Wissenschaft trifft Kunst – Biochemie trifft Kreativität
Von Zellen, Viren und Proteinen
English Texts

1 Science Meets Art - Biochemistry Meets Creativity: On Cells, Viruses, and Proteins

This exhibition brings together science and art through biochemical themes by presenting their creative processes, questions, and results in comparison.

It is based on the research of Professor Sebastian Springer: the exhibits were developed from scientific data and images from his laboratory. The focus is on cells, viruses, and proteins, which are explored by the artist Heike Seyffarth through painting, graphics, sound, digital experiments, and textile works. Through visual and textual connections, it becomes clear that science and art share common ground: both can be experimental, engaging, and aesthetic.

Both scientific and artistic work require creativity,for example when designing experiments or transforming data into new forms of expression. While science often reinterprets existing knowledge, art seeks radical new creation. Both fields draw on existing knowledge, but differ in their aims: scientific understanding versus artistic expression.

The exhibition raises questions about parallels in creative processes, the potential of interdisciplinary exchange, and the role of aesthetics. It presents the results of an ongoing dialogue between the two fields.

The exhibits in the four sections—Cells, Viruses, Proteins, and Creativity—are accompanied by color-coded index cards:

* orange cards contain scientific information,
* blue cards explain creative processes,
* green cards present quotes on creativity.

The following scale can be used for orientation. The x axis shows a logarithmic scale, meaning that values increase tenfold with each section.

2 Cells

Humans, animals, and plants are made up of cells. Cells are very small—about 50 placed side by side measure only one millimeter in width. They cannot be seen with the naked eye. Cells can be spherical, elongated, flat, or star-shaped, depending on the function they perform in the body.

Each cell is like a small factory: it takes in nutrients, consumes energy, and communicates with other cells. Most cells can divide to give two daughter cells, equal or different.

3 Viruses

Viruses are extremely small—about one million viruses together equal the volume of a single cell. For their outer shell, they use simple geometric structures composed of only a few building blocks. Thus, viruses often have symmetrical forms such as spheres or icosahedra, resembling soccer balls. This efficiency reveals parallels between biology, geometry, and architecture.

Viruses cannot reproduce on their own; they depend on components found within the cells they infect.

4 Proteins
Proteins are versatile. Some act as enzymes that accelerate chemical reactions. Others serve as structural components, give cells their shape, or enable muscles to move. They transport oxygen throughout the body or function as hormones that transmit messages between cells. Viruses also contain proteins, for example in their outer capsids.

Proteins are key to understanding biological processes—this is why their study is so important.

5 Creativity in Science
Scientists observe, measure, and collect data.

But: explaining the world requires theories that are formulated and then tested against reality.

To really understand the world, we need theories that can be checked against what we see. So, where do these theories come from? They come from a creative process, much like in art, where skill and knowledge are important, but so is experience, intuition and a bit of luck. The researcher’s personality also plays a big part.

6 Orders of magnitude
Smaller than what we can perceive with the naked eye, there exists an astonishingly rich universe of forms and structures: cells, viruses, molecules, and atoms. Some of these are visible with modern microscopes; others are so tiny that we only know of their existence indirectly.

Researchers use sophisticated technical methods—such as X-ray diffraction, electron microscopy, or genetic analyses—to detect traces of this invisible world. In this way, they can prove even the existence of a virus that no-one can see directly.

7 Where am I?
On their inside, every human being harbors a bewildering diversity at every scale. Life means flow and change on all levels.

The illustration shows the biochemical transformations of some molecules in the cell (the metabolism).

Each individual arrow on this map is a chemical reaction that takes place in the cell under strictly controlled conditions. If one of them gets out of balance, diseases can arise. They appear to us, here on this chart, like interlocking gears.

8 Cells are the building blocks of life
Humans, animals, and plants are made up of cells.

Cells are very small—about 50 placed side by side make up just one millimeter. They cannot be seen with the naked eye. There are spherical, elongated, flat, or star-shaped cells, depending on the function they perform in the body.

