SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

This project was funded in part by the National Science Foundation. Opinions expressed are those of the authors and not necessarily those of the Foundation.

SCOPE, SEQUENCE, and COORDINATION

SS&C Research and Development Center
Gerry Wheeler, *Principal Investigator*
Erma M. Anderson, *Project Director*
Nancy Erwin, *Project Editor*
Rick McGolerick, *Project Coordinator*
Arlington, Va., 703.312.9256

Evaluation Center
Frances Lawrenz, *Center Director*
Doug Huffman, *Associate Director*
Wayne Welch, *Consultant*
University of Minnesota, 612.625.2046

Houston SS&C Materials Development and Coordination Center
Linda W. Crow, *Center Director*
Godrej H. Sethna, *School Coordinator*
University of Houston-Downtown, 713.221.8583

Houston School Sites and Lead Teachers
Jefferson Davis H.S., Lois Range
Lee H.S., Thomas Ivy
Jack Yates H.S., Diane Schranck

California Coordination Center
Tom Hinojosa, *Center Coordinator*
Santa Clara, Calif., 408.244.3080

California School Sites and Lead Teachers
Sherman Indian H.S., Mary Yarger
Sacramento H.S., Brian Jacobs

Iowa Coordination Center
Robert Yager, *Center Director*
University of Iowa, 319.335.1189

Iowa School Sites and Lead Teachers
Pleasant Valley H.S., William Roberts
North Scott H.S., Mike Brown

North Carolina Coordination Center
Charles Coble, *Center Co-Director*
Jessie Jones, *School Coordinator*
East Carolina University, 919.328.6172

North Carolina School Sites and Lead Teachers
Tarboro H.S., Ernestine Smith
Northside H.S., Glenda Burrus

Puerto Rico Coordination Center*
Manuel Gomez, *Center Co-Director*
Acenet Bernacet, *Center Co-Director*
University of Puerto Rico, 809.765.5170

Puerto Rico School Site
UPR Lab H.S.

* * * * * * * * * * * *

Pilot Sites
Site Coordinator and Lead Teacher
Fox Lane H.S., New York, Arthur Eisenkraft
Georgetown Day School, Washington, D.C., William George
Flathead H.S., Montana, Gary Freebury
Clinton H.S., New York, John Laffan*

*not part of the NSF-funded SS&C Project.

Student Materials

Learning Sequence Item:

968

Identifying and Explaining Reactions

March 1996
Adapted by:Cynthia Heath and Linda W. Crow

Contents

This micro-unit was adapted by **Cynthia Heath** (Northside High School, Pinetown, N.C.) and
Linda W. Crow (Baylor College of Medicine, Houston, Texas)

Student Sheet

Science as Inquiry

Reactions that Produce Reactions

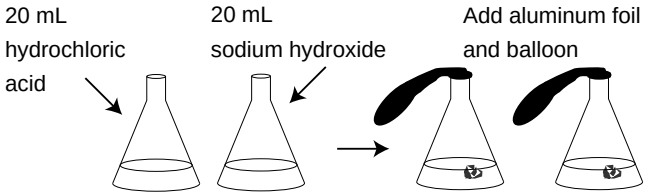
What are the characteristics of a chemical reaction?

Overview:

How do we know a reaction has occurred? This activity will provide some examples.

Procedure:

How can you tell if a chemical reaction has taken placed? To find out, place 20 mL of 3M hydrochloric acid in one flask and 20 mL of 3M sodium hydroxide in the other flask. Next drop a wadded piece of aluminum foil into each flask and quickly place a balloon over the opening.



Questions:

1. What did you observe occurring in each flask?

2. How did the rates of reaction compare in each flask?

3. What evidence existed that indicated a reaction occurred?

4. What difference do you notice in the flasks as the reactions occur?

Student Sheet

Science as Inquiry

Pasta Reactions

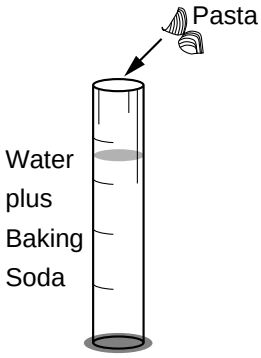
What are the characteristics of a chemical reaction?

Overview:

How do you know if a chemical reaction has taken place? Try this experiment and see if you notice anything occurring.

Procedure:

Fill a large cylinder, beaker or jar with water and place 2 tablespoons of baking soda in the water. Add a small amount of dried pasta and observe any changes!



Questions:

1. How did the pasta behave in the cylinder?

2. What evidence existed that indicated a reaction occurred?

3. What variables might be change to affect the speed of the pasta?

Student Sheet

Science as Inquiry

A Handy Reaction

What are the characteristics of a chemical reaction?

Overview:

How do you know if a chemical reaction has taken place? Try this experiment and see if you notice anything occurring.

Procedure:

Place a small amount of ammonium chloride in the palm of their hand that is covered with a glove. Add an equal amount of calcium hydroxide on top of the ammonium chloride. Then briskly rub your hands together. Observe any changes.

Questions:

1. Describe what you observed during this experiment.

2. What evidence existed that indicated a reaction occurred?

Science as Inquiry

Reactions in a Baggie

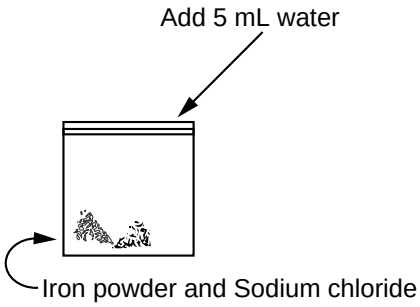
What are the indicators of a chemical reaction?

