MEHAU KULYK/SCIENCE PHOTO LIBRARY

The Nobel Prize in Physics 2008

"for the discovery of the mechanism of spontaneous broken symmetry in subatomic physics"

"for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature"

LLOYD DEGRANE/THE UNIVERSITY OF CHICAGO

Yoichiro Nambu

1/2 of the prize

Born: 1921

Birthplace: Japan

Nationality: US citizen

Current position: Harry Pratt Judson Distinguished Service Professor Emeritus, Enrico Fermi Institute, University of Chicago, Illinois, USA

HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION (KEK)

Makoto Kobayashi

1/4 of the prize

Born: 1944

Birthplace: Japan

Nationality: Japanese citizen

Current position: Professor Emeritus, High Energy Accelerator Research Organization (KEK), Tsukuba, Japan

KYOTO UNIVERSITY

Toshihide Maskawa

1/4 of the prize

Born: 1940

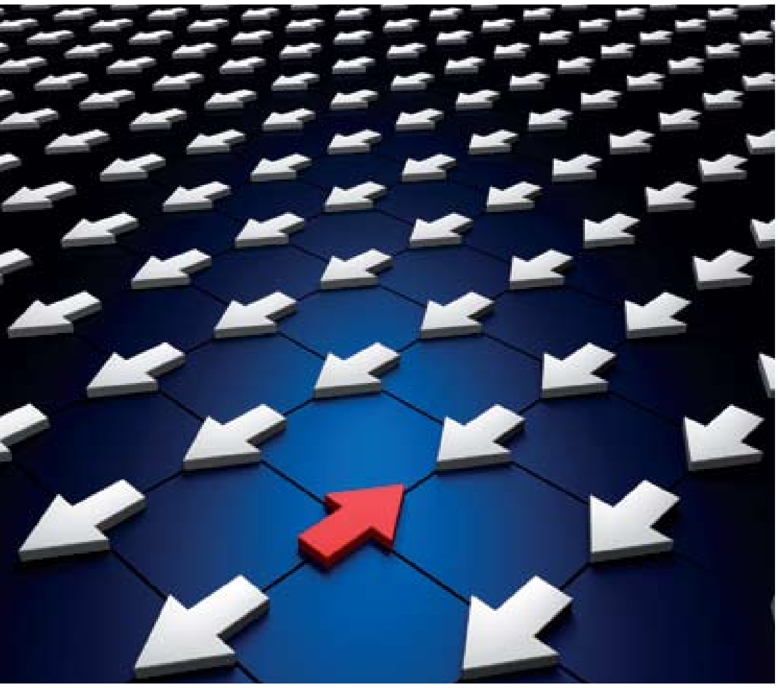
Birthplace: Japan

Nationality: Japanese citizen

Current position: Professor Emeritus, Yukawa Institute for Theoretical Physics (YITP), Kyoto University, Japan