Each cell is like a small factory: it takes in nutrients, consumes energy, and communicates with other cells. Most cells can divide to give two daughter cells, equal or different.

9 Cells contain organelles
1 nucleus
2 ribosomes
3 mitochondria
4 microtubule (cytoskeleton)
5 actin filaments (cytoskeleton)
6 clathrin vesicle
7 Golgi apparatus
8 endoplasmic reticulum

10 T cells of the immune system destroy virus-infected cells
Our immune system protects us from viruses in many ways. T cells play a particularly important role. These immune cells are distributed throughout the body—in the blood, in the skin, and in special collection points, the lymph nodes. T cells recognize whether a body cell is infected by a virus. They destroy the infected cell to prevent the virus from spreading further.

The film shows a T cell (left) attacking and destroying a virus-infected cell. Caution, time-lapse: the real duration is about two hours!

11 Viruses are much smaller than cells
If you were to enlarge a cell a million times in every dimension, it would be as large as this exhibition room. At this scale, a virus would be about as large as this crocheted model.

In reality, a virus is about 100 nanometers in diameter. Viruses are invisible to the naked eye—only electron microscopes can show them. Nevertheless, viruses have an enormous impact: they infect cells and reprogram them, they cause diseases, and they influence evolution.

12 Genetic classification of viruses
One can classify viruses according to their genetic material. This consists of nucleic acids—either DNA or RNA—and there are many variants: double-stranded or single-stranded, positively (forward) or negatively (reverse) coded. This classification reveals how a virus uses a cell’s machinery to reproduce. Knowing this, researchers can better understand how infections proceed and which strategies—and medications—are suitable for combating a particular virus.

13 Diversity of viral forms
Viruses sometimes resemble geometric works of art. They appear in many shapes: spheres, rods, cubes, or highly complex forms. This diversity arises from the combination of proteins that form the virus shell.

The diversity of shapes has a biological purpose: it helps viruses adapt to different hosts and to be particularly stable or efficient.

14 Virus envelopes: membrane or capsid
Not all viruses are built the same way. Many protect their genetic material with a stable protein shell called a capsid. Others also possess an outer membrane, which they steal from the host cell when they leave it. Such viruses are called enveloped viruses.

Capsid and membrane envelope are not only protection but also tools: they enable the virus to dock onto cells and penetrate them. The structure of the shell determines which cells a virus can infect and how.

1 - genetic material
2 - capsid
3 - membrane

15 Viruses can be viewed in very different ways
For some people, they are primarily seen as a threat because they can cause disease.
For scientists, they represent a challenge: how can we better understand them and develop therapies?
Others admire their efficiency: how they reproduce, adapt to their hosts, and use complex mechanisms to survive. Still others are fascinated by their symmetrical structures and delicate forms.

What is your perspective?

16 Viruses defend themselves and fight the immune system
To escape destruction by the immune system, some viruses have developed sophisticated strategies.

One example is the cytomegalovirus that causes monomucleosis (the 'kissing disease'). Cytomegalovirus produces immuno-evasins, i.e., proteins that block the MHC proteins of the immune system. As a result, T cells can no longer recognize virus-infected cells.

This scientific poster explains this blocking mechanism.

17 Form and color
Shown are models of viruses combined into a tableau.

Each individual form was created from the coordinates of individual atoms (and thus roughly corresponds to reality). These coordinates are obtained from black-and-white images from scanning electron microscopy. The colors are assigned arbitrarily to make it easier to discuss the resulting structures.

One might say: "the form is real, the color invented."

18 Virus capsids consist of proteins
The protective shell of a virus, the so-called capsid, consists exclusively of proteins. The construction of capsids is remarkably economical—with only a few types of proteins (highlighted here in color), a complex and functional structure is formed. Thus, viruses impressively demonstrate how versatile proteins can be.

Proteins are therefore much smaller than the virus capsids that are composed of them.

