mute mudstones of the seafloor.

Now, another marker, and one that signals — at least in the Indian and Pacific Oceans — the last great climatic event on earth, has been honed for use by researchers at Lamont-Doherty Geological Observatory in Palisades, N.Y., Centre des Faibles Radioactivités in France and The Godwin Laboratory in England. The marker is a pink-pigmented variety of the more commonly white planktonic foraminifera *Globigerinoides ruber,* which exists in the present-day tropical and subtropical Atlantic Ocean and Mediterranean Sea but is no longer found in the Indian and Pacific Oceans. And conveniently for researchers, the pink *G. ruber* met its demise in the Indo-Pacific 120,000 years ago, at the beginning of — and probably because of — the last full interglacial age. Researchers had noted the disappearance of the pink species in the Indian and Pacific Ocean sediments, but no one had correlated its extinction so closely to the glacial-interglacial transition — or as Peter R. Thompson of Lamont says, "... no one did it as well."

The beginning of the interglacial period — which is believed to have been quite similar to the present climate and therefore is studied for its predictive value — is usually detected in sediments by a change in the temperature-dependent ratio of $^{18}0$ to $^{16}0$. Thompson, Allan W. H. Bé of Lamont, Jean-Claude Duplessy of France and Nicholas J. Shackleton of England correlated that change in the oxygen isotope ratio to the disappearance of the pink foram in drill cores from the tropical and subtropical Indo-Pacific. The planktonic marker is quite obvious — "you can't help but identify them" — and is complementary to the sometimes mangled oxygen isotope record, says Thompson. The technique is of particular usefulness to Thompson and co-workers, who are part of the project CLIMAP, which has been gradually reconstructing the ancient climate from the information stashed in drill cores.

The disappearance of pink *G. ruber* from the Indo-Pacific region may be another example, the researchers say, of the many foraminifera species that appear to have died or diverged genetically when the Isthmus of Panama — which formed about 2 million years ago — created a migrational barrier between the two great oceans. Curiously enough, the warm-surface-water-dwelling pink *G. ruber* lasted through the Ice Age, only to die at the beginning of a warm period. Possibly, says Thompson, the warmer conditions altered such factors as the salinity of the surface layers and stressed the Indo-Pacific pink *G. ruber* to a genetic limit that did not exist in its Atlantic cousins. In any case, say the researchers in the Aug. 16 NATURE, "stratigraphers now possess a most useful and widespread datum for the identification of the [glacial-interglacial transition] throughout the Indo-Pacific area." □

Summer of the gluons: Jets of evidence

It is a basic principle of the physics of atoms and smaller structures that a force is embodied or mediated by a special kind of particle. Such particles are called field quanta, and whether the science itself, quantum mechanics, takes its name from them or they from it, they are central to its operations. Every influence of one subatomic particle on another — attraction, repulsion, change of motion, change of identity, radioactive decay — is mediated by an appropriate field quantum, the one belonging to the class of force that happens to be operating.

If an electron is bound to the nucleus of an atom, the theorist views the binding as equivalent to a continuing exchange between nucleus and electron of the field quantum belonging to electromagnetic forces, the photon, otherwise known as the particle of light. There is abundant evidence for the existence of photons, but up to now they were the only sort of field quantum of which that could be said. Now some physicists are claiming that several experiments done at the PETRA colliding beam facility in Hamburg and reported at the International Symposium on Lepton and Photon Interactions at High Energy held at Fermilab this week give indirect evidence for a second field quantum, the so-called gluon, the motivating particle of the color force or chromodynamic force, proposed by the relatively new theory called quantum chromodynamics. Not only is the gluon only the second of all the field quanta of physics for which evidence is claimed, it happens also to play a particularly important role in the structure of matter and in the structure of physicists' attempts to unify all of physics into a single grand theory of forces and particles.

It is the electrodynamic class of force that holds together atoms (and molecules), and the science of quantum electrodynamics is largely the explanation of the structure of atoms and molecules. The color force is believed by theorists to hold together the structures inside the atomic nucleus, the internal composition of the neutron and proton as well as the large class of particles related to them, the hadrons.

