

Gravity's Repulsive Side

A means of reversing or screening the pull of gravity has been a fascination for many. Antigravity is one of those scientific cats that keep coming back no matter what effort is taken to put them out. Physicists have often found themselves explaining to enthusiastic people exactly why it is impossible. Now perhaps they may have to begin explaining how it is possible.

J. Scherk of the Laboratoire Normale Supérieure in Paris suggests in a recent issue of *PHYSICS LETTERS* (Vol. 88B, p. 265) that such a thing as antigravity may really exist. The suggestion arises from current efforts to unify everything in physics into one theoretical description, a totally unified field theory. A part of these unifying efforts is a theory called supergravity, which in the opinion of some specialists, notably P. C. W. Davies of Kings College, London, writing in the Feb. 21 *NATURE*, could show the way to a successful theory of gravity as applied to the level of subatomic particles — that is, a quantum theory of gravity, something that has eluded theorists for 60 years.

It is supergravity that contains antigravity, and it contains it through the sort of complication that frequently attends these unifying field theory efforts. In physics to unify different collections of phenomena, different interactions, different transformations, means finding ever larger symmetry principles in nature that can order and interrelate all the different happenings the theorist desires to unify. Finding such a pattern of symmetry, such a larger symmetry group, sometimes brings an extra into the bargain. Filling out the symmetry properly means going back and searching for complications, new effects in old departments, that had not appeared to exist before.

This seems to be what is happening in the case of antigravity. It's a story of the multiplication of gravitons. On the level of particle physics every kind of force has one or more intermediate particles, particles that embody the force, as it were, and mediate its effects. If two other particles exchange the intermediate particle of a given kind of force, that means that a force of that sort exists between them or some related effect occurs between them. For example, if two particles exchange a photon, which is the intermediate particle of electromagnetism, an electric force may exist between them or some other electric or magnetic effect may take place.

In the older theory gravity was believed to have one intermediate particle, called a graviton. There is no experimental evidence for the existence of gravitons, but theory can describe several of their properties. One of the most important is spin. A graviton has two units of spin. (A photon

has one unit of spin.) The mathematics will show that a particle with two units of spin will mediate an attractive force between bodies with the same kind of charge. Gravitational charge is mass, and there is only one kind, so gravitational forces with a spin-two graviton should always be attractive. That seems all right; it squares with what has been observed since Isaac Newton's day. (A particle with one unit of spin mediates a repulsive force between like charges; electric and magnetic charges of like polarity do repel one another as they should operating through the spin-one photon.)

Supergravity, in attaching gravity to larger and larger symmetries, theorizes the multiplication of gravitons. The single spin-two graviton is expanded to a family of four, one of them with two units of spin, two with one-and-a-half units of spin and one with one unit of spin. This spin-one graviton ought to mediate a repulsive force in exactly the cases where the spin-two graviton mediates attractive ones. Antigravity from antigraviton.

But not so's you'd notice. It seems at first look as though antigravity should go along with gravity, and Scherk points out cases where they might cancel each other, the gravity and antigravity between two neutrons, for example. Davies calls this nonsensical, pointing out that more than half the earth's mass is in neutrons. Such a cancellation would remove a strong reason for the world's sticking together. Nor do we see anyone leaping tall buildings in a single bound.

Scherk gets out of the trap in two, not

necessarily unrelated, ways. One is to propose that gravity and antigravity view a given particle in different ways: Gravity connects to the whole of the body; antigravity to its constituents, the quarks. There is a tremendous mass difference between the view of a whole neutron and of the three quarks that compose it. The binding energy that the quarks give up is enormous. The mass of this binding energy and the differences in composition of different particles combine so that Scherk can estimate that the earth's gravitational force on a body would lose about one part in a million due to antigravitation depending on the proportion of neutrons to protons in the body.

