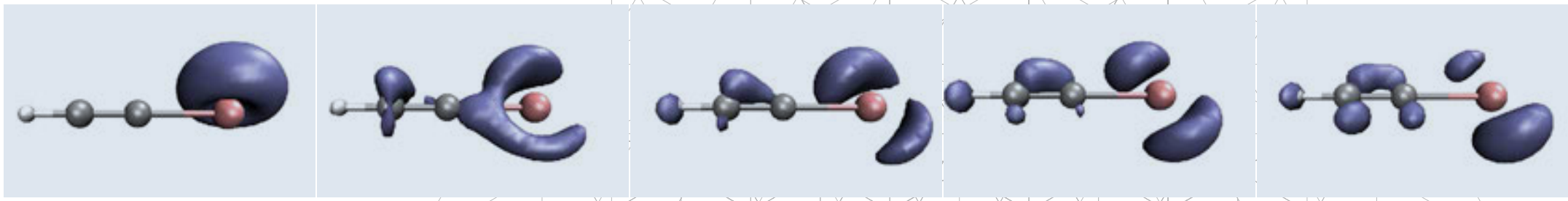
The idea for this book came during a train journey between Zürich and Bern on the way to an NCCR MUST meeting. Jürg Osterwalder spoke about the book "Powers of Ten: about the relative size of things in the universe" by Philip and Phyllis Morrison, 1990 and its memorable impact as a method of illustrating an enormous breadth of scientific knowledge. From a central photograph of a couple picnicking in New York, the book illustrates what is happening at measured distances from the original image, going deep into the human body and expanding out into the universe. Jürg's idea was to take this concept and transfer it to illustrate processes in time – so it could be used to explain dynamics occurring over fixed time periods. Every process would then be represented by a sequence of snapshots showing the subject as it evolves in time.

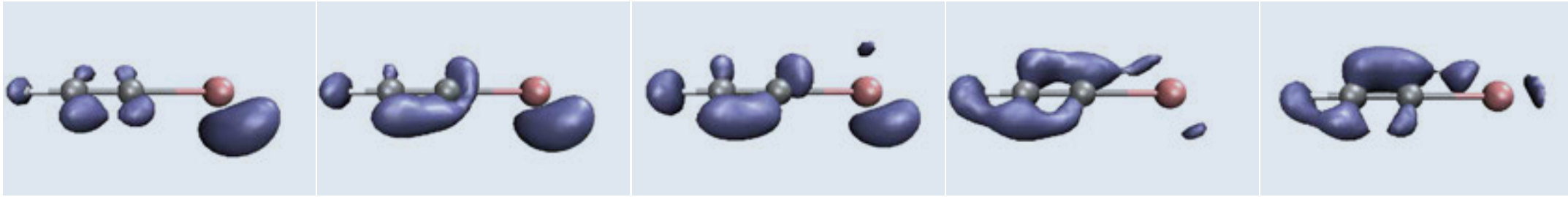
This concept enables our research network to illustrate up-to-the-minute research in the fastest processes occurring in time and then set it in the context of events that happen over a wider range of time periods; from minutes, to decades to millennia.

We searched for original contributions to each timescale. When our scientists did not have the knowledge and expertise for the longer timescales we solicited input from other disciplines. The contributions on the formation of mountain ranges, of continents, the evolution of humans and the development of solar systems came from geologists, anthropologists and astronomers. There were more than 40 contributors, who provided us with ideas, photographs, and created simulations and text. Some contributions, which do not appear in the book, will be shown on a website, which will be created from this project.



ELECTRONIC MOTION IN MOLECULES

0.0000000000000001 | 100 attoseconds



10^{-16} SECONDS

When a photon is absorbed by a molecule it usually causes a perturbation to the electrons. In the molecule shown one electron, being suddenly kicked away from its normal position, tries to get back to where it was as quickly as possible. Such electron dynamics in a molecule are amongst the fastest processes known in nature, they take place in only a few hundreds of attoseconds. Since electrons are **quantum objects** we must not think of them as particles, such as billiard balls, rather we should visualize them as clouds of **charge density** meandering through the valleys of the molecular landscape. The sequence of images shows the electron density rearranging itself in the molecule **ICCH** after one electron has been ripped away upon absorption of one photon.