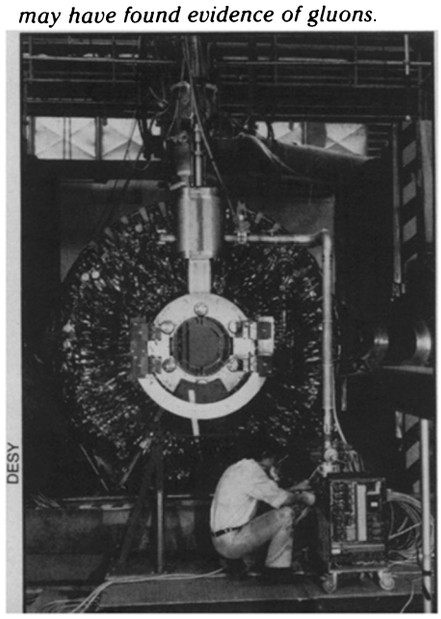
For more than a decade now it has seemed that the best way to explain the properties and behavior of the hadrons is to view them as built of subparticles called quarks, some hadrons being made of three quarks, some of two. It had seemed that with a hundred or more different kinds of hadrons on record some way of classifying and simplifying was necessary. It turns out that a small number of quarks, six in most current versions of the theory, in continually permuted combinations can account for all the hadrons (see p. 148).

Some physicists would argue that it isn't really necessary to worry about what might hold quarks together, but those who do have elaborated a theory of a force, the color force, that binds them. (The name has about as much to do with the common meaning of the word as electricity has with the Greek word for amber, from which it is derived.) The theory of the color force, or chromodynamics, attempts to do for internal structure of hadrons what quantum electrodynamics does for atomic structure, but it does so in a much more complicated way. There is just one kind of photon (although in modern theory it has a number of yet undiscovered close relatives); there are eight kinds of gluons. An experiment to find direct evidence of photons is trivial; an experiment to find gluons must be difficult, indirect and more than a little controversial.

The experiments in question are four arrays of detectors set up at the places where high-energy electrons collide with high-energy positrons in the PETRA colliding beam facility. The detectors are called MARK J, TASSO, PLUTO and JADE, and their function is to record whatever happens after the collision of electrons and positrons. The four experiments involve more than 250 physicists, undoubtedly the largest crew of physicists yet assembled for essentially the same investigation.

One of the things that can happen in an electron-positron collision at PETRA energies is the production of a quark, an antiquark and a gluon. These come away from the interaction in three different directions and each of them immediately produces a bunch of particles that the detectors can record. These "jets" of particles, three of them coming off at definite angles to each other, are the signal that a gluon has manifested itself. Their presentation in the reports of the PETRA experiments, led Haim Harari, a theorist from the Weizmann Institute in Israel, who reviewed recent developments, to conclude that 1979 would be the summer on which physicists would look back as the time when gluons began to appear real. And he

PLUTO: *One of the detectors at* PETRA *that may have found evidence of gluons.*



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suggests that it will be regarded as the "main discovery of this conference that gluons exist."

His evaluation appears to be recommending itself to many physicists. It is especially welcome to those who seek grand unification theories. These are formulations that would unite all of physics, all forces, in a single formulation. The indication that gluons exist and therefore that the color force may behave in a similar fashion to quantum electrodynamics, which was always the beau ideal of subatomic physics, gives hope that such a unification can take place. There are two (or perhaps one and a half) other forces to make their way into a total unified theory of physics: gravitation and the weak nuclear force, which governs many of the slow radioactive decays. Gravitation (whose quantum would be the graviton) is usually put aside by particle physicists since it has no observable effect in particle physics at present energy levels. The weak force has three field quanta called the intermediate vector bosons, which are now seen as close relatives of the photon even though they have never yet been discovered. (They are the subject of intense searches). Nevertheless, one of the great theoretical and experimental achievements of the last few years has been the unification of electromagnetism and the weak force into a single framework that is now being called electroweak or by some quantum asthenodynamics. The major practical task then for the grand unification theorists is to unite electroweak and quantum chromodynamics. The determination that the two behave in analogous fashion is taken by many to be an indication that efforts at grand unification may be on the right road.

But not everyone is on the bandwagon. The theory of quantum chromodynamics itself prohibits quarks or gluons from ever leaving the confines of the hadrons in which they are bound up. They may be exchanged and interact when the structures they build interact, but they do not fly free as electrons, protons or lambda hyperons can. Therefore, any evidence of them must be indirect. The jets are the best, giving a definite kind of signal, but they are controversial, and some commentators are critical.