19 Proteins are the fundamental building blocks of viruses—and of cells
In the cells of humans, animals, and plants, proteins also have crucial roles: maintaining structure, movement, transport of substances into the cell, communication, metabolism.

Proteins have many different shapes or forms that always follow their function, optimized by evolution.

20 The geometry of viruses
Viruses are small. They have very little genetic material that codes for only a few building blocks (proteins). For their capsids (protein shells), they use simple geometric structures composed of a few building blocks. This often results in symmetrical shapes such as spheres or icosahedra that resemble soccer balls.

This efficiency makes viruses so successful: with minimal effort, they build stable and elegant structures.

Science finds parallels here between biology, geometry, and architecture.

21 Mathematical principles of capsids
The capsid, the protein shell of a virus, is a masterpiece of mathematical logic. To ensure stability and to reliably protect the viral genetic material, it is composed of as few repeating subunits as possible. These fit together like pieces of a geometric puzzle.

Icosahedral shapes are especially common—structures with 20 equilateral triangles.

This design saves energy and material while being extremely stable. For biologists and mathematicians, the virus capsid is an example of how nature finds elegant solutions to complex problems.

22 Many tasks are done by proteins
Proteins fulfil many different roles. Some act as enzymes that accelerate chemical reactions. Others serve as structural materials, giving cells their shape or enabling muscles to move. Still others transport oxygen through the body or act as hormones that transmit messages between cells. Proteins also play a central role in defending against pathogens, for example as antibodies.

Their versatility makes proteins key to understanding biological processes—and explains why protein research is so important.

23 Structure and function
The human body contains at least 30,000 different kinds of proteins (and many copies of each type).

Each protein has a three-dimensional structure, which is essential for its function.

24 An archive of all protein structures
The PDB database ("Protein Data Bank") is a global archive where the structures of proteins and even of entire viruses are stored.

For each molecule, the exact positions of its atoms are recorded—like a three-dimensional blueprint. These can be retrieved and visualized with computer programs.

25 Proteins are often symmetrical
Some proteins consist of several identical subunits arranged in fascinating symmetry, reminiscent of works of art.

In reality, most proteins are colorless. Only through coloring their structure does their elegance become visible to the eye.

26 The folding art of proteins
Proteins are long chains of amino acids that fold into complex three-dimensional structures. Their structure is essential for their function: an enzyme must have exactly the right shape to enable a chemical reaction.

The information for the structure is contained within the protein itself—in the sequence of amino acids.

27 How protein structures are determined
Individual protein molecules cannot be seen by the naked eye. There are several methods to determine protein structures: X-ray crystallography, nuclear magnetic resonance, and cryo-electron microscopy.

All these methods require complex technology (such as a synchrotron) and extensive computational work. To illustrate this, the image shows multiple structural models of a protein, as they might appear during the computational process, superimposed on X-ray films.

28 Models and reality
We will never truly know what proteins "really" look like—in fact, we cannot. They are too small, we cannot see them directly. Our models are representations of reality that help us grasp certain aspects of it, much like a work of art highlights and enhances aspects of reality. This is why there are many different ways to visualize proteins.

The image shows the ability of protein molecules to move - not by themselves, but pushed by water molecules.

29 Structures
Protein molecules have unique three-dimensional shapes.

That shape is not random but closely linked to its function: only with the correct structure can a protein perform its task.

30 Similarities between small and large
Sometimes biochemical structures resemble familiar objects.

This MHC protein, which helps fight viral infections, resembles a butterfly with outstretched wings—but it is a million times smaller!

31 Proteins are dynamic, they breathe and stretch
Proteins have stable structures, but they are also flexible and constantly pushed by surrounding water molecules. As a result, they appear alive, they move as if they were breathing or pulsing.

This flexibility is not incidental—it is often necessary for proteins to perform their functions.

In computer simulations, proteins appear as fascinating, dancing structures—tiny machines moving continuously to the rhythm of life.