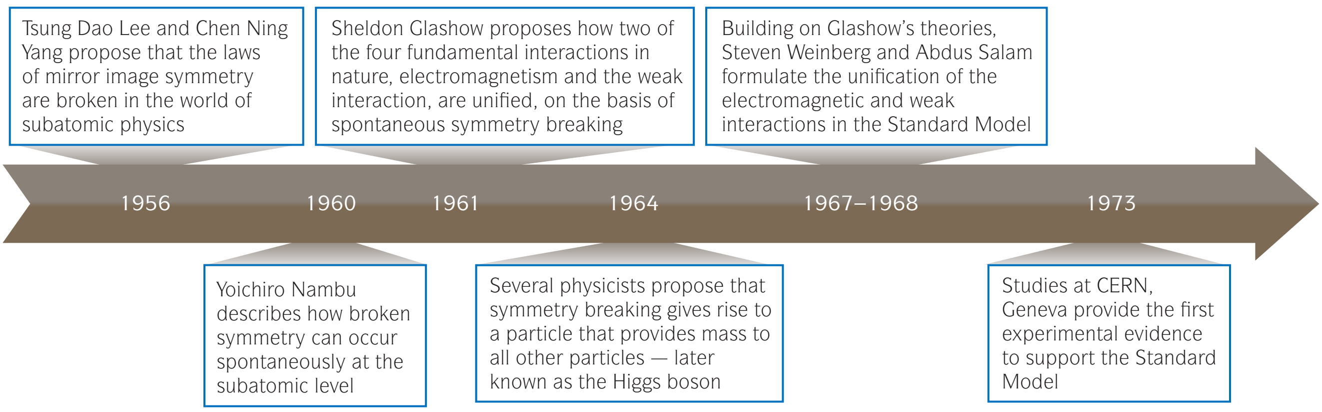
Speed read:
The importance of asymmetry

Luckily for us, the Universe is not symmetrical, at least at the subatomic level. If it was, the newly formed matter at the Universe's birth would have been annihilated by an equal and opposite amount of antimatter, and nothingness would have resulted. Instead, a small imbalance, or asymmetry, in the amount of matter and antimatter created led to a slight excess of matter, from which we are all eventually formed. Such so-called 'broken symmetry' is one key to our existence.



Understanding symmetry, or the lack of it, is an ongoing task, and the 2008 Nobel Prize in Physics rewarded two discoveries concerning symmetry violation in the field of particle physics. In the 1960s Yoichiro Nambu, who had been working on asymmetries underlying superconductivity, was the first to model how broken symmetry can occur spontaneously at the subatomic level. The mathematical descriptions he formulated helped refine the standard model of particle physics, the current working theory that best explains much, but not all, of the way that fundamental particles and the forces that govern their behaviour interact to create the known Universe.

In the early 1970s, Kobayashi and Maskawa formulated a model that explained certain symmetry violations that had recently surprised observers in particle physics experiments. Their model suggested that the collection of subatomic particles known at

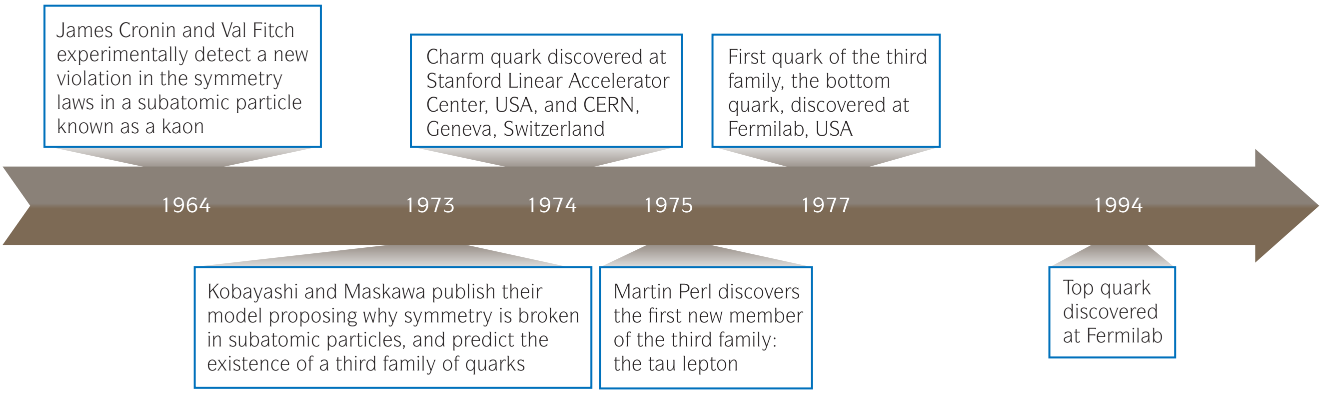


Timeline: Milestones for the 2008 Nobel Laureate in Physics, Yoichiro Nambu.

the time was insufficient to explain the observed behaviours, and predicted the existence of as yet undiscovered elementary particles. It did not, however, specify precisely what form these particles should take. Kobayashi and Maskawa hypothesized the existence of a third family of quarks, which are some of the building blocks from which all matter and antimatter are formed. They then had to wait almost three decades for the experimental results that would fully verify their hypothesis. The existence of all three families was finally confirmed when the last member was observed in the mid 1990s.

MARK GARLICK/SCIENCE PHOTO LIBRARY

Symmetry breaking in particle physics continues to be the focus of intense speculation and investigation. One of the most infamous examples of symmetry breaking, the particle or set of particles known as the Higgs boson, thought to be responsible for breaking the symmetry between electromagnetism and the so-called weak nuclear force, could help solve one of the greatest outstanding questions in physics – how particles acquire mass. Whether or not this mysterious particle exists will be the main subject of scrutiny at the Large Hadron Collider, the giant particle accelerator soon to go into operation outside Geneva, Switzerland.



