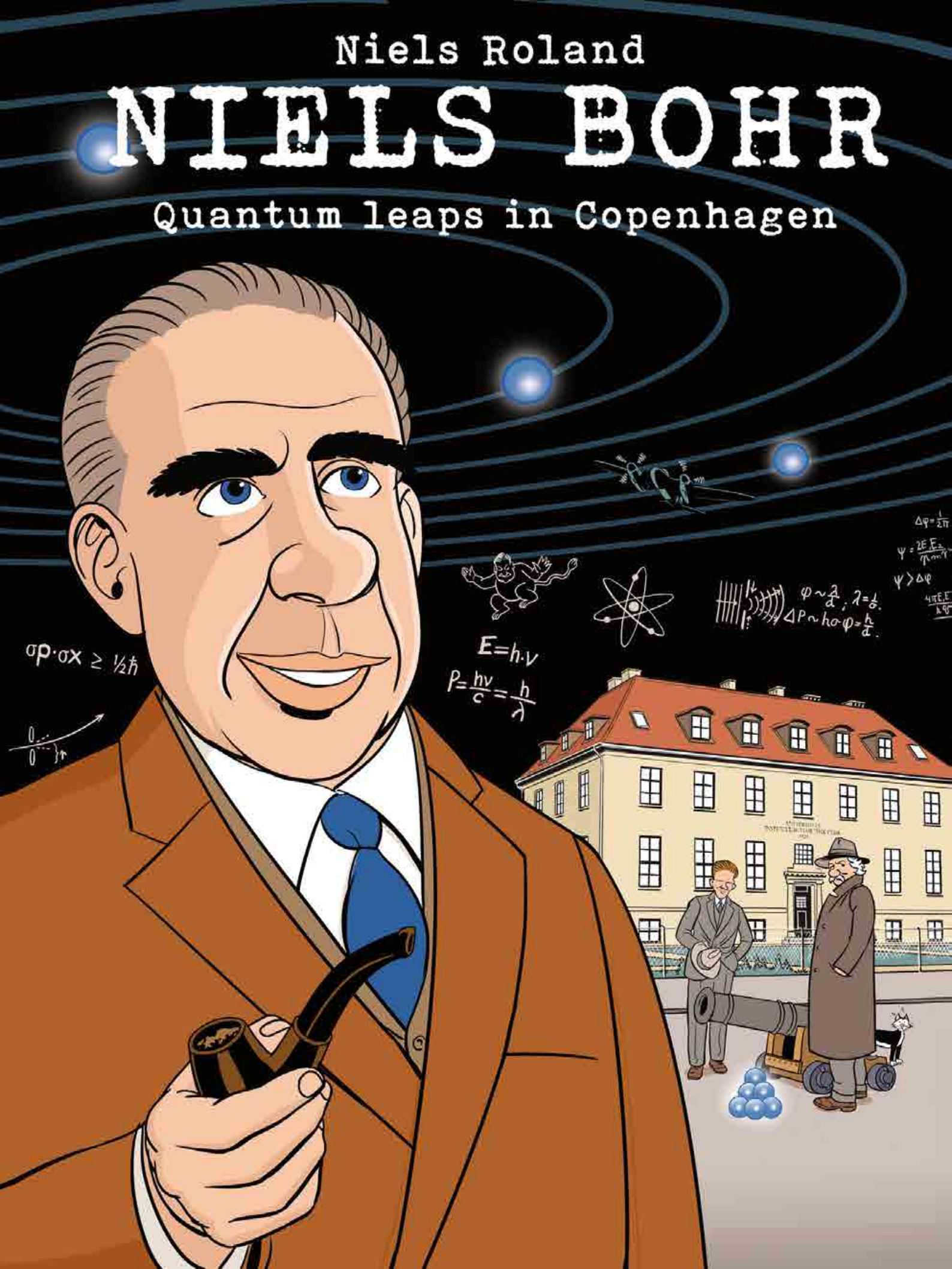
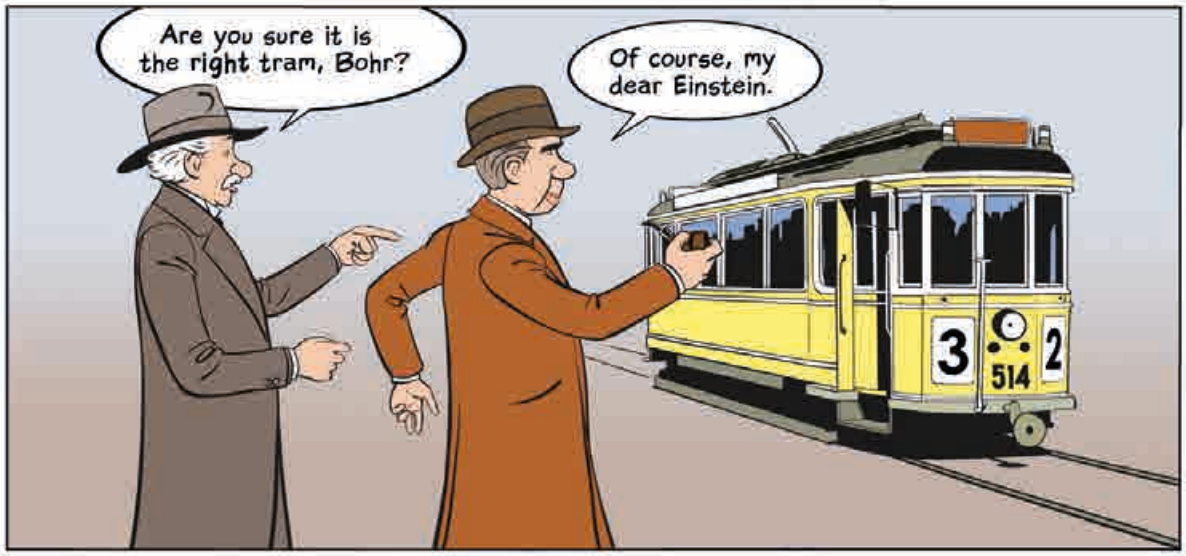
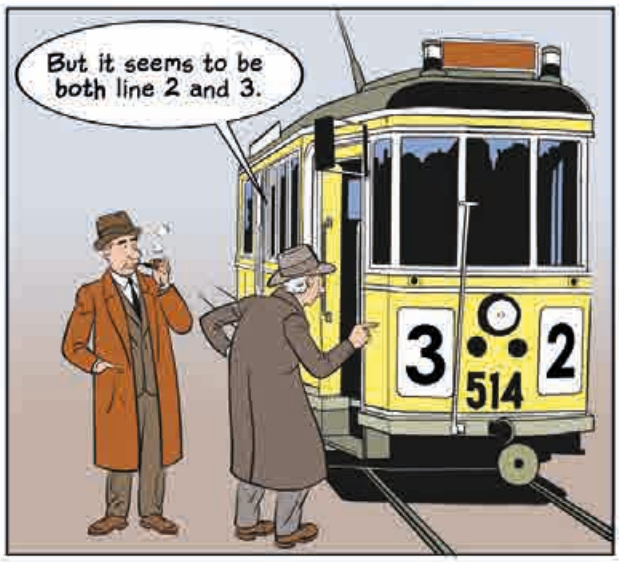
Niels Roland