Theorist John R. Ellis of the CERN Laboratory in Geneva, who is regarded as a "guru" by some younger physicists, made a remark about not being able to tell quantum chromodynamics from a hole in the ground. A more delicate phrase came from another theorist who told her colleague across the table, "This discovery of gluons was not my interpretation of what happened."

Conviction is likely to spread further and faster, Harari suggested in a remark seconded by Fermilab Director Leon M. Lederman, when higher energies are available. Then the three jets will become narrower and more distinct and therefore perhaps convince more people.

Another possibility is the discovery of a particle built entirely of gluons. Unlike photons, gluons are capable of exerting forces on each other, a quality that depends on an important characteristic of the theory of quantum chromodynamics. It is conceivable that a "glueball" might appear, a conglomeration of gluons stuck together. No one seems yet to know what would be decisive evidence of a glueball, but supposing there could be, it might convince some physicists that quantum chromodynamics is what it says it is. Chris Quigg, head of the theory group at Fermilab, quotes a colleague telling a third colleague what will convince doubters of the legitimacy of quantum chromodynamics: "When you've got 'em by the glueballs, their hearts and minds will follow." □

NRC urges reform in undergrad math

Undergraduate mathematics departments must redefine the traditional mathematics major to increase its applicability, its flexibility and its scope. This conclusion emerged from a recently completed three-year study undertaken by a special committee of the National Research Council. To encompass increasing applications, the committee recommends that the number of credits required in the undergraduate mathematics major must be increased.

The NRC's blue ribbon committee of mathematical scientists, chaired by Peter Hilton of Case Western Reserve University and Battelle-Seattle Research Center, was created to study the "mismatch between college mathematics curricula and opportunities for employment." The committee concluded in its 25-page report, "The Role of Applications in the Undergradaute Mathematics Curriculum," that the principal source of the problem was mathematicians' attitudes — "a strong and pervasive tendency towards scholasticism." To reverse this trend the committee put forward a platform of 14 recommendations that it hopes will influence national policy toward mathematics education in the 1980s.

Chief among these are recommendations that encourage colleges to reorient their mathematics curricula to be outward rather than inward directed; to require minors in nonmathematical subjects, as well as work in computing that is closely tied to mathematics courses; and to offer experience in applications of mathematics as an integral part of every program for the major in mathematical science. Implementation details concerning these curricular recommendations are currently under study by the Committee on the Undergraduate Program in Mathematics of the Mathematical Association of America. □

Fluoride effective against caries?

The apparent reduction in dental caries in children using fluoride toothpaste or tablets compared with controls using neither, which has emerged in a number of recent studies, may be an artifact introduced by dissimilar samples of children in each group. In a large study carried out recently in Holland, Dutch scientists found esentially no reduction in caries when the fluoride users and non-users had been carefully matched.

This surprising conclusion was announced last month by a group led by T. J. Tijmstra from the University of Groningen and the Utrecht Health Organisation TNO at the Sixth International Conference on Social Science and Medicine, held in Leeuwenhorst, Holland. Tijmstra has always felt dissatisfied with past fluoride surveys because of the high rate at which children dropped out, leaving a final sample invariably motivated to good dental behavior.

He determined to design a study in which the two groups of children were as closely matched as humanly possible. He began with 583 randomly selected children born in 1961 and now in the schools of Leeuwarden, a town in northern Holland that does not have fluoridated water. About 95 percent of the children and their mothers agreed to take part in the study. The children were all given detailed dental examinations and they and their mothers completed lengthy questionnaires. Children who had taken fluoride tablets for eight years scored 16.6 on their dental index (a measure of the proportion of teeth missing, filled or suffering decay) compared with 19.0 for children who used no fluoride. Fluoride toothpaste users scored 17.5, while children using both supplements scored 14.2.

This scoring was suspect, however, because Tijmstra's group found that those children with eating and teeth cleaning habits most likely to cause caries were the very ones who tended not to use fluoride at all. The scientists therefore compiled two samples of children who were as near identical as possible with regard to father's occupation, candy consumption and toothbrushing habits. The reduction in caries among fluoride users vanished. Children who used either fluoride toothpaste or tablets scored essentially identical dental indices as the non-users. Only in the case of the few children who used both toothpaste and tablets did a small reduction remain.

Tijmstra's conclusion is that fluoride products are of dubious value in reducing dental caries. Such a conclusion, however, is not likely to be widely accepted (especially by producers of fluoride toothpastes) without confirmation of the results by other researchers. □