Timeline: Milestones for the 2008 Nobel Laureates in Physics, Makoto Kobayashi and Toshihide Maskawa.

In his own words: **Yoichiro Nambu**

By his own admission the concept that Yoichiro Nambu devised in the early 1960s — that of spontaneous broken symmetry in particle physics — is “a bit difficult to explain” in simple terms. But while lecturing the day before he had been awarded the Nobel Prize in Physics, Nambu chanced upon an elegant analogy to describe how such broken symmetry can occur spontaneously.

“I saw a roomful of people all looking towards me and I thought that’s strange, why do they look only in one direction?” But if one person in that crowd turns their head and looks in the opposite direction then of course people nearby will turn around to see what that person is looking at. “So there is a kind of wave propagating from that person. And that is the wave associated with broken symmetry.”

Having begun his career as a theoretical physicist in Japan during the Second World War, Nambu is no stranger to looking for explanations in the midst of turmoil. Nambu describes being “lucky enough” to get a research position at the University of Tokyo after the war, though he was working under conditions that are a world away from the conditions enjoyed by most physicists nowadays. “I spent two, three years sleeping in my office, shared with maybe eight or so people. Everyday I had to go shopping, and sleep on my desk.” But the bleak conditions did provide one huge advantage, says Nambu: “I kept thinking about physics.”

By good fortune, a student of Sin-Itiro Tomonaga, who would receive the Nobel Prize in Physics in 1965, happened to be working at the neighbouring desk. By discovering what Tomonaga was doing

“If one person in that crowd turns their head and looks in the opposite direction then of course people nearby will turn around to see what that person is looking at”

LLOYD DEGRANE/THE UNIVERSITY OF CHICAGO

Yoichiro Nambu at the University of Chicago.

Nambu eventually joined his group, and thanks to Tomonaga’s recommendation Nambu was able to get a job first in Japan and then at Robert Oppenheimer’s Institute at Princeton University. The few years he originally planned to spend in America would become a lifetime. “I was not able to do good research to my satisfaction while I was in Princeton, so I wanted to stay for a few more years in America before going back to Japan.” Fortunately Nambu was able to get a postdoctoral position at the world-renowned Physics Department at the University of Chicago. “I jumped at the opportunity! I came here and I have stayed here ever since.”

All of which illustrates the virtues of being in the right place at the right time, and Nambu feels grateful to have been a theoretical physicist at the time he began his research. “I was very fortunate. Particle physics was created in the early 1930s. Ernest Lawrence invented the cyclotron on the one hand, and [Hideki] Yukawa in Japan invented particle physics, the theoretical side, and they went along side by side.”

When asked whether young physicists should follow his example and only eat and think about physics, Nambu laughs. “Yes! That’s a very good thing! My whole career was formed by the three years I was in Tokyo.”

This article is based on a telephone interview with Yoichiro Nambu following the announcement of the 2008 Nobel Prize in Physics. To listen to the interview in full, visit http://nobelprize.org/nobel_prizes/physics/laureates/2008/nambu-interview.html

In his own words: **Makoto Kobayashi**

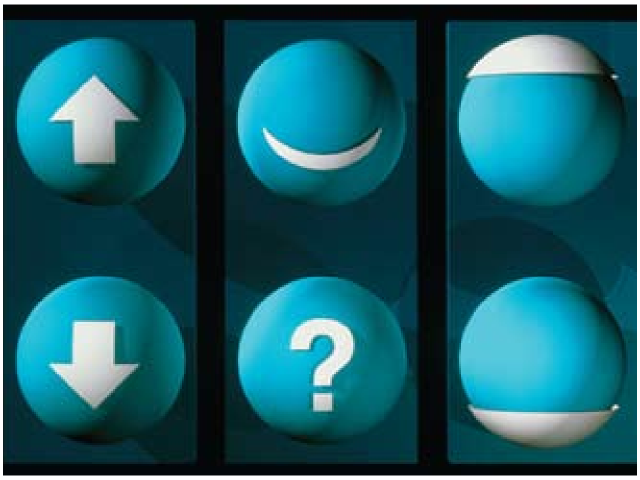
When recalling the groundbreaking theory he developed with Toshihide Maskawa that has been rewarded with the 2008 Nobel Prize in Physics, Makoto Kobayashi reveals a refreshing degree of honesty. "We were confident about the first part because it's quite logical. But the second point was quite uncertain at that time."