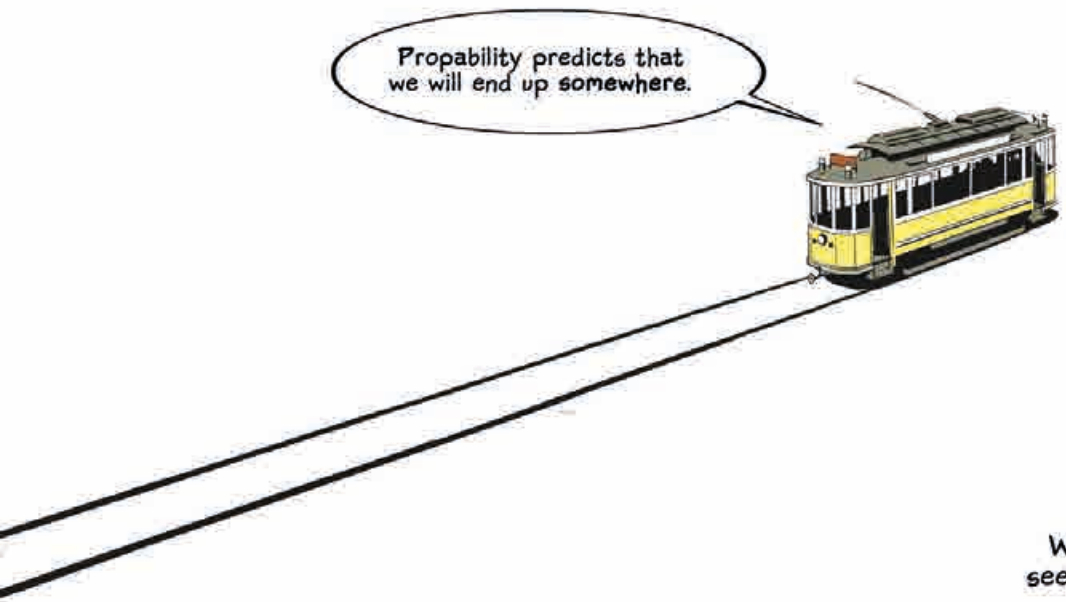
NIELS BOHR

Quantum leaps in Copenhagen



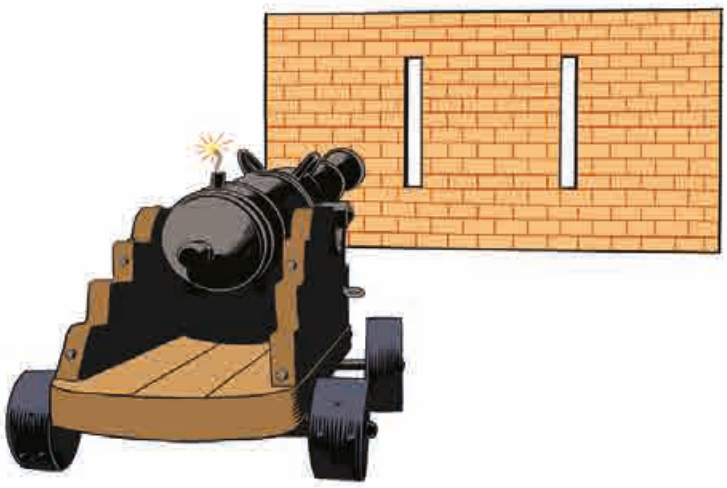




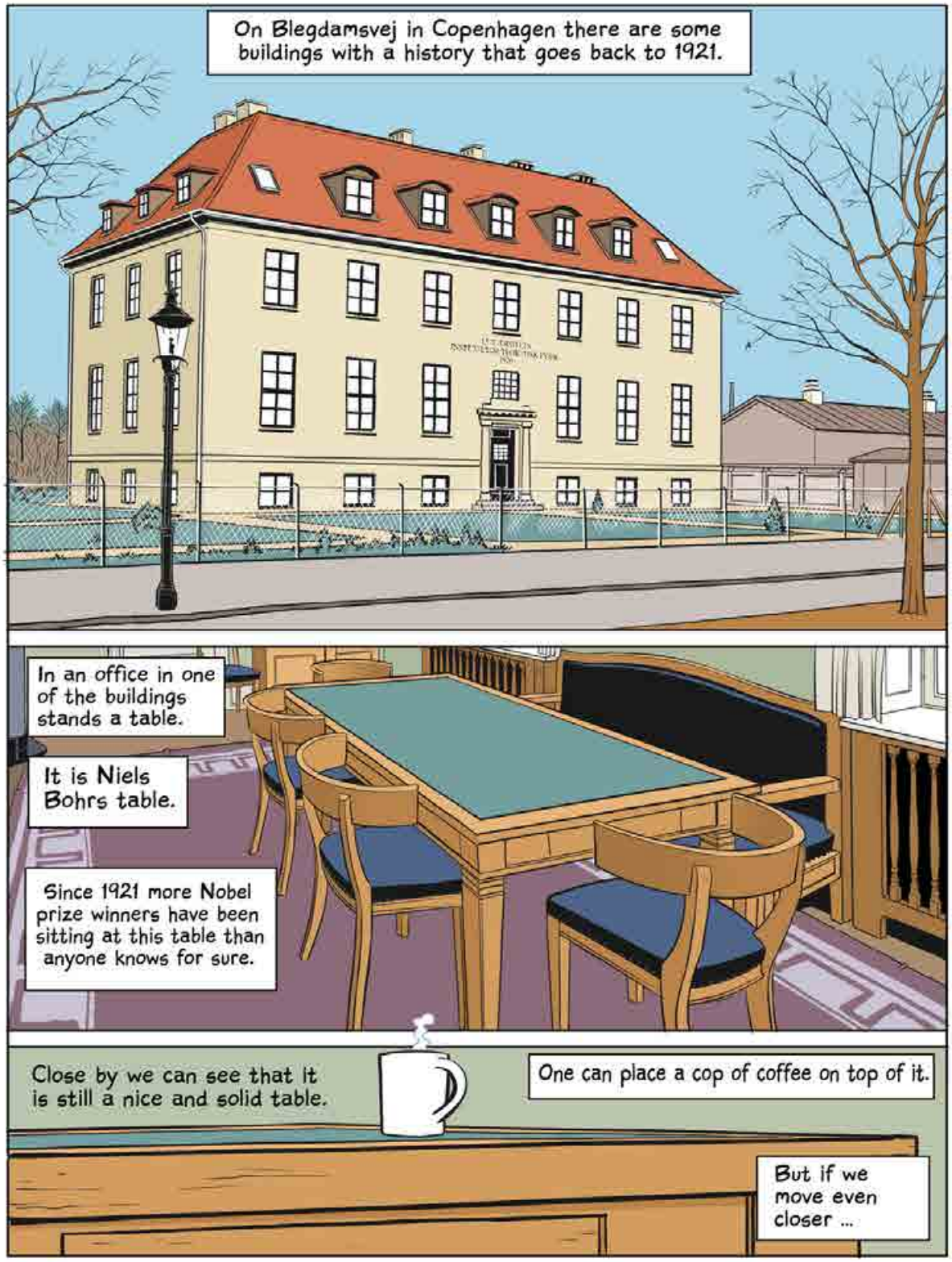


Confused?

Well, you haven't seen anything yet.



PART I - THE JUMP



... very, very, **very** much closer we see ....

... that the table consists of **molecules** ...