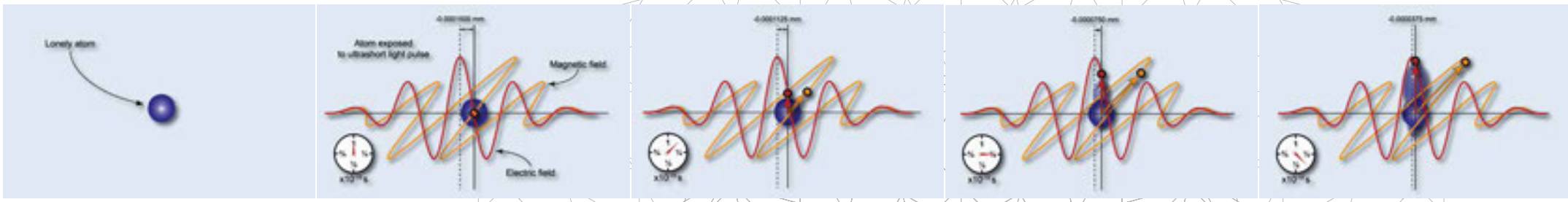
Ursula Röthlisberger
EPFL, Lausanne

Good to know

ICCH: Iodoacetylene consists of two strongly bonded carbon atoms with a hydrogen and an iodine atom on either side.

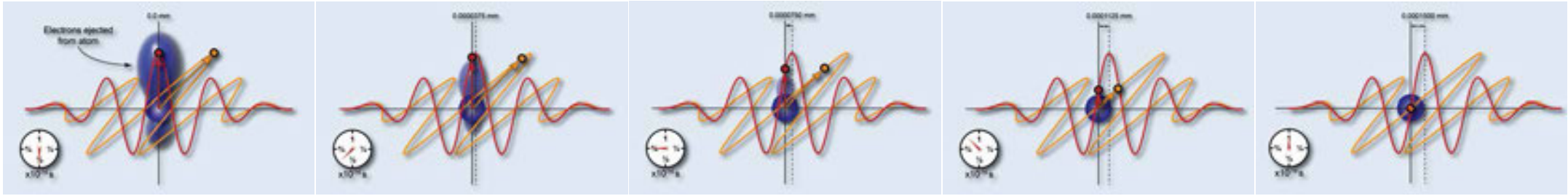
QUANTUM OBJECTS: When objects become really small they no longer follow the classical laws of motion. Classical mechanics needs to be replaced by quantum mechanics and so the objects are called quantum objects.

CHARGE DENSITY: An electron is an elementary particle carrying one negative charge. This charge is not localized at a single point in space, rather it is spread over a certain volume and a charge distributed over a volume is called a charge density.



ULTRASHORT PULSES OF LIGHT

0.000000000000001 | 1 femtosecond



10^{-15} SECONDS

Visible light is an electromagnetic wave that oscillates just like the ripples of a water wave on the surface of a pond. The reason the wave is called electromagnetic is because its energy is contained in the oscillations of electric and magnetic field components. Unlike water waves, which can be observed by the naked eye, visible light oscillates so fast that no one has ever seen it do so; one oscillation takes about 2 femtoseconds. Scientists in the NCCR MUST can make pulses of visible light so short that the electromagnetic fields oscillate only once or twice. When focused on an atom or a molecule the electric field can become so high that the atom or the molecule fall apart and often release electrons. Under certain circumstances these electrons return back to their mother atoms/molecules and emit even shorter light pulses in the process. Those can be as short as several tens of attoseconds and are amongst the shortest man-made events.

Lukas Gallmann
University of Bern and ETH Zürich

Good to know

VISIBLE LIGHT covers the wavelength range from about 390 to 700 nanometers and the frequency range from 430 to 770 THz corresponding to oscillation periods between 1.3 and 2.3 femtoseconds.