32 Listening to proteins
From the x-y-z coordinates of proteins, fascinating images can be generated, sometimes in altered representations such as polar coordinates, as shown in the image. These structures can even be translated into sounds. What do you feel when you hear them?

33 Serial art from protein data
For this serial artwork, biochemical data were used as the basis for further processing. Each row shows properties of a specific protein: the statistics (frequency) of individual amino acids, or the frequency of consecutive pairs of amino acids (bigrams) and of triplets (trigrams). The final column visualizes the three-dimensional protein structure.

Such representations can provide a quick overview of similarities and differences between structurally similar proteins.

34 When proteins meet
To perform their functions, proteins often need to work together. Often, they bind to each other like puzzle pieces that fit perfectly. This creates larger complexes that carry out additional functions, for example in metabolism or signal transmission between cells.

At the same time, these interactions are dynamic—they can dissolve once the task is complete.

Such “molecular encounters” are the basis of almost all biological processes in the body.

35 How does the immune system recognize a virus-infected cell?
Imagine this: an inspector does not know which house a criminal is hiding in, but he knows the criminal’s preferred brand of chewing gum. In the yellow trash bag outside, he finds the wrapper—this could be the place!

MHC proteins are like that yellow trash bag: they bring fragments of proteins from inside the cell to the cell surface, so the immune system can see them. If a virus infects a cell, its fragments are also presented and recognized by the immune system’s T cells. This cell is infected!

36 Diversity of MHC proteins
MHC proteins vary greatly from person to person. This is why individuals have different immune responses, for example to the SARS coronavirus.

Here, we imagined different personality traits of various MHC proteins to illustrate their diversity.

The images show structures of MHC proteins from different perspectives.

37 The personality of MHC proteins
Scientists who study the different MHC proteins come to know them very well over the years.

For them, these proteins almost take on a kind of personality—depending on their organism of origin, significance in research and medicine, biochemical peculiarities, and how easy or difficult they are to work with.

38 Amino acids – The building blocks of proteins
Proteins are long strings made of smaller building blocks called amino acids.

You can think of an amino acid as a letter in an alphabet. From just twenty different "amin acid letters," cells can assemble countless "protein words"—just as thousands of words and sentences arise from an alphabet.

The sequence of amino acids determines how the protein folds into a three-dimensional structure, and what function it can perform. From twenty simple molecules arises an astonishing diversity that enables all processes of life.

39 The common core of all amino acids
All amino acids share a similar basic structure. At their center is the so-called alpha carbon atom. Attached to it are always the following three groups: a carboxyl group (-COOH), an amino group ($-NH_2$), and a hydrogen atom (-H). These components are the same in all amino acids.

Only the fourth group—called the side chain—differs and gives each amino acid its unique properties.

This simple yet elegant design allows nature to create countless combinations from a limited set of basic elements.

40 Diversity through side chains
All twenty amino acids share a common core structure, but they differ in their side chains. These can be small or large, hydrophilic (water-soluble) or hydrophobic (water-insoluble), acidic (negatively charged) or basic (positively charged), resulting in very different chemical properties.

When many amino acids join to form a protein, the sequence of these side chains determines the protein's three-dimensional shape and its function. This explains the immense diversity of proteins: even small differences in amino acid sequence can lead to big differences in structure and function.

41 Protein as a bracelet
Proteins are formed in the cell when amino acids are linked together into long strings. Imagine a charm bracelet: the backbone of the protein corresponds to the bracelet, while the different side chains of the amino acids hang down like small charms. Each amino acid contributes to the protein's properties through its side chain.

This bracelet is modeled after a real protein, with backbone and side chains according to the real chemical formulas. (In reality, proteins often consist of hundreds of amino acids and are not circular.)

42 DNA as a blueprint for proteins

The structure and function of a protein depend entirely on the sequence of its amino acids—this is called the protein sequence. But where does this information come from? It is stored in the DNA, the genetic material of all living organisms. Genes are sections of DNA that precisely specify the order in which amino acids are linked. Thus, DNA acts like a blueprint that the cell reads step by step.