"Our work consisted of two parts", Kobayashi goes on to explain. The first part of the theory, that the number of subatomic particles thought at the time to make up all matter were not enough to explain a long-standing mystery in particle physics called broken symmetry, "is a quite logical consequence of the argument", says Kobayashi. However, the second, trickier part of the theory involved forecasting what these extra, new particles actually are. And as Kobayashi admits "there are many possibilities logically". Only two families of a particular subatomic particle known as quarks were known at the time, and Kobayashi and Maskawa predicted that there had to be one more. "At first we were not confident about this six quarks scheme, but gradually we came to believe that this actually is the case."

"At first we were not confident about this six quarks scheme, but gradually we came to believe that this actually is the case"

"Gradually" might seem like an understatement. After all, Kobayashi was 28 years old when he devised his theory, and it would take almost 30 years to discover the new types of quarks in particle accelerators. Yet this illustrates that sometimes theoretical physics leads experiment, and at other times experiments produce results that theoretical physics must explain. Kobayashi feels very fortunate to have started out as a theoretical physicist at the time he did, "particularly in the 1970s", a time he describes as being a "liberation in particle physics", because "at that time we had many chances to do many things."

Now the situation is different, says Kobayashi. "This is actually quite a new phase … we are waiting for some kind of new physics. Theoreticians predict, propose many theories, and we just wait for experimental proof of those models." Kobayashi particularly hopes that the new particle accelerator called the Large Hadron Collider (LHC) at CERN in Geneva, Switzerland, will help fill in missing information in the so-called Standard Model of particle physics, the best theory that physicists currently have to explain how fundamental particles and forces interact to create the known Universe. "We need to add something on top of this Standard Model. That is what we expect at the LHC experiment."



LAGUNA DESIGN/SCIENCE PHOTO LIBRARY

The six types of quark (clockwise from top left: *up, charm, top, bottom, strange and down*) from the three families predicted by Makoto Kobayashi and Toshihide Maskawa.

"This is actually quite a new phase… we are waiting for some kind of new physics"

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In his own words: **Toshihide Maskawa**

"For a theorist, the most exciting period is waking early one morning to discover a truth that you could not have imagined." Toshihide Maskawa describes the intellectual thrill of being a theoretical physicist, perhaps matched only by witnessing one's theories eventually being proved true. In 1972 he and Makoto Kobayashi formulated their model for broken symmetry, which predicted the existence of a third family of elementary particles called quarks, but did Maskawa ever have any doubts that experiments decades later would prove their bold theory to be correct? "In any research thesis there is always an element of supposition," he candidly states before revealing, "to be honest, I didn't imagine that the top quark would ever be as heavy as it is."

For anyone trying to understand the concept of broken symmetry Maskawa offers the following analogy: "There is a saying that if you put the grass that a cow likes in a circle around the cow, then whatever grass the cow eats, as far as the cow is concerned, will be the same. However if the cow sooner or later chooses a certain direction in which to eat the grass, then we have a state of broken symmetry."

Maskawa provides more food for thought when discussing whether there was anything particular about the Japanese educational system that helped him and his fellow Nobel Laureates develop as theoretical physicists. "The period in which I was raised as a researcher was at a time after a brutal and reckless war and before the calmer period of the 1960s was first coming into view," he says. "What was often said was that as there are no natural resources in Japan, we must survive on the strength of science and technology." It was within this testing environment that Maskawa says he gained his yearning and an affinity for science.

"For a theorist, the most exciting period is waking early one morning to discover a truth that you could not have imagined"

All young and eager scientists require nurturing, and Maskawa was no exception. He cites his professor at university, Shoichi Sakada, as the person who provided especially useful direction on his path to becoming a physicist. He describes Sakada as "a pioneer in Quark Theory", and Maskawa recalls how he and his colleagues were encouraged to collectively gather and discuss research. "It was there that I studied how to think and in what form things should be accomplished," says Maskawa.

And now that the student is himself a mentor, what advice would he offer young people thinking of entering theoretical physics today? "My advice to young people is to be ambitious and to have sincerity toward our natural world."

KYOTO SANGYO UNIVERSITY

Toshihide Maskawa was encouraged and inspired to collectively gather and discuss research.

"To be honest, I didn't imagine that the top quark would ever be as heavy as it is"

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