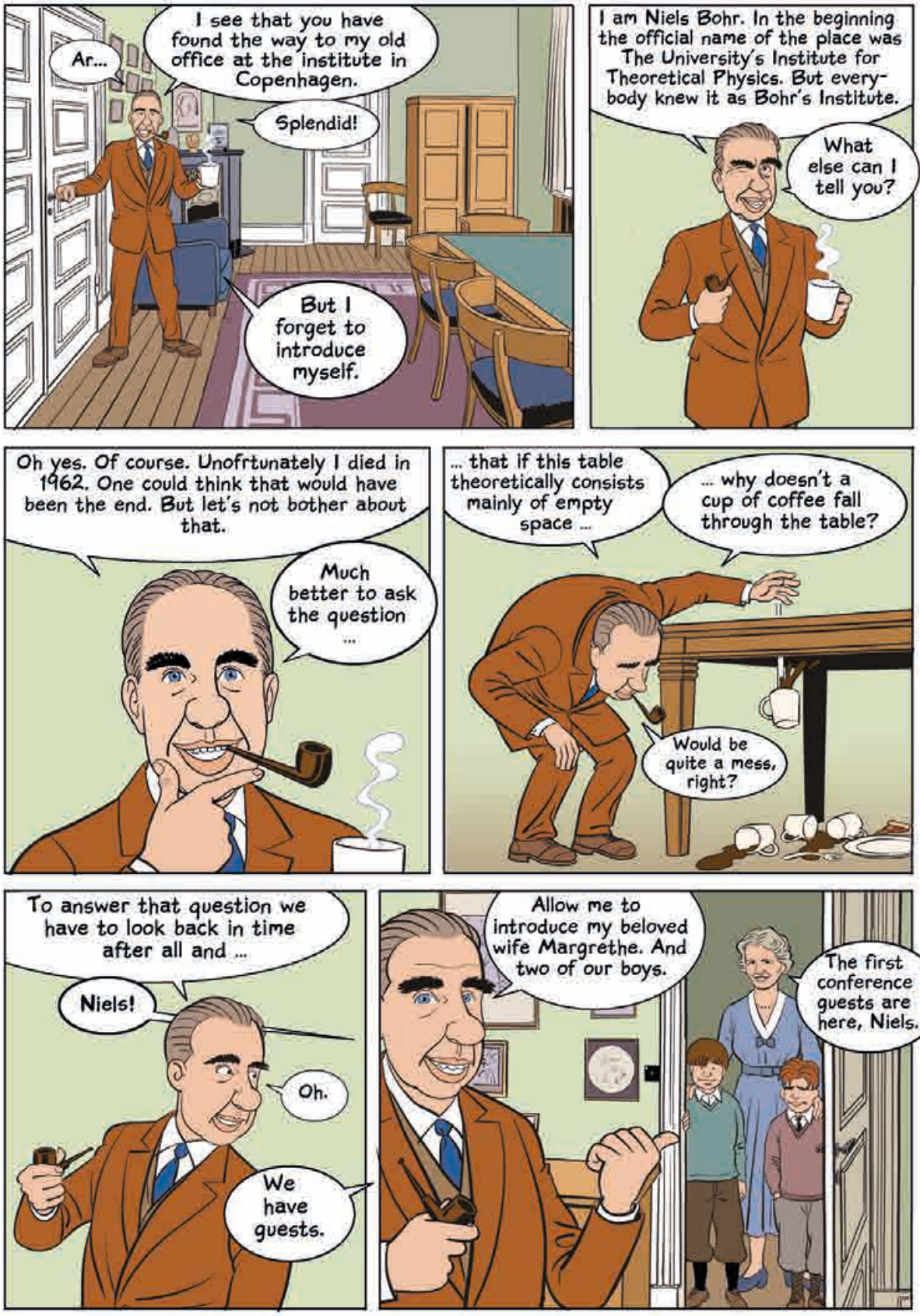
... that consist of **atoms.**

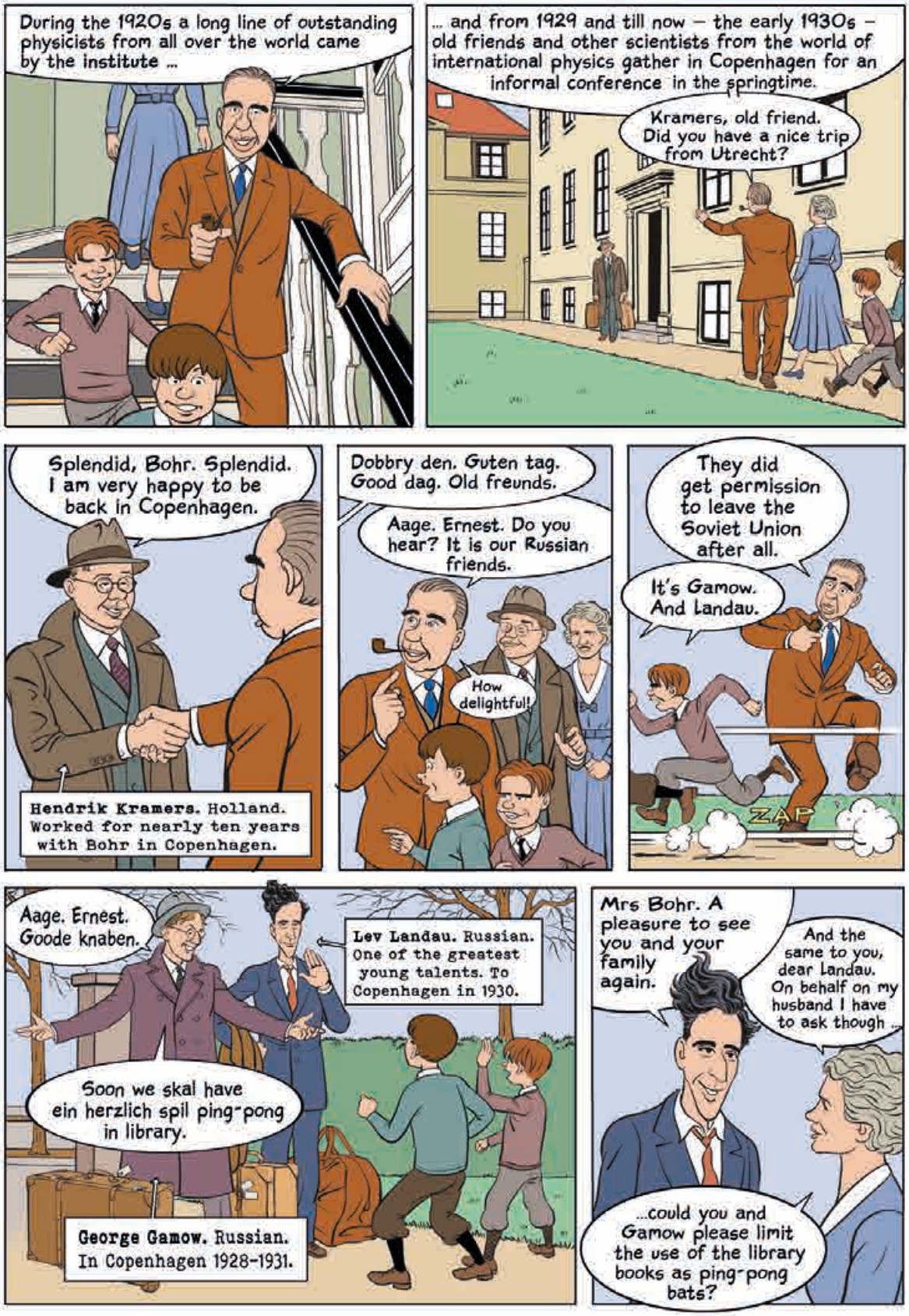
Atoms in which the size of the nucleus compared to the rest of the atom is like ...

