

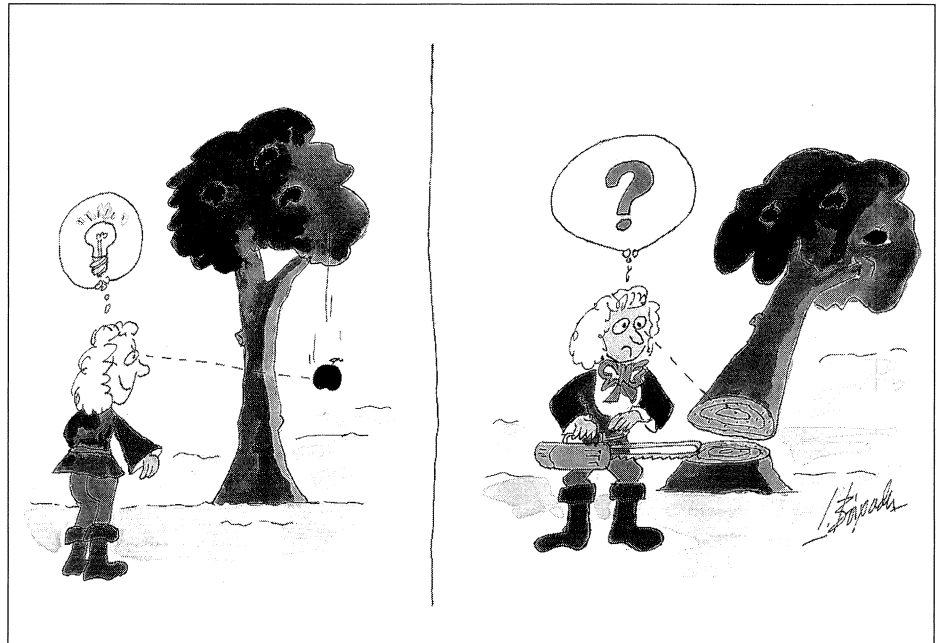
Physics monitor

CERN artist Georges Boixader's interpretation of Simon Hands' higgs explanation.

Hands on higgs

With the higgs particle one of the big unsolved mysteries of physics, last spring UK science minister William Waldegrave asked 'what is the higgs particle and why do we want to find it?', offering a bottle of vintage champagne to whoever could best answer this question in everyday language and on just one side of paper.

There were in fact four winning entries, all receiving Waldegrave champagne. The CERN Courier found the winning entry by Simon Hands, at the time a visitor in CERN's Theory Division, particularly enlightening, and asked Simon to develop his prizewinning entry.



Against the grain

The higgs particle is an undiscovered elementary particle, thought to be a vital piece of the closely-fitting jigsaw of particle physics. Like all particles, it has wave properties akin to those of ripples on the surface of a pond which has been disturbed: indeed, only when the ripples travel as a well-defined group it is sensible to speak of a particle at all.

Quantum mechanics naturally incorporates both particle and wave-like aspects of matter. In quantum language the analogue of the water surface which carries the waves is called a field. Each type of particle has its corresponding field. The higgs field is a particularly simple one - it has the same properties viewed from every direction, and in important

respects is indistinguishable from empty space. The particle-ripples associated with many other fields in particle physics spin on their axes, which clearly is not a property of empty space.

If the lowest energy state of the higgs field were one in which the field were zero, then the field would always interact the same way with all the other fields - physicists call such a state 'symmetric'.

However the laws which govern the behaviour of the higgs field dictate that even in its quiescent, ripple-less state the field is somehow "switched on", that is, it differs from zero. With the higgs switched on, pervading all of space and redefining its nature, the symmetry is destroyed: space is endowed with a "grain", like that of a plank of wood. The direction of the grain is undetectable, and only becomes important once the higgs' interactions with other particles are taken into account. Particles called vector bosons can travel with the grain, in which case they move easily over large distances and may be

observed as photons - particles of light. Against the grain, particle ranges are much shorter - these are the W or Z particles, the carriers of the weak nuclear force.

