sity and half at Cetus. His university schedule will be revised to emphasize research. He will drop formal teaching responsibilities, but he says that he will give priority to keeping contact with students. Cetus is still seeking zoning changes for a laboratory site near the campus and will start in temporary quarters. The plan for the first phase of operations is to have a staff of 25 Ph.D.'s with double that number of master's and bachelor degree personnel in support. Agrigenetics Corporation will also operate a plant research lab in Madison.

A different formula has been worked out by Peter S. Carlson, a tissue culture expert at Michigan State University. Carlson is spending 3 months a year at Occidental Oil's Zoecon division. His title is chief scientist, and he is helping the firm to build a bioengineering capacity in agriculture equal to that in nonchemical measures of insect control.

Carlson says his dual role creates "no problem." He thinks that being "direct and up front" about negotiating such arrangements is important in avoiding difficulties. Carlson is candid in saying that the expertise he and his colleagues possess is in demand and provides "good leverage." In 10 years that may not be so.

Worries about conflict of interest are relatively new in the life sciences sector of agricultural research. Such concerns are much more familiar in engineering and other scientific disciplines with connections to industry, such as chemistry. In the universities, the 1980's are likely to be a sometimes uncomfortable period of adjustment for the biosciences. For industry, the decade will impose a test of patience on investors and company officials awaiting the dawn of the brave new world of biotechnology.—JOHN WALSH

Sir Isaac Newton: Mad as a Hatter

Historians spin complex theories to explain Newton's year of lunacy, but hairs from his head tell a simpler story: mercury poisoning

That Sir Isaac Newton went mad for a short period in the middle of a brilliant scientific career has never been the subject of debate among contemporary historians of science. The signs, especially from the dark year of 1693, are clear. Newton broke with associates, accused friends of plotting against him, slept little, and reported conversations that did not take place.

What puzzles historians are the reasons for this short-lived lunacy. Some scholars propose psychological factors and point to the death of Newton's mother. Others suggest more mundane causes, such as overwork, Newton's failure to get certain administrative posts, and the traumatic loss by fire of some valuable manuscripts.

Not about to settle for speculation on causes of the derangement, a chemist and a historian a few years ago wrote to Newton's descendants and other keepers of Newtonian relics and received four hairs from the head of the master, which they subjected to laboratory tests. The results of their detective work revealed elevated concentrations of mercury, leading P. E. Spargo and C. A. Pounds to conclude that the madness was "due principally to poisoning by the metals which he used so frequently and with such cavalier disregard for his own safety" (*1*). The explanation fits nicely, since before his bout with lunacy Newton was immersed in alchemical experiments on which he would toil late into the night. At times he would doze off next to a bubbling retort.

The signs of Newton's mental illness appeared sometime during 1692 and reached a peak during the following year. In September 1693, at the age of 50, he wrote to a colleague saying, "I am extremely troubled at the embroilment I am in, and have neither ate nor slept well this twelve month, nor have my former consistency of mind. . . . I must withdraw from your acquaintance, and see neither you nor the rest of my friends any more."

Newton wrote many odd letters during this period. One of the strangest was to his friend philosopher John Locke, whom he accused of "endeavoring to embroil me with women." One month later, on 15 October 1693, Newton tried to apologize, saying in a letter, "The last winter by sleeping too often by my fire I

Madness by mercury?

Pictured in this mezzotint by Johan Faber is Sir Isaac Newton as he appeared in 1725, some 2 years before his death.

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got an ill habit of sleeping and a distemper which this summer has . . . put me further out of order, so that when I wrote to you I had not slept an hour a night for a fortnight together and for 5 nights together not a wink."

For nearly a century after Newton's death, the curious episode was ignored or suppressed by his biographers, who evidently felt no need to portray Newton as anything other than the supremely rational being that most of his 17th century peers and a reverential public believed him to be. Suggestions of Newton's madness emerged during the 19th century, and in the 20th, with the publication by the Royal Society of Newton's *Correspondence*, the troublesome episode was placed before the public.

A common explanation is that the death of Newton's mother in 1689 ultimately led to his nervous collapse. At the time of her death she was perhaps the only person to whom he was genuinely close (*Science*, 30 January, p. 466).

Another is the loss of manuscripts in a fire. Like the story of the falling apple, this anecdote has become part of the Newton folklore, even though there are few facts to support it. If Newton did suffer the loss of certain papers in a fire, most historians now believe it probably occurred long before his illness.