Errors in this blueprint can cause a protein to malfunction, and lead to disease.

43 Three major biopolymers

Life is based on three major groups of biomolecules: carbohydrates, nucleic acids, and proteins.

Carbohydrates are primarily energy sources, such as sugars or starch. Nucleic acids like DNA and RNA contain the genetic information that controls every cell. Proteins, finally, are the most versatile molecules, carrying out countless functions in the organism.

Together, these biopolymers form the foundation of life. Without them, no cell could exist, no organism could grow, and even viruses could not function.

44 How does science work?

Scientists observe, measure, and collect data. But that alone is not science, yet.

To really understand the world, we need theories that can be checked against what we see. So, where do these theories come from? They come from a creative process, much like in art, where skill and knowledge are important, but so is experience, intuition and a bit of luck. The researcher's personality also plays a big part.

45 Creativity vby bombination

Combining things is an easy way to spark creativity. We can take what we already have and put it together in a different way, then tweak it as we need to for a new idea, a specific shape or a different goal.

This molecule is a combination of known structures that have been assembled into a new, imaginary molecule.

46 Creativity by analogy

When we see something for the first time, the brain instantly compares it with patterns that it knows already. Protein structures, , enlarged like this, might remind us of letters, for example.

What do the protein structures in this space remind you of? Feel free to write down your associations on a Post-it note.

47 Creativity by change of medium
This photo series presents different views of a protein in an artistic black-and-white aesthetic.

The corkscrew-like structures are called helices. They might remind us of tendrils of beans or pumpkins, as photographed by artists such as Karl Blossfeldt.

48 Creativity by play
The protein database [https://www.rcsb.org/, freely accessible] contains downloadable images of proteins. We placed them on invented tarot cards and assigned fictional positive traits and preferences to them.

From this, stories "from the lab" emerged in a productive dialogue about the studied properties of proteins, as shown in the exhibit "Creativity through stories."

49 Creativity through stories
This collection of notecards, each for one MHC protein, contains true stories from many years of laboratory research. It holds, in a condensed way, the work, the hope, and the joy of science, from many years.

This exhibit demonstrates how a shift in perspective can open up new ways of communicating familiar knowledge.

50 Creativity by abstraction
By transforming a protein shape in several steps, we end up with an image that looks quite abstract at first. But, if you look at it alongside the original protein, you can spot some similarities!

51 Creativity by random correspondence
The key visual of the Springer research group at Constructor University depicts the processes studied there as a meaningful graphic.

It can be compared with an earlier acrylic sketch created independently in an artistic context. The effect is similar to analogy formation.

52 Creativity by statistics
Proteins do not occur in isolation. They are constantly in motion. Statistical and mathematical methods are used to determine the positions and the movements of their atoms.

This exhibit shows several possible structures of a protein. When they are overlaid, one sees a model of its possible movements.

53 Creativity by visualization, image processing, and comparison
For this serial artwork, biochemical data were used as the basis for further processing. Each row shows properties of a specific protein: the statistics (frequency) of individual amino acids, or the frequency of consecutive pairs of amino acids (bigrams) and of triplets (trigrams). The final column visualizes the three-dimensional protein structure.

Such representations provide a quick overview of similarities and differences between structurally similar proteins.

54 Creativity by experiment
The Petri dishes are not actually showing real cells, but rather watercolour paintings that capture the variety and beauty of life—and a gentle reminder that cells are too small to see with the naked eye.

Inspired by experiments in the Springer lab, artistic experiments were created in which mixtures of paper, acrylic paint, and water produced interesting forms and color combinations.

55 Creativity by design
Here, the chain structure of amino acids in proteins was used as a blueprint for a bracelet.

The main chain (backbone) is recognizable by the repeating sequence of nitrogen (red) + hydrogen (white), carbon (dark blue) + hydrogen, and carbon + oxygen (light blue).