THE EVOLUTION OF HUMANS

100000000000000 | 3 Million years

10^{14} SECONDS

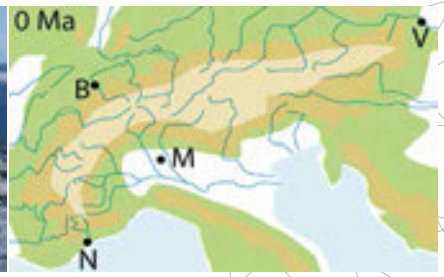
Human evolution represents a tiny bit of the long and diverse evolutionary history of life. Humans can be characterized as **bipedal**, large-brained, small-jawed, techno-cultural great apes that have managed to live in almost any imaginable ecosystem, and subsist on a wide diversity of food sources. The evolution from **quadrupedal**, small-brained tropical forest dwellers to our global species still remains largely unexplored, but we know that we are the only survivors of a once ramified family tree that originated about 7 million years ago. It includes many fossil species such as the australopithecines, Homo erectus, and the **Neanderthals**. We also know that bipedal locomotion evolved as the first human trait, while our brains started growing bigger only about 2 million years ago. The pictures show the imaginary transition from ape-like to human-like forms.

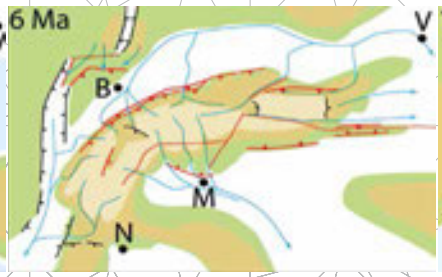
Christoph Zollikofer and Marcia Ponce de León
Anthropological Institute and Museum
University of Zürich

Good to know

BI- AND QUADRUPEDAL: Walking on two legs or on all-fours, using arms and legs.

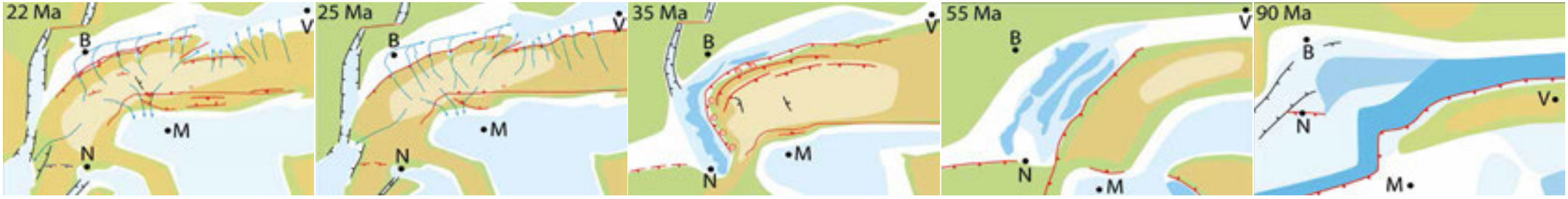
NEANDERTHALS: Our closest fossil relatives evolved in Ice Age Europe and Asia, and died out approximately 30,000 years ago. Some of their genetic heritage still looms in our DNA, testifying close encounters between the local Neanderthals and our own species dispersing from Africa all over the world.





THE RISING OF THE ALPS

1000000000000000 | 30 Million years



10^{15} SECONDS

The Alps formed from the collision of two continents, once separated by narrow deep seas. The images show the distribution of land and water at different time frames. With time the seas became shallower and smaller. Within the evolving mountain chain rock units were pushed on top of each other along thrust faults, thereby raising the land surface to higher elevations. Simultaneously erosion wore down the rising mountain chain keeping elevations nearly constant. The river network changed, drainage flipping from east to west and back. Volcanoes straddled the northern rim of the ancestral Alps at around 30 million years. Extension in the foreland of the Alps caused the formation of steep normal faults, where the land surface subsided; the depressions were quickly flooded by the sea. Around 6 million years ago the Mediterranean dried up leaving the Alps towering over the surrounding lowland.

Othmar-Adrian Pfiffner
Institute for Geology
University of Bern

Legend

Mountains	**B** Berne
Hills	**N** Nice
Land	**M** Milano
Lowland	**V** Vienna
Shallow sea	Volcano
Deep sea	