Some biographers suggest that the failure of the young, reclusive Newton to get an administrative post on his first try may have touched off his depression. Another cause may have been simple exhaustion, as suggested in a just-published comprehensive biography of Newton (*2*). Five years before the bout with madness, after feverish work, Newton finished his *Principia*, which established the gravitational laws of the universe. What was left to be achieved after Newton had given birth to his system of the world? Perhaps he suffered from a post-*Principia* depression.

Of course, none of these explanations has ever seemed completely adequate. During the past decade historians have proposed an entirely different cause for Newton's mental disturbance—poisoning as a result of constant exposure to heavy metals (*3*). Considering the symptoms of chronic mercury poisoning—disturbance of the gastrointestinal tract, lack of appetite, foul breath, diarrhea, morbid irritability, insomnia, and mental hyperactivity—the suggestion seems to have merit. One manifestation of mercury poisoning is erethism, which a medical textbook (*4*) defines as follows: "Nervous irritability, tendency to blush easily, a history—often best obtained from friends or members of the family—of change of temperament, a tendency to avoid meeting friends, and unexplained outbursts of temper." Mercury was once used in the felt hat industry, and the resulting condition in workers was highlighted by Lewis Carroll with his characterization of the Mad Hatter.

That Newton was exposed to mercury and other heavy metals is clear from his laboratory notebooks and from the observations of his peers. Most of his alchemical experiments were carried out before the first signs of illness emerged in 1692, though some were performed during the illness. In many of the experiments metals were heated to convert them to volatile form. "After I had stirred the mercury and salt together," wrote Newton in one notebook, "I . . . put it in the fire to evaporate. The salt flew away quickly and left the mercury coagulated in a hard rugged lump." Pointed out by Spargo and Pounds in their paper is a fact that other scholars have overlooked: Newton had great enthusiasm for tasting the products of his chemical experiments, recording the results of such empirical nonchalance on 108 occasions. Typical comments by Newton were "tastless," "sweetish," "saltish," and the very powerful "strong stiptick vitriolique tast." At the end of one experiment with mercury, Newton notes that the product tasted "strong, sourish, ungrateful." A joke that Newton told in his later years was that his hair had turned gray at the age of 30 because of his experiments with quicksilver.

Having deduced from their reading that Newton was poisoned, authors Spargo and Pounds set out to prove their hypothesis. For this they obtained hairs from Newton's head, a feat that "proved rather easier than expected."

"Several locks were located, two in the possession of the Earl of Portsmouth and the others in the library of Trinity College, Cambridge," where Newton had spent his academic career. "In both cases the owners of these Newton relics responded warmly to our request."

In the lab, Spargo and Pounds subjected the relics to the rigors of neutron activation analysis and atomic absorption spectrophotometry, which revealed abnormally high concentrations of chlorine, gold, arsenic, antimony, lead, and mercury. One hair had 197 parts per million (ppm) of mercury. The normal mean is 5.1 ppm. By way of comparison, Spargo and Pounds present a contemporary case of mercury poisoning. A schoolboy took 200 grams of mercury home to play with. It was spilled and the

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Soviet Oil Projections Up for Grabs

The Central Intelligence Agency (CIA) and the Defense Intelligence Agency (DIA) have come up with wildy different projections of Soviet oil production. The estimates are so far apart that they lead to essentially opposite conclusions about the Soviet Union's export potential and, by extension, its economic relations with East and West Europe.

The CIA, which has been consistently conservative in estimating Soviet oil prospects, said in May that it expects production to level off in the next 3 years and decline thereafter. By 1985, the agency predicts, Soviet oil output will have dropped from its current level of about 12 million barrels per day to between 10 and 11 million barrels. This could turn the Soviet Union from an oil exporter into an importer, and in the process it would dry up the nation's most important source of foreign exchange (*Science*, 12 June, p. 1252).

Gloomy though it may be, this projection is a good deal more optimistic than an earlier CIA analysis. In 1977, the agency said that it expected Soviet oil production to peak in the late 1970's and drop to 8 to 10 million barrels per day by 1985. It was forced to change its projections in the light of record oil output in the past few years.

By contrast, the DIA, an intelligence unit attached to the Pentagon, is positively bullish about Soviet oil prospects. In a report presented to the Joint Economic Committee in July and released on 2 September, the DIA said that "the outlook for Soviet energy, from the perspective of the USSR's leadership, is highly favorable. Prospects for full satisfaction of domestic needs, planned exports to East European countries, and negotiated quantities for customers in Western Europe appear to meet Soviet expectations through the 1980s and beyond."