The side chains, which are like the details that give each protein its unique job and look, are shown here as pretty decorations.

56 Creativity by experience
Peptides—short strings of amino acids that are embedded between the helices of MHC proteins—are key carriers of biochemical information in the immune system.

The overview image shows a colorful peptide nestled between its helices.

At this interactive station, you can take the place of the peptide yourself and experience what such embedding might feel like.

57 Creativity by butterflies
"If you always take the same path, you will always end up in the same place." Even tiny changes can lead to big surprises (this is called the butterfly effect).

A key success factor for creative individuals is the ability to deviate from the established.

58 Creativity by simplification
Modeling always involves simplification.

Art pieces like a cubist painting of a three-dimensional landscape or a wool model of a virus help us focus on the most important parts of reality to answer particular questions: What surfaces are most prominent in the landscape? What shapes does a coronavirus take?

59 Creativity by classification
Works of art are often classified into so-called "-isms" such as Impressionism or Expressionism.

At the time of creation, however, it is usually not yet possible to assign a work to a specific period. This classification is done later, typically by art historians, to create structure and understanding.

Scientific communication also uses established terminology, which may vary depending on the field.

60 Creativity by chance
Sometimes chance determines what is discovered in science or what emerges in art.

Then, it may depend on what we had for breakfast, whom we met on your way to work, or what other news we received.

New answers can emerge from unrelated questions questions, from unrelated existing knowledge that we had not considered relevant, and from chance.

61 Creativity by series
Serial art tells stories about similarities and differences.

"What if?" asked Vincent van Gogh after completing his first sunflower painting. He then created seven more.

Only one of them later sold for over 100 million dollars.

62 Creativity by recognition
"You only see what you know." Recognizing patterns is enjoyable and helps us make sense of the world.

It is even more rewarding when we extend what we already know to find new, previously unseen patterns or connections.

63 Creativity by change of perspective
Paintings can be framed.

Scientific concepts can also be "framed," meaning they can be viewed in different contexts.

In both cases, framing helps to organize, distinguish, or enhance—and ideally to focus on what matters most, and even create new perspectives.

64 Creativity by transformation (defamiliarization)
From the coordinates of proteins stored in the protein database, fascinating images can be generated, sometimes in altered forms such as polar coordinates, as shown here.

These structures can even be translated into sound (see QR code). What do you feel when you listen to them?

65 Creativity by gardening
These flower-like shapes made from protein models can help us see things differently by changing how we look at scientific information. It is becoming more and more important to have this skill in research, along with technical, social and communication skills.

66 Creativity by serial art
Serial art based on protein data: biochemical data were used as the basis for further processing.

Each row shows properties of a specific protein: the statistics (frequency) of individual amino acids, or the frequency of consecutive pairs of amino acids (bigrams) and of triplets (trigrams). The final column visualizes the three-dimensional protein structure.

Such representations provide a quick overview of similarities and differences in structurally similar amino acids.

67 Creativity by questions about science

How does science "work"? Scientists observe, measure, and collect data.

To really understand the world, we need theories that can be checked against what we see. So, where do these theories come from? They come from a creative process, much like in art, where skill and knowledge are important, but so is experience, intuition and a bit of luck. The researcher's personality also plays a big part.

68 Creativity by asking questions about art

Questions about art can often also be applied to science:

* How and why does art (or science) work?
* Is knowledge always better than ignorance?
* What makes us curious?
* What stimulates imagination?
* Do new ideas arise more from knowledge or from not knowing?

69 Creativity by the visual language of form

Form is a central aspect of both artistic and scientific representation.

We perceive certain forms as ordered, symmetrical, asymmetrical, or chaotic.

Which forms attract our attention the most—and why?

Feel free to mark your favorite form directly on our beauty poster.

70 Creativity by form and sound

These flower-like shapes made from protein models can help us see things differently by changing how we look at scientific information. It is becoming more and more important to have this skill in research, along with technical, social and communication skills.