Overview:

Refrigerators have lots of reactions occurring in them. Even cold food in plastic bags changes and shows the effects of reactions. Try this activity, then look in your own refrigerator.

Procedure:

Add 5 mL of water to your baggie of chemicals. Close the bag and wait.



Questions:

1. Describe what occurred in the baggie.

2. What evidence existed that indicated a reaction occurred?

3. How could this experiment be used in everyday life?

Student Sheet

Science as Inquiry

More Reacting Events

What are the indicators of a chemical reaction?

Overview:

Formation of a precipitate is a common indicator of a chemical reaction. This activity involves a Re-
actions are occurring all around you. Watch this mixture closely.

Procedure:

Place 200 mL of clear lime water in a beaker and add 1 mL of cobalt nitrate solution.

Questions:

1. How did the liquids behave when they were mixed?

2. What evidence existed that indicated a reaction occurred?

Student Sheet

Science as Inquiry

Explanations

What are the characteristics of a chemical reaction?

Overview:

Now for the big finale. We must try to describe what we saw and how it works. Put on your thinking caps.

Procedure:

First describe how you know a reaction has occurred. Then either with words or a drawing, describe how these reactions are occurring. What is going on in the liquids in these reactions? the solids?

Questions:

1. How do you know a reaction has occurred?

2. How does your explanation relate to solids, liquids, and gases?

History and Nature of Science

Gout and Genius: A Chemical Connection?

Gout is a manifestation of the presence of irritating crystals of sodium urate in the joints. Contrary to popular medical belief, the etiology of this disease was not discovered only recently but was established over three centuries ago by the very first microscopist, A. Van Leeuwenhoek, who had examined a gouty tophus of a friend.[1] The urate appears when there is a metabolic overproduction or urinary underexcretion of uric acid. In consequence, uric acid accumulates in the blood so that hyperuricemia develops.

This sets the stage for some abnormal physiological consequences, such as gout.

Table 1. Prominent people thought to have had gout.

Politicians	Writers	Scientists	Clergy
Alexander the Great	Bacon	Berzelius	Calvin
Charles V	Gibbon	Columbus	Luther
Benjamin Franklin	Goethe	Darwin	Wesley
James I	Samuel Johnson	Harvey	
Kublai Khan	Milton	Linnaeus	
Louis XVIII	Stendhal	Newton	
Philip IV	Tennyson		
William Pitt			
Winfield Scott			

For additional names, see D. W. Stetten.[2]

History of Linkage of Gout with Genius

That gout and genius are associated is an idea that has surfaced a number of times in the past. This notion was espoused particularly on the basis of the purported very high frequency of gout among famous historical individuals (Table 1).[2] The idea appealed especially to the wealthier classes in England, in which gout was endemic in the 18th and 19th centuries.

Also, the absence of women in Table 1 may gratify males with convictions about the inferiority of women. In modern times such "sexist" perspectives can be bolstered by information available from clinical chemistry. The mean concentration of uric acid in the blood of normal men is about 5.6 mg/100 mL, whereas in women it is about 4.3. Thus, the high concentrations of uric acid that predispose one to gout are much more likely to appear in men. Indeed, gout is less prevalent among women. Thus, if gout, and by implication superintelligence, is linked with hyperuricemia, the absence of women from the list of Table 1 becomes fully rationalized.

However, before we congratulate gouty individuals on their genetic endowments, we should take cognizance of the finding that gout has been, and still is, very prevalent among poor rural blacks in the Southeastern United States. What could such poor blacks possibly share in common with wealthy WASPs of the 18th and 19th centuries?

Gout and Lead Ingestion

As has been pointed out by G. V. Ball,[3] in the Southeastern United States, poor blacks make their "moonshine" with stills that adapt discarded radiators from automobiles to serve as condensers. During the distillation, lead is continuously leached from the solder of the radiators into the homemade liquor. Periodic ingestion of this whiskey leads to progressive lead poisoning. Among other effects, lead blocks excretion of uric acid by the kidneys,

so gout appears. G. V. Ball[3] found that 40% of the samples of moonshine manufactured privately during the 1960s in Alabama had toxic quantities of lead. A survey by J. T.

Halls and G, V. Ball[4] in the Birmingham Veterans Administration Hospital in the 1970s showed that 36% of the patients with gout had lead poisoning and had been drinking moonshine.

Of course, the 18th century English aristocrats did not drink Alabama moonshine. They inadvertently ingested lead with their favorite alcoholic beverages: fortified wines, port, and Madeira. In the early 1700s these wines from the Iberian peninsula and the Canary Islands became very popular with the English gentry. They preferred these beverages for more than just their flavor. They cost less than French wines, and the choice was concordant with the current British political antagonism toward France. Analyses by G. V. Ball[3] of port from that period revealed lead contents tenfold greater than the highest concentrations found in modern vintages. The lead probably came from the tubing of the distillation apparatus used by the Portuguese to prepare the brandy that provided the added ingredient in fortified wine.

In addition, the wealthier families of 17th and 18th century England displayed their affluence by using crystal decanters and glasses for their port. It is now known that spirits kept in crystal containers can elute astonishing quantities of lead from these lead-glass vessels.[5] As Tables 2 and 3 illustrate,[5] storage of port or other beverages in most crystal containers leads to enormous increases in lead concentrations.

Thus, the correlation between alcoholism and gout in the upper classes in England makes sense. Likewise, the low frequency of gout among members of the alcoholic aristocracy on the continent can be understood because their preference in liquor was vodka and unfortified wines.