The DIA projects a slight rise in oil production to 1985, a leveling off in the late 1980's, and a further rise in the 1990's. Oil exports to Western Europe and Japan may bring in as much as $11.4 billion a year in hard currency in 1985, the study predicts, and natural gas sales—which will be

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mother tried to pick it up with a vacuum cleaner. Later the family suffered tremors, flaking skin, and, in one person, hallucinations. Analysis of hair from the family members showed the following concentrations of mercury: father, 6.9 ppm; son, 17.5 ppm; mother, 141 ppm; and daughter, 8.3 ppm.

Conclude Spargo and Pounds: "The very high levels of mercury obtained in the hair of Newton and the correlation between them and his symptoms suggests that he may well have been suffering from mercury poisoning." Since the publication of their paper, the same journal has printed a rejoinder (*5*) that raises questions about possible weak links in the poisoning hypothesis, such as the difficulty in assuring the authenticity of the hair. As has always been the case with conjectures about the dark year, the debate will no doubt continue.

And if it was mercury poisoning? The effects are reversible, and after Newton in 1696 gave up his reclusive ways at Cambridge he went on to become Master of the Mint, President of the Royal Society, and a lion of London Society. It is clear, however, that his scientific displays were never again the equal of those in the early, pre-alchemical years when he discovered the calculus, the nature of white light, and the theory of gravitational attraction. Perhaps poisoning by mercury was not only the cause of Newton's brief lunacy, but was also the pivotal event that nudged the superstitious genius away from his researches in the lab to the seemingly less dangerous ways of the world.—WILLIAM J. BROAD

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Problems Continue at Three Mile Island

GAO says public will not benefit if utility is forced into bankruptcy

Time is running out for General Public Utilities (GPU), the holding company that owns the twin nuclear reactors at Three Mile Island. The General Accounting Office (GAO) examined the troubles facing the company as a result of the accident in March 1979 and, in a report* released on 26 August, concluded that an emergency aid package will be needed to save the company from bankruptcy.

The accident has already taken its toll. GPU stockholders have forfeited $150 million in lost income and customers throughout the GPU grid in Pennsylvania and New Jersey have been assessed slightly higher rates to pay for electricity bought from other companies. Corporate and customer costs will continue to rise, but the GAO claims that a rescue package could prevent them from climbing as high as they would if a bankruptcy occurs.

The GAO notes that no investor-owned utility has ever gone under before. GPU's demise would affect the entire industry. By one estimate, the accident has already added a risk premium of 0.75 percent to utility financial offerings, which is passed along to consumers in the form of rate increases of $170 million a year. If GPU were to go bankrupt, the study says, the risk premium would grow by an additional 1 percent, costing consumers $400 million more each year.

Although these financial penalties may not prove exactly correct, the GAO presents a strong case for believing that a bankruptcy proceeding would become bogged down in competing claims filed by investors, creditors, consumers, and regulators. Working out the etiquette of regulatory intervention would be a nightmare, for the federal government would join the fray in the guise of the Nuclear Regulatory Commission (NRC), the Federal Energy Regulatory Commission, and the Securities and Exchange Commission. Pennsylvania and New Jersey would jump in, with governors and legislatures offering solutions to the problem. And the state utility commissions would become preoccupied with the details of running a handful of orphaned electric plants.

Many people have a desire to make GPU pay for its mistakes at Three Mile Island. But in this report GAO raises an important question: would the public benefit by forcing GPU into bankruptcy? The GAO suggests it would not. One thing is clear: the less money GPU takes in, the less it will spend on cleaning up Three Mile Island. No one else has offered to finance the job, and GPU is running out of funds. The longer this chore is put off, the more it will cost.

The GAO report indicates that GPU has spent so much in dealing with the immediate problems raised by the accident that it cannot get out of its financial hole without help. The two decisions that hurt GPU the most were (i) the NRC's decision not to allow the company to turn on the power at the undamaged twin reactor at Three Mile Island (known as TMI-2) and (ii) the decision of the local rate-setting commission not to allow the company to charge for maintenance until the reactors are back in operation. If TMI-1 were restarted, the company would benefit in two ways: by reducing the amount of power it must purchase at a premium from outside and by making profits on the sale of electricity from TMI-1.

John Fidler, a spokesman for GPU, says the company hopes to receive approval to restart the reactor in November. After 9 months of hearings, the regulatory commission decided in late August that the company had reorganized its management sufficiently to merit public trust once again. A second decision on the adequacy of safety equipment is expected in late September. If this review is favorable and if the NRC goes along, the plant could be generating power by the end of the year. Fidler says this would bring in about $130 million annually.

The GAO report says that a favorable decision on TMI-1 will help stem GPU's losses, but will not pay for the cleanup of

*"Greater Commitment Needed to Solve Continuing Problem at Three Mile Island" (GAO, Washington, D.C., 26 August 1981).

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