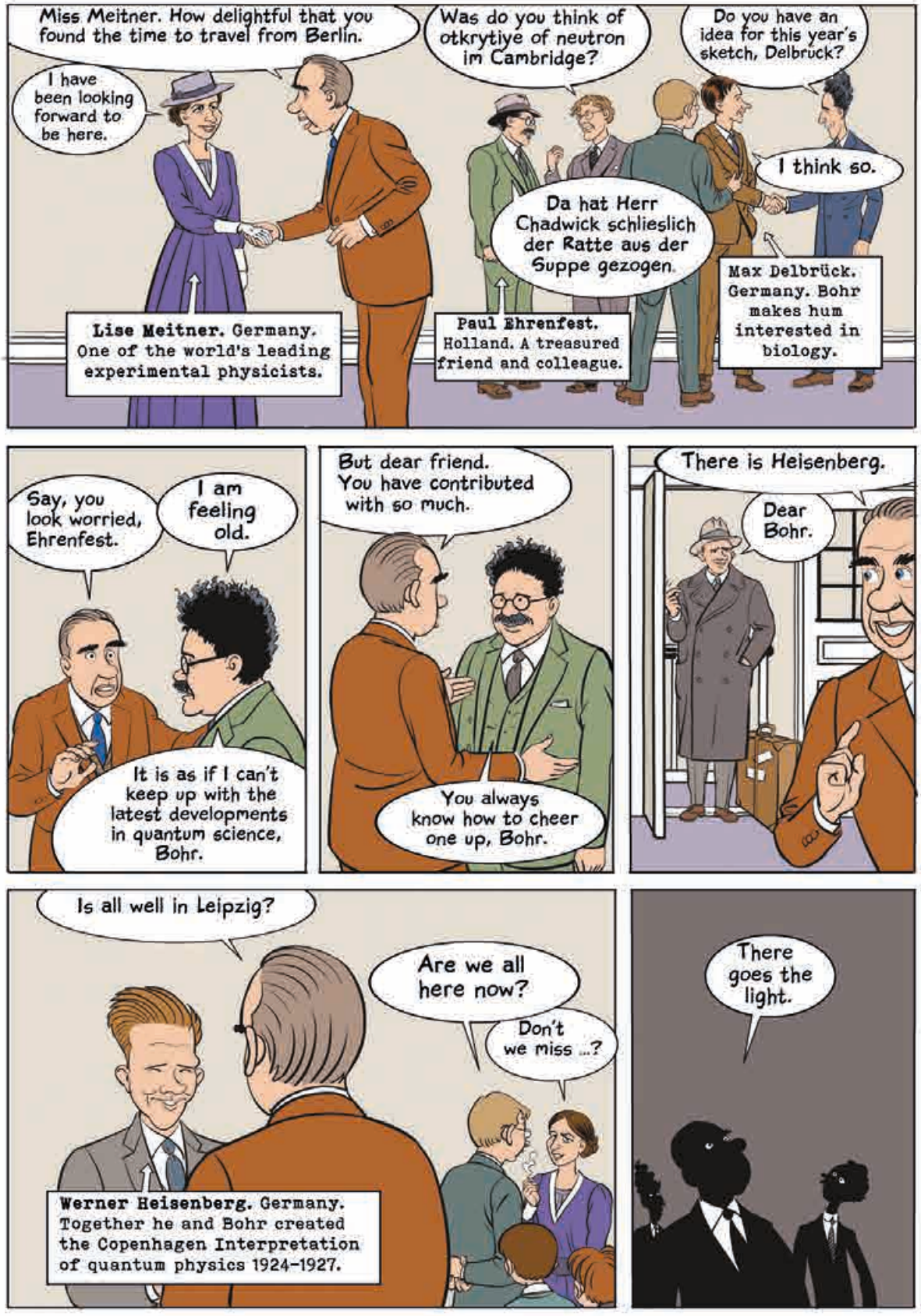
... a **gnat** in a **cathedral.**

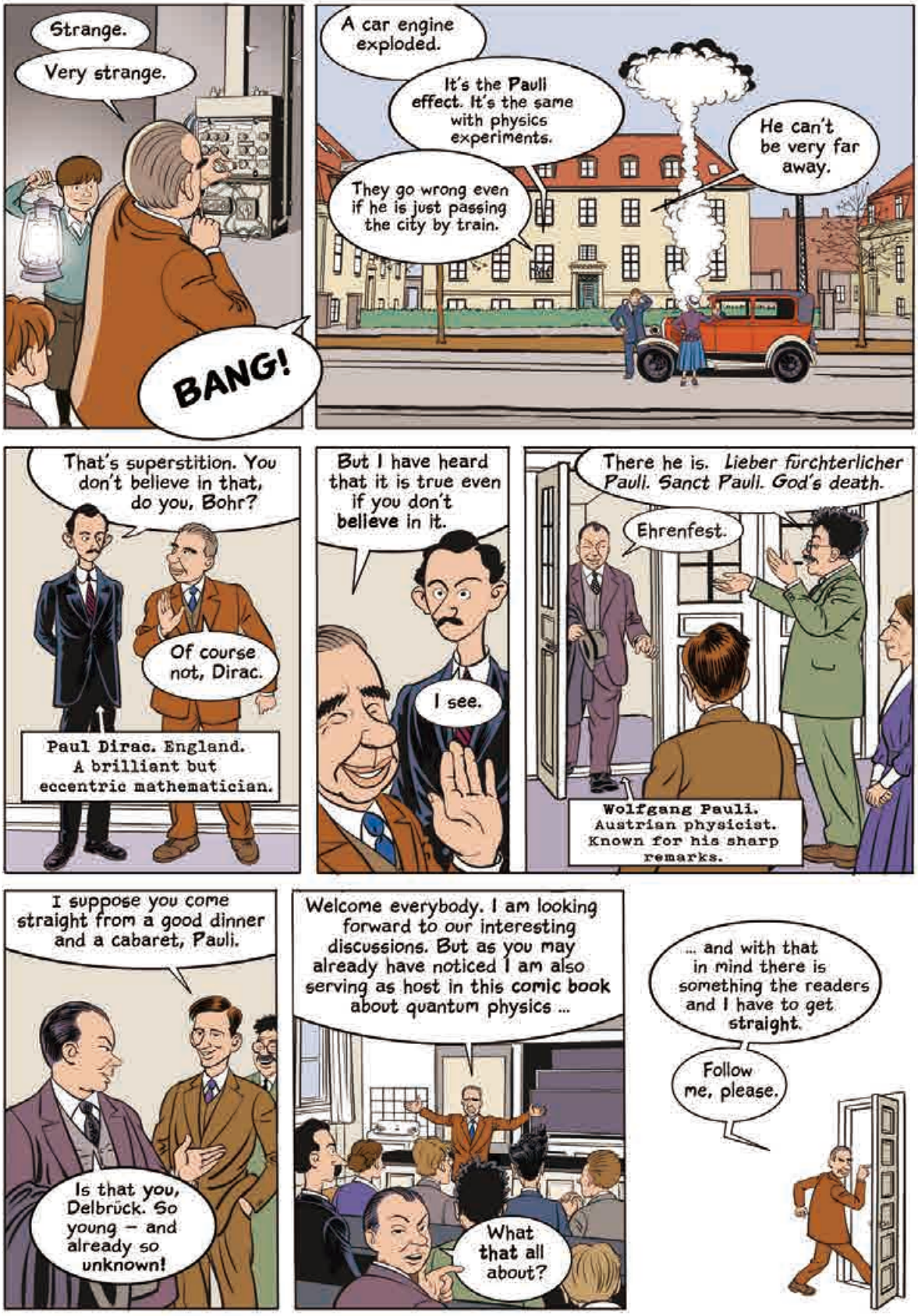
KNOCK! KNOCK!

Anybody in here?