The higgs field enables us to view these apparently unrelated phenomena as two sides of the same coin; both may be described in terms of the properties of the same vector bosons.

When particles of matter such as electrons or quarks travel through the grain, they are constantly flipped "head-over-heels". This forces them to move more slowly than their natural speed, that of light, by making them heavy. Only the elusive neutrino seems (as far as we can tell) to spurn interaction with the higgs and remain massless. We believe the higgs field responsible for endowing virtually all the matter we know about with mass.

Like most analogies, the wood-grain one is persuasive but flawed: we should think of the grain not as defining a direction in everyday three dimensional space, but rather in

some abstract internal space populated by the various kinds of vector boson, electron and quark. In a world without the higgs, symmetry would reign supreme; photons, Ws and Zs would be indistinguishable, as would electrons and neutrinos, and "up" and "down" quarks (and therefore protons and neutrons). Thus the higgs indirectly gives structure to our world and makes it an interesting place.

The higgs' ability to fill space with its mysterious presence makes it a vital component in more ambitious theories of how the universe burst into existence out of some initial quantum fluctuation, and why the universe prefers to be filled with matter rather than antimatter - why there is something rather than nothing. To constrain these ideas more rigorously, and indeed to flesh out the whole picture, it is important to find the higgs particle.

There are unanswered questions: the higgs' very simplicity and versatility, beloved of theorists, makes it hard to pin down. How many higgs particles are there? Might it/they be made from still more elementary components? Most crucially, how heavy is it? Our current knowledge can only put its mass roughly between that of an iron atom and three times that of a uranium atom.

It is a completely new form of matter about whose nature we still have only vague hints and speculations, and its discovery is the most exciting prospect in contemporary particle physics.

By Simon Hands

Other higgs winners

Among the other winning entries, David Miller of London's University College introduced the higgs idea by imagining a cocktail party with Conservative Party workers uniformly distributed across the floor, all talking to their nearest neighbours, when suddenly ex-Prime Minister Margaret Thatcher enters. All in her immediate neighbourhood cluster around. As she moves across the room, she attracts those nearest to her, while the ones left behind return to their even spacing. Because of this surrounding knot she has more momentum for the same speed across the room, a political higgs effect.

Tom Kibble of London's Imperial College, who played a major role in the development of the higgs ideas in the mid-1960s (May 1993, page 22), was strong on spontaneous symmetry breaking. 'Spontaneous symmetry breaking is a ubiquitous phenomenon. For example a pencil balanced on its tip looks the same from every side - but when it falls it must do so in one particular direction, breaking the symmetry. The masses of the W and Z (and of the electron) arise through a similar mechanism. It is as though there are "pencils" throughout space, even in the vacuum.'

The remaining winners were Roger Cashmore of Oxford, and a joint entry by Mary and Ian Butterworth of London's Imperial College and Doris and Vigdor Teplitz of Southern Methodist University, Dallas, Texas.

New computing techniques in physics research

New techniques were highlighted by the "Third International Workshop on Software Engineering, Artificial Intelligence and Expert Systems for High Energy and Nuclear Physics" in Oberammergau, Bavaria, Germany, from October 4 to 8. It was the third workshop in the series; the first was held in Lyon in 1990 and the second at France-Telecom site near La Londe les Maures in 1992. This series of workshops covers a broad spectrum of problems.

New, highly sophisticated experiments demand new techniques in computing, in hardware as well as in software. Software Engineering Techniques could in principle satisfy the needs for forthcoming accelerator experiments. The growing complexity of detector systems demands new techniques in experimental error diagnosis and repair suggestions; Expert Systems seem to offer a way of assisting the experimental crew during data-taking. Evolutionary Algorithms could help resolve difficult optimization problems. Artificial Neural Networks are being adopted in the present generation of experiments. Special hardware is being implemented in trigger systems, software simulated networks are used for event classification in data analysis. The larger volumes of experimental data demand higher precision computation in theoretical physics; systematic procedures are being developed to compute higher order Feynman diagrams with the Techniques of Algebraic Manipulation.

Experts at the workshop included B. Botella (Constraint Logic Program-