The second way out is to propose that the symmetry that decrees the existence of the four-graviton family is not as perfect as it might be, but slightly broken. By this means the spin-one graviton will be found to have some mass. The spin-two graviton has zero mass as it did in older theories. Positive gravity thus remains a force of infinite range (because of the zero-mass intermediate particle). Antigravity becomes a fairly short-range force that is much weakened by comparison with gravity.

Antigravity may thus exist, but it does not seem as if it will ever power a speeding spacecraft. Its effects as calculated by Scherk lie somewhat beyond the reach of current experiment so nothing can be inferred from their not having been seen. If experiment ever gets good enough to find antigravity, the procedure is more likely to cost money than to make money. □

INFCE: Tying nuclear power and weapons

A 66-nation investigation on how to divorce the proliferation of nuclear-weapon states from the proliferation of nations harnessing nuclear power was undertaken at the request of President Jimmy Carter two years ago. Conclusions of the study, issued last week in Vienna, came to the less-than-profound conclusion that such a divorce was effectively impossible. So the U.S. position that the International Nuclear Fuel Cycle Evaluation "has been a success" may need an explanation. Even more important, the fact that sections of the report run counter to major components of the Carter administration's antiproliferation stance brings into question just how meaningful any consensus among INFCE participants is.

By any reckoning, the essence of Carter's antiproliferation posture — that both the reprocessing of spent nuclear fuel and the commercialization of breeder-reactor technology be forestalled as long as eco-

nomically possible — won no stunning endorsement. Although the study generally backed Carter's contention on reprocessing, saying that plutonium recycling in light-water reactors "may be regarded as a relatively marginal matter," it came out supporting breeder reactors. And whereas Carter claimed the once-through light-water-reactor cycle minimized accessibility to weapons-grade nuclear materials, the study chose not to single it out as the overwhelmingly best choice for all.

What's more, the INFCE report stressed a perceived need that new international agencies or associations be created to assure that supplies of nuclear fuel not be interrupted so long as fuel-short nations abide by international nuclear safeguards to prevent the diversion of fuel for weapons production. Why are these agencies necessary? An INFCE working paper by David Fischer of the International Atomic Energy Agency, and reported in the

Nov. 26, 1979 issue of NUCLEARFUEL (a McGraw-Hill newsletter) explained that unforeseen instabilities had developed in the commercial nuclear-fuel market "as a result of government intervention in pursuit of national policies and objectives."

It's not fair to withhold fuel supplies from signers and abiders of the Nuclear Nonproliferation Treaty, the INFCE report seems to say, even though the report goes on to suggest that a nation's signing of the Treaty may be insufficient to ensure that it will not develop the wherewithal to produce nuclear weapons; yet the U.S. position on that issue, according to documents reported on in the Dec. 24 NUCLEARFUEL, indicates that the United States would flatly oppose negotiation of universal conditions to assure nuclear supplies.

One reason the United States might be assuming this posture is suggested in a report commissioned by the U.S. National Security Council and authored by Albert Wohlstetter and Henry Rowen. Their report says only two nations — the United States and the Soviet Union — are capable of stabilizing developing political conflicts that threaten to cut off future oil supplies from the Mid East. Europe relies on the Mid East for half its oil, the pair claim. Therefore, Rowen and Wohlstetter suggest that the United States might profitably peg a promise to secure those oil supplies — with a beefed up U.S. military presence in the Mid East — in exchange for an agreement by the United States' European allies that they shift their current pro-breeder-development stance to one more consistent with the deferred-breeder-development policy Carter advocates.

Although the United States disagrees with the aggressive breeder-reactor development pursued by France, West Germany and Britain, it has basically done less than it could to discourage them, Rowen and Wohlstetter claim, according to the Oct. 1 NUCLEARFUEL. This may in fact signal a shift in U.S. State Department policy, they charge — from one opposing breeder commercialization in general to one opposing breeder commercialization only in developing countries. If so, that is not an attitude that is likely to set well with the large number of developing countries that hope to "go nuclear" in the next few years.

