sponds Wolpoff. There is no justification for removing the three specimens from the study, he says, but even without them the sample is large enough to be unaffected by the loss of a few individuals.

"The more interesting issue now is to examine the speed and direction of evolutionary change in *Homo erectus,*" says Wolpoff.

Adds Philip D. Gingerich, director of the Museum of Paleontology at the University of Michigan: "I think Wolpoff was quite conservative in his definitions of which specimens are *Homo erectus.* We always want more details, but his study is a step above anything that has been done before." —*B. Bower*

Standby storage for nuclear waste

A cleared construction site near the Clinch River in Tennessee is the preferred location for temporarily storing high-level radioactive waste until a permanent repository is ready, Department of Energy (DOE) officials announced last week. This "monitored retrievable storage" (MRS) facility, costing about $1 billion to build, would process, package and store up to 15,000 tons of spent nuclear fuel from the nation's licensed nuclear power plants (SN: 1/7/84, p. 5; 1/5/85, p. 6).

The Clinch River site, abandoned since late 1983 when Congress killed the breeder reactor project that was to occupy the land (SN: 11/19/83, p. 329), is near enough to most of the nation's nuclear power plants to reduce the distance spent nuclear fuel must be shipped to get it to a storage facility, says Ben C. Rusche, director of DOE's Office of Civilian Radioactive Waste Management. DOE's two alternative storage sites are also in Tennessee: one on federal land near Oak Ridge and the other at the Tennessee Valley Authority's canceled Hartsville nuclear plant site northeast of Nashville.

"Siting, construction and operation of an MRS can be based on available technologies," says Rusche. "Facilities essentially identical to the proposed MRS have been built, licensed and operated safely over the last 30 years. For this reason, we are confident that we can adhere to the strictest safety standards."

Next January, DOE will submit to Congress a detailed proposal including environmental assessments and two facility designs for each location. This will allow Congress to choose one of the six possible combinations of design and site. If approved by Congress, the MRS facility could begin operating as early as 1996. DOE is obligated on Jan. 31, 1998, to begin accepting shipments of spent fuel for final disposal, whether or not a permanent geological repository, already behind schedule, is completed and able to accept radioactive waste by then. —*I. Peterson*

Stringing together a unified theory

Physicists are eagerly pursuing a unified field theory that will explain everything in physics, even though the search has frustrated Albert Einstein and a number of other intellects over the years.

The latest approach, which promises to overcome some of the difficulties of the others and to be unique where they are troublesomely multiple, leads to what are called superstring theories. They get their name from the change they make in the basic mathematical way in which fundamental particles are represented. The fundamental particles in all these unified theory attempts are the quarks (out of which neutrons, protons and a host of others are built) and the leptons (building blocks of electrons, muons and neutrinos). It has been customary to represent them as geometrical points, dimensionless objects without any spatial extension. That simplifies the mathematical operations. The superstring theories, however, represent them as strings, geometrical objects that extend in one dimension.

Such a change is necessary to provide a theory that will include gravity and subatomic phenomena and be consistent with the quantum mechanics that govern the subatomic domain, according to Michael B. Green of Queen Mary College of the University of London (now temporarily at California Institute of Technology). Such a union of gravity and subatomic phenomena has been the sticking point of other approaches.

Superstrings are no longer than 10^{-35} of a meter, as Green pointed out at last week's meeting in Crystal City, Va., of the American Physical Society. But that is enough to give theorists "the hope...that this will provide a realistic unified theory that will explain observations with few or no free parameters," he writes in the April 4 NATURE. Free parameters are mathematical terms that can be adjusted more or less at will to make predictions of experimental values come out correctly. Theorists don't like free parameters. A good theory should predict correct experimental values without any such fiddling.

Superstrings are so short that they almost look like points. But choosing them yields a mathematical derivation that determines almost uniquely the mathematical group that can be used to represent the symmetries of physics. Superstrings also specify uniquely the number of dimensions in which to calculate. These two features get rid of a lot of free parameters.

Symmetry is a basic principle on which physical explanations or theories are built. Physicists notice symmetries in the properties of subatomic particles and in the processes and interactions they engage in. They try to represent symmetries with mathematical groups. Mathematically, a group is a collection of related objects with a rule that allows one member to be generated out of other members. For instance, the real numbers are a group, with the ordinary rules of arithmetic. Other groups come from geometric operations, such as the possible rotations of an equilateral triangle or those of a regular hexagon (with appropriate combining rules).

These geometrically derived groups are particularly useful for representing physical symmetries. In general, the larger the group, the more physical symmetries can be included in a given formulation. Theorists have tried quite a variety of them. Superstring theory limits the choices to two, thereby chucking a lot of free parameters.

The two allowed groups, Green says, have the advantage of being huge. They start out with the ability to contain very many symmetries, so, as the theory is broken to subtheories of different classes of phenomena, the smaller groups into which these two can be broken have more than enough symmetries to accommodate any needs. They also contain nature's one notorious asymmetry, known as chirality (from the Greek word for hand). In some phenomena, nature distinguishes between left-handed and right-handed things. Other approaches to unified field theory do not successfully explain chirality, Green says.

Superstring also determines that 10 dimensions should be used. Frustrated in attempts to derive a consistent theory in the four dimensions we experience (three of space and one of time), theorists have gone into more dimensions, hoping that when they were finished they could return the theory to our experienced four dimensions by "compacting" the extra dimensions. That is, the extra dimensions are so tightly curved that an object moving along them comes back to its starting point after no more than 10^{-35} meter; we are not able to notice such tightly curled dimensions. In other approaches, various numbers of dimensions from five to 26 have been tried. By specifying 10, superstring gets rid of many important free parameters.

Superstring theories have a long way to go, however, before they reveal the mass of a top quark or of a tau neutrino or other similar things they are supposed to tell us, but NATURE's editor, John Maddox, writing in the April 4 issue, calls them "... the best hope yet that theories of particle physics will be united with gravitation...." —*D. E. Thomsen*