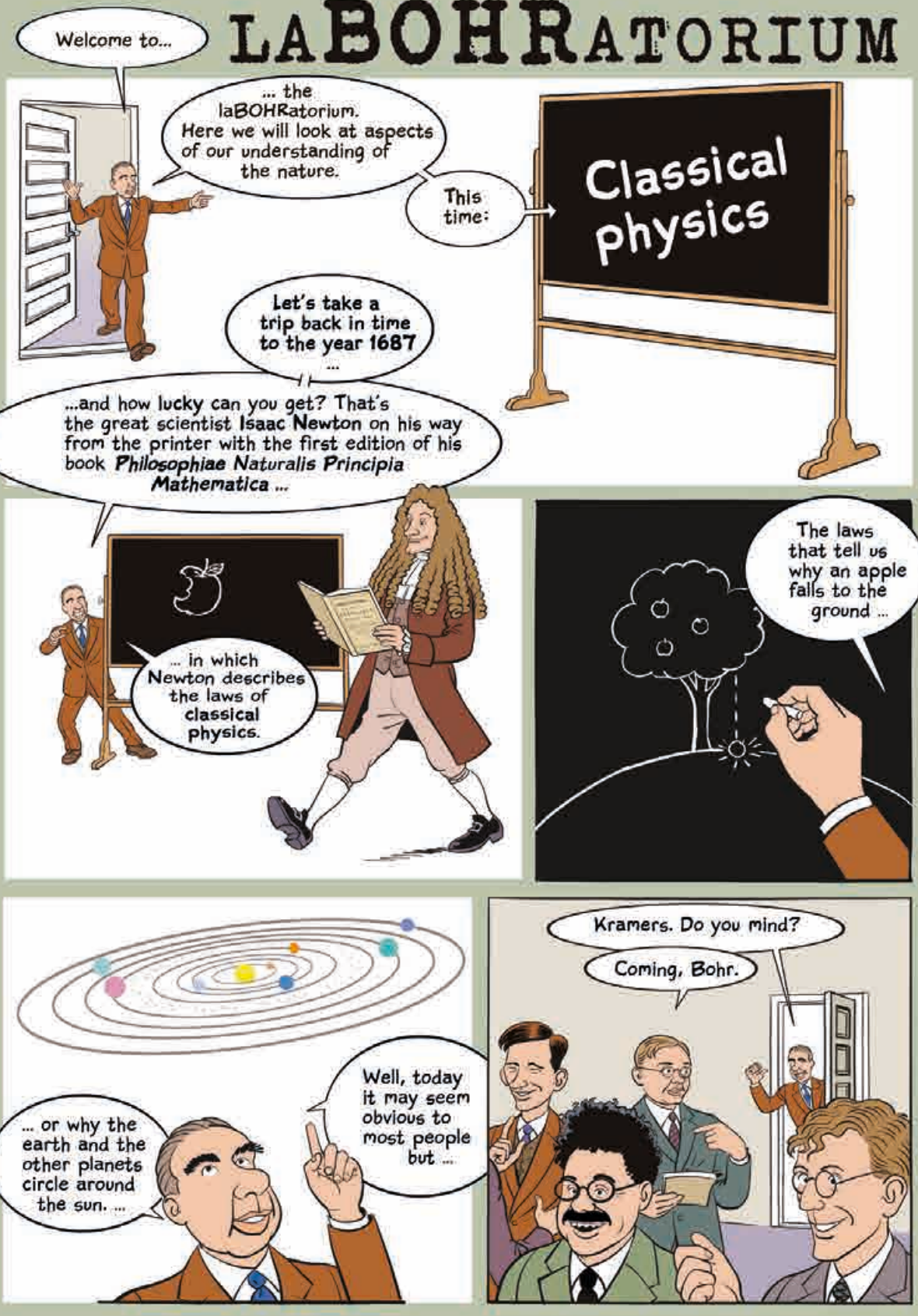

I see that you have found the way to my old office at the institute in Copenhagen.
Ar...
Splendid!
But I forget to introduce myself.
I am Niels Bohr. In the beginning the official name of the place was The University's Institute for Theoretical Physics. But everybody knew it as Bohr's Institute.
What else can I tell you?
Oh yes. Of course. Unofrtunately I died in 1962. One could think that would have been the end. But let's not bother about that.
Much better to ask the question ...
... that if this table theoretically consists mainly of empty space ...
... why doesn't a cup of coffee fall through the table?
Would be quite a mess, right?
To answer that question we have to look back in time after all and ...
Niels!
Oh.
We have guests.
Allow me to introduce my beloved wife Margrethe. And two of our boys.
The first conference guests are here, Niels.


During the 1920s a long line of outstanding physicists from all over the world came by the institute ...
... and from 1929 and till now – the early 1930s – old friends and other scientists from the world of international physics gather in Copenhagen for an informal conference in the springtime.
Kramers, old friend. Did you have a nice trip from Utrecht?
Splendid, Bohr. Splendid. I am very happy to be back in Copenhagen.
Hendrik Kramers. Holland. Worked for nearly ten years with Bohr in Copenhagen.
Dobbry den. Guten tag. Good dag. Old freunds.
Aage. Ernest. Do you hear? It is our Russian friends.
How delightful!
They did get permission to leave the Soviet Union after all.
It's Gamow. And Landau.
ZAP
Aage. Ernest. Goode knaben.
Lev Landau. Russian. One of the greatest young talents. To Copenhagen in 1930.
Soon we skal have ein herzlich spil ping-pong in library.
George Gamow. Russian. In Copenhagen 1928–1931.
Mrs Bohr. A pleasure to see you and your family again.
And the same to you, dear Landau. On behalf on my husband I have to ask though ...
...could you and Gamow please limit the use of the library books as ping-pong bats?


Miss Meitner. How delightful that you found the time to travel from Berlin.
I have been looking forward to be here.
Lise Meitner. Germany. One of the world's leading experimental physicists.
Was do you think of otkrytiye of neutron im Cambridge?
Da hat Herr Chadwick schlieslich der Ratte aus der Suppe gezogen.
Paul Ehrenfest. Holland. A treasured friend and colleague.
