astronomer named Clyde Tombaugh, who was hired by Percival Lowell, a wealthy Bostonian, to carry out the search.

A 1950 estimate by the Palomar Observatory's Gerard Kuiper put Pluto's diameter at 3,800 miles, about half that of the Earth. A 1965 experiment that measured the time Pluto took to cross a star of known size narrowed the estimate to a maximum of 3,600 miles. When another "occultation" took place on Easter Sunday 1980, a new measurement technique allowed astronomers to fix the diameter at 2,500 miles—barely larger than Earth's moon.

It took nearly as long to discover Pluto's mass. Early estimates had put its weight at 6.6 times that of Earth; by 1955, Pluto had shrunk to roughly Earth's size. Astronomers believed that it was composed mostly of rock and iron, like Earth. Finally, in June 1978, James Christy of Washington's U.S. Naval Observatory discovered that Pluto had a moon, which he named Charon. Since the period of a moon is governed by its "parent" planet's mass, it was possible to calculate Pluto's weight—.0024 that of Earth.

Putting information about the planet's diameter and mass together, astronomers determined that Pluto's density is only 35 pounds per cubic foot, making it the lightest planet in the solar system. A 1978 spectroscopy experiment revealed that Pluto is composed partly of frozen methane, possibly mixed with some rock and ice. Its dark side probably has no atmosphere; the sunny side's atmosphere contains methane gas and, probably, argon, oxygen, carbon dioxide, or nitrogen. When Charon crosses between Pluto and the sun two years from now, it will cause parts of the planet's atmosphere to freeze. By observing how quickly its gases turn to frost, astronomers will be able to pinpoint their identities.

Paring Pluto down to size has raised an intriguing question. Back at the turn of the century, scientists first hypothesized the planet's existence when they noticed that some unknown celestial body caused nearby Uranus and Neptune to wobble slightly. But Pluto is too small to produce such effects. That means there is probably a 10th planet yet to be found on the fringes of the solar system.

Man's Delicate Body Clocks

"What Hath Night to Do With Sleep?" and "Sleeping as the World Turns" by Martin C. Moore-Ede, in *Natural History* (Sept. and Oct. 1982), P.O. Box 4300, Bergenfield, N.J. 07621.

Sleeping by night and working by day are not merely habits, but rhythms dictated by internal human "clocks." According to Moore-Ede, a Harvard physiologist, understanding these regulators is particularly important now that one-fifth of the U.S. labor force works on night shifts.

Two "pacemakers" located within the brain appear to govern human sleep and wakefulness. Each functions on about a 25-hour cycle, modified by environmental cues, such as darkness or work schedules.

The crucial "X" pacemaker, so named because its precise location is unknown, regulates body temperature and other patterns. The "superchiasmatic" pacemaker consolidates sleep into a single extended period. Sleep normally begins when body temperature is falling; a "warm up" period rouses the sleeper; temperature peaks in late afternoon. How long an individual will slumber is determined by how close he is to the automatic "warm up": A San Diego boy who set a 264-hour record for staying awake in 1966 afterwards slept only 14 hours before his rising temperature woke him.

While temperature cycles vary little, other circadian (24-hour) rhythms can change. People confined to windowless rooms for long periods often experience "internal desynchronization"—hormone levels and mental alertness begin to vary independently of the body's temperature cycle.

Internal clocks can be adjusted, says Moore-Ede, but there are limits to human adaptability. Workers with frequent shift changes perform poorly because of desynchronization. Indeed, mice and insects whose day-night cycle is shifted weekly suffer from 5 to 20 percent reductions in life span.

Desynchronization is particularly worrisome among people providing round-the-clock services—policemen, firemen, hospital personnel. Yet few work schedules take account of natural rhythms, Moore-Ede claims. Enlisted men in the U.S. Navy's nuclear submarine fleet, for example, exist on an artificial 18-hour day, six hours on duty, 12 hours off.

...as devised in 1745 by Linnaeus, "so that even in overcast weather, out in an open field, a person would be able to tell the time as precisely as if he had a clock with him."

A clock based on Swedish scientist Carolus Linnaeus's (1707–78) discovery that plants have their own internal "clocks." Different plant species open and close their flowers at certain times of day.

Adhering to the 24-hour day, to infrequent shift changes, and to rotations only from earlier to later shifts to ease the body clocks' adjustment, Moore-Ede concludes, would not only improve the quality of workers' lives, but increase safety and efficiency as well.

Computers That Think Better

"Artificial Intelligence: Making Computers Smarter" by Paul Kinnucan, in *High Technology* (Nov.-Dec. 1982), 38 Commercial Wharf, Boston, Mass. 02110.

During the 1960s, "smart" computers that could defeat humans in chess matches caused a short-lived sensation, but failed to meet the higher expectations of their admirers. Today, however, artificial intelligence (AI) is making a comeback.

The first smart computers suffered from exaggerated claims, a high failure rate, and unwieldy size. But all this has changed, thanks to the semiconductor revolution and other technological advances, writes Kinnucan, a *High Technology* senior editor.

The keys to AI technology are "heuristic" computer programs that use knowledge to find short-cut solutions to problems. Conventional programs, by contrast, analyze data by following a rigid series of predetermined steps. The procedure is not only slow, but unworkable when answers are not clear cut.

Most AI systems rely on "expert" programs using "rules" of logic drawn up by human specialists. One 500-rule system developed at Stanford University diagnoses blood diseases; Cognitive Systems, Inc., is working on a program that will prepare income tax returns and interpret IRS regulations. Such systems perform long, complex tasks at which humans often err. Still other AI computers employ "fuzzy thinking," i.e., reasoning on the basis of uncertain or partial information and ranking answers according to the computer's "confidence" in them. One such system has already been used to help locate a several-million-dollar molybdenum lode in Canada. On the drawing boards are artificial vision systems for automated inspection robots and systems that will respond to verbal orders.

So far, home computers lack the speed and memory capacity to handle AI software, but specialists believe that the next computer generation will put expert legal, financial, and medical advice at consumers' fingertips. Prices of AI systems have already dropped from millions of dollars a few years ago to an average of $50,000 today, and the size of the systems has shrunk accordingly.

AI technology is still in its infancy. Although the United States now dominates the field, Japan recently embarked on a $450 million effort to produce a 20,000-rule system. Meanwhile, computer scientists are working to eliminate one of the "expert" systems' chief drawbacks—human error. "Deep knowledge" computers will be programmed not with rules, but with the theories, scientific models, and other information used in making rules.