An Iranian nuclear-power official explained to SCIENCE NEWS two years ago what may sum up the developing nations' attitude: "If you don't sell us your reactors with your safeguards today, you'll force us to develop our own. It will take us 10 years longer to do it ourselves, but then you won't be able to touch us with your non-proliferation diplomacy."

So what in all this makes INFCE a success? First, it exorcised the myth that nuclear power and weapons are unrelated. Second, it brought nuclear supplier and importer nations together in a forum where the sobering issues of economics and safeguards were addressed by all. □

Found: Tooth-making genes in chickens

Chicken teeth have been coaxed out of their evolutionary hiding place by scientists using tissue transplant techniques. Edward J. Kollar and Christopher Fisher of the University of Connecticut School of Dental Medicine have produced four complete teeth derived substantially from chick embryonic tissue. They believe their achievement indicates that the genes for making teeth were not lost from birds' repertoire during evolution, but rather that change in the pattern of embryonic development rendered those genes silent and all birds toothless.

"The absence of teeth in chickens can be viewed as an evolutionary birth defect," Kollar says. Events during early development prevent the tooth-making genes from functioning. In recent experiments Kollar and Fisher provided conditions that allow those long-quiescent bird genes to express their potential.

In toothed animals, two types of embryonic tissue participate in dental development. One type, the mesenchyme, differentiates into cells that form the basic tooth structural material called dentin. The other type, the epithelium, provides cells that lay down enamel on the teeth. Each tissue is dependent on the other. No enamel is made without mesenchyme, and no dentin forms if the epithelium is absent.

To demonstrate bird epithelium's genetic ability to make tooth enamel, and to trigger dentin formation, Kollar and Fisher dissected epithelium from the lower face area of 5-day-old chick embryos and layered it on top of mesenchyme from the tooth buds, the earliest rudiments of molars, from 16- to 18-day-old mouse embryos. The mouse-chick tissue packet was grafted into the cavity between the cornea and iris of the eye of an adult mouse. Blood circulation there nourished the implanted tissue, so it could grow for weeks.

"The eye chamber is the trick," Kollar says, to explain the success of these experiments. Almost 10 years ago he did experiments with chick and mouse tissues in laboratory culture that suggested the existence of chick genes for tooth formation. The tissues produced an "enamel organ-like arrangement," but they could not be kept alive long enough to develop a fully formed tooth. "We had to wait for nude athymic mice to be developed," Kollar says. These mice serve as ideal hosts for maintaining experimental tissues; they provide blood but because they lack a thymus gland they do not mount an immune attack on grafted foreign tissue.

The tooth arising from the grafted chick and mouse tissues meets Kollar's expectations of what a bird tooth should be like. In the most visible sample, the tooth does not have the cusp pattern characteristic of mammalian molars, but more closely re-



Fully formed tooth arose from chicken and mouse embryonic tissue. Enamel was provided by chicken cells.

sembles reptile teeth. "Primitive teeth [in lower animals] are more peg-like, they have a smoother surface," Kollar says.

The scientists do not yet know whether tooth enamel produced by chick and mammalian cells is chemically distinguishable, but newly available antibodies to the enamel protein may resolve that question. Kollar expects there to be little difference between the enamels. He says that as a consequence of their survival importance, teeth are very highly conserved during evolution.

Evolutionary hints of the possibility of bird teeth have long fascinated Kollar. "Reptilian teeth were beautiful. What happened?" he asks. Work by others almost forty years ago indicated that a dental mandible starts to form naturally in early chick embryo, then disappears. That suggested to him that a shortcoming during development halts tooth formation. Kollar suggests that the architecture of the bird head, perhaps as it changed to allow for a beak, interfered with the interactions, between embryonic epithelium and mesenchyme, required for teeth.

Kollar sees his finding as support for the idea that evolution moves in broad changes — for instance, involving interactions during development — rather than in tiny genetic steps. With recently developed genetic and tissue transplant techniques, students of evolution may soon obtain as much information from history coded in the genetic material of living creatures as they do from the preserved traces of those long dead. □

Kollar and Fisher/Science (Magnification x 45)