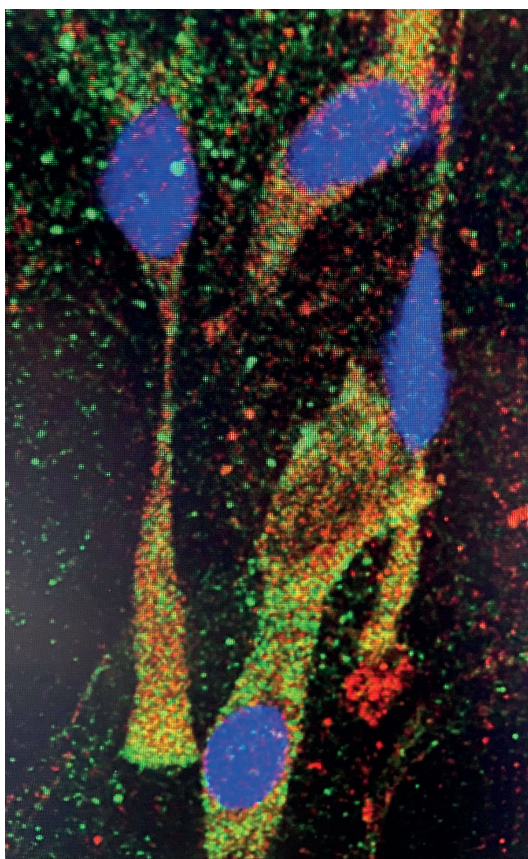
This is not merely about “teaching chemistry.” It is about educating a society capable of understanding contemporary health, environmental, and biotechnological challenges. A person who understands what the coronavirus spike protein is will find it easier to decide to get vaccinated. Likewise, someone familiar with the basics of enzymology is better equipped to critically assess dietary supplements or alternative therapies.

We live in an era in which the boundaries between biology and technology are becoming increasingly blurred. Concepts such as synthetic biology, gene editing, and nanomedicine – each rooted in biochemical research – are no longer speculative visions but emerging realities. It is therefore worth asking: are we, as a society, ready for these changes? Can we benefit from science without becoming either uncritically enthusiastic about technology or reflexively technophobic?

The role of scientists in this process is twofold: on the one hand, they are obliged to conduct rigorous and ethically responsible research; on the other, they must actively participate in shaping public awareness. This is not an easy task. It requires time, patience, empathy, and a willingness to engage in dialogue.

## The Centre for Biological Chemistry: Bridging Education and Science

The establishment of the Center for Biological Chemistry at the Institute of Physical Chemistry of the Polish Academy of Sciences, under the ERA Chairs grant which lead, is an event of great significance both for Polish science and society. Until now, research in biological chemistry – a key discipline at the intersection of biology, chemistry, and medicine – has been largely absent within the Polish Academy of Sciences. Yet, as noted earlier, it is biological chemistry that provides



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Human cells infected with SARS-CoV-2 with the viral Mpro protease stained using a chemical marker (green)

the tools to understand life processes at the molecular level and forms the foundation of modern therapies, diagnostics, and biomedical technologies.

The creation of a dedicated center at IPC PAS opens entirely new opportunities: attracting outstanding scientists, developing interdisciplinary research projects, and, above all, generating innovations that can deliver tangible benefits for public health, the environment, and the economy. It also signals that Polish science not only keeps pace with global trends but is increasingly capable of setting its own directions of development in areas with the greatest social impact.

## Science as a Common Good

Biological chemistry is a field with the power to change the world – but not in isolation. Its social role is fulfilled only when it is imbedded in the broader contexts of culture, politics, education, and everyday life; when it becomes part of a shared conversation about who we are as humans and where we are heading as a species.

This cannot be achieved without trust. It cannot happen without openness. And it cannot occur without reflection. For although biological chemistry speaks the language of molecules, its true meaning is ultimately expressed in a social language – the language of care, responsibility, and hope. ■

### Further reading:

*Biological Chemistry – A Science That Speaks Two Languages*, PAS podcast “Has PAS heard of this?”, <https://www.youtube.com/watch?v=L1UBC9m2Xvo>

*Inauguration of the PERFECTION Project – The First Center for Biological Chemistry Established at the Polish Academy of Sciences*, <https://ichf.edu.pl/wydarzenia/inauguracja-projektu-perfection-powstaje-pierwsze-centrum-chemii-biologicznej-w-polskiej-akademii-nauk>

*Prof. Drag: I Discovered Positive and Negative Aspects of Science in the Pandemic*, <https://www.pap.pl/aktualnosci/news-%2C1581877%2Cprof-drag-poznałem-w-pandemii-jasna-i-ciemna-strona-nauki.html>