Do you have an idea for this year's sketch, Delbrück?
I think so.
Max Delbrück. Germany. Bohr makes hum interested in biology.
Say, you look worried, Ehrenfest.
I am feeling old.
It is as if I can't keep up with the latest developments in quantum science, Bohr.
But dear friend. You have contributed with so much.
You always know how to cheer one up, Bohr.
There is Heisenberg.
Dear Bohr.
Is all well in Leipzig?
Are we all here now?
Don't we miss ...?
Werner Heisenberg. Germany. Together he and Bohr created the Copenhagen Interpretation of quantum physics 1924–1927.
There goes the light.


Strange.
Very strange.
BANG!
A car engine exploded.
It's the Pauli effect. It's the same with physics experiments.
They go wrong even if he is just passing the city by train.
He can't be very far away.
That's superstition. You don't believe in that, do you, Bohr?
Of course not, Dirac.
Paul Dirac. England. A brilliant but eccentric mathematician.
But I have heard that it is true even if you don't believe in it.
I see.
There he is. Lieber furchterlicher Pauli. Sanct Pauli. God's death.
Ehrenfest.
Wolfgang Pauli. Austrian physicist. Known for his sharp remarks.
I suppose you come straight from a good dinner and a cabaret, Pauli.
Is that you, Delbrück. So young – and already so unknown!
Welcome everybody. I am looking forward to our interesting discussions. But as you may already have noticed I am also serving as host in this comic book about quantum physics ...
What that all about?
... and with that in mind there is something the readers and I have to get straight.
Follow me, please.

LABOHRATORIUM



Could you please review the principles of classical physics?

For the reader's sake? Yes, sure.

In classical physics the principle of **continuity** is fundamental. Nature don't make jumps. The water in a kettle on the stove will get warmer gradually ...

In the meantime I will light my pibe.

Well, I know that in the 2020's smoking is considered dangerous but in this narrative we are in the 1930s...

...and if we send a rocket from Earth towards the moon with a speed of 40,000 km/h...

it will, during acceleration, fly at any speed between 0 and 40,000 km/h.

Along the way, it will pass through **every** point along the path.

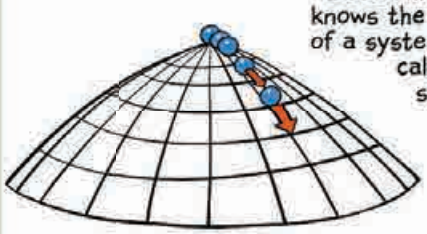
If we know the rocket's speed and its trajectory, we can also calculate precisely where it will be located at any given time in the future.

It will be here by eleven o'clock

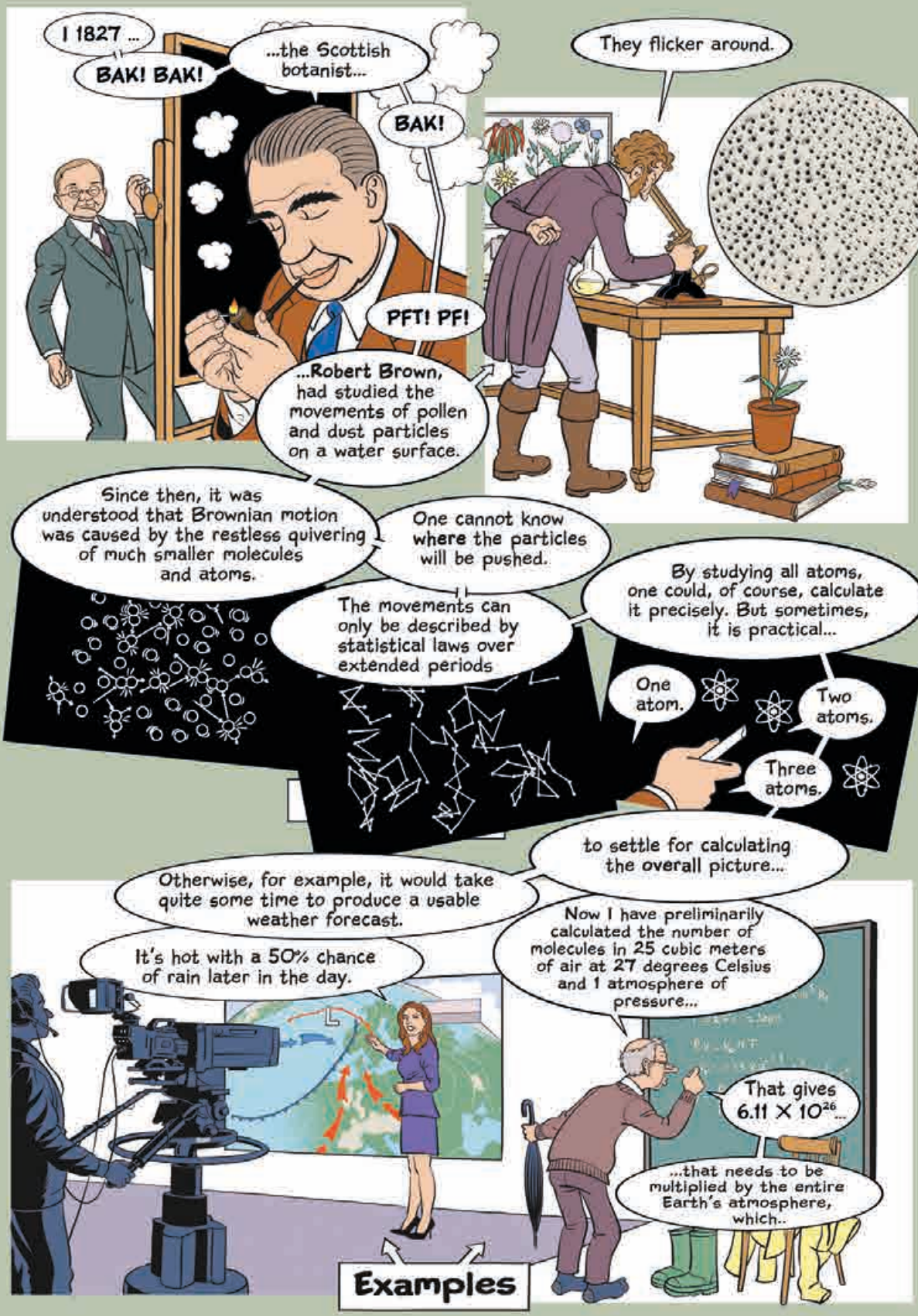
And here at tea-time.

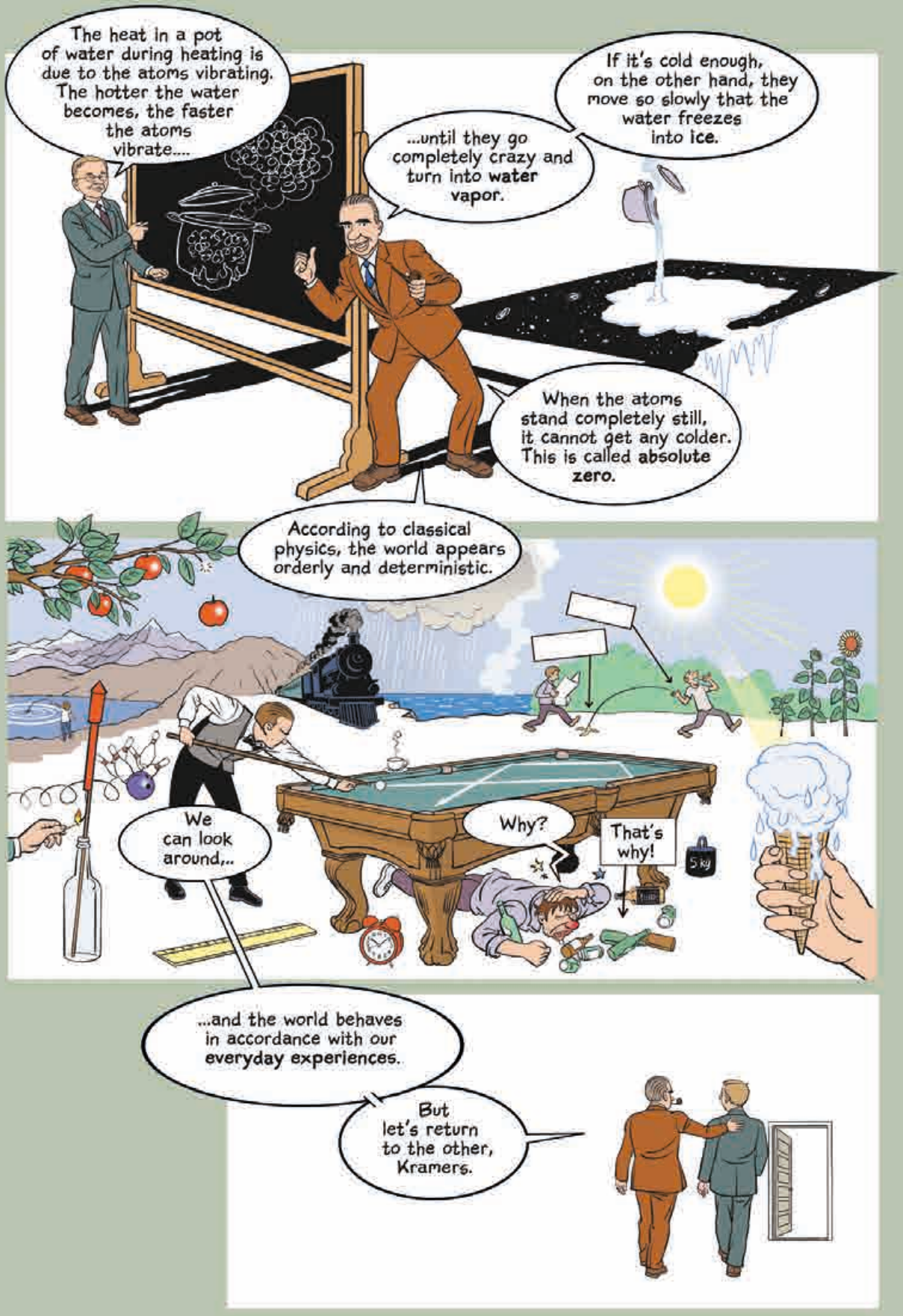
The future is thus determined by the past. All phenomena are a matter of cause and effect.

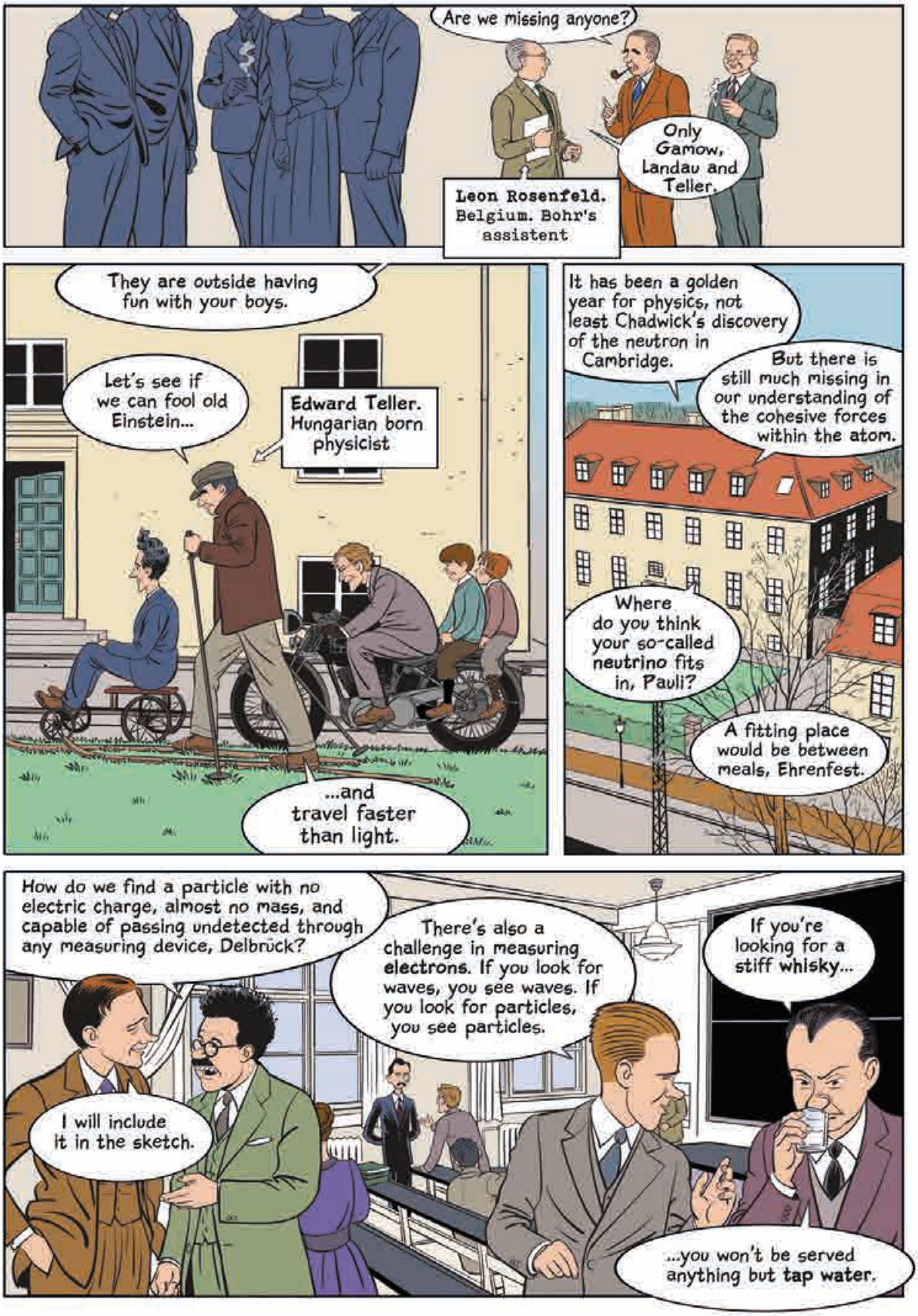
Determinism. If one knows the conditions of a system, one can calculate **any subsequent state.**



Continuity. Nature does not make leaps. "Natura non facit saltu"


I 1827 ...
BAK! BAK!
...the Scottish botanist...
BAK!
PFT! PF!
...Robert Brown, had studied the movements of pollen and dust particles on a water surface.
They flicker around.
Since then, it was understood that Brownian motion was caused by the restless quivering of much smaller molecules and atoms.
One cannot know where the particles will be pushed.
The movements can only be described by statistical laws over extended periods
By studying all atoms, one could, of course, calculate it precisely. But sometimes, it is practical...
One atom.
Two atoms.
Three atoms.
to settle for calculating the overall picture...
Otherwise, for example, it would take quite some time to produce a usable weather forecast.
It's hot with a 50% chance of rain later in the day.
Now I have preliminarily calculated the number of molecules in 25 cubic meters of air at 27 degrees Celsius and 1 atmosphere of pressure...
That gives 6.11×10^{26}...
...that needs to be multiplied by the entire Earth's atmosphere, which..
Examples


The heat in a pot of water during heating is due to the atoms vibrating. The hotter the water becomes, the faster the atoms vibrate....
...until they go completely crazy and turn into water vapor.
If it's cold enough, on the other hand, they move so slowly that the water freezes into ice.
When the atoms stand completely still, it cannot get any colder. This is called absolute zero.
According to classical physics, the world appears orderly and deterministic.
We can look around,..
Why?
That's why!
5 kg
...and the world behaves in accordance with our everyday experiences.
But let's return to the other, Kramers.


Are we missing anyone?
Only Gamow, Landau and Teller.
Leon Rosenfeld. Belgium. Bohr's assistent
They are outside having fun with your boys.
Let's see if we can fool old Einstein...
Edward Teller. Hungarian born physicist
...and travel faster than light.
It has been a golden year for physics, not least Chadwick's discovery of the neutron in Cambridge.
But there is still much missing in our understanding of the cohesive forces within the atom.
Where do you think your so-called neutrino fits in, Pauli?
A fitting place would be between meals, Ehrenfest.
How do we find a particle with no electric charge, almost no mass, and capable of passing undetected through any measuring device, Delbrück?
I will include it in the sketch.
There's also a challenge in measuring electrons. If you look for waves, you see waves. If you look for particles, you see particles.
If you're looking for a stiff whisky...
...you won't be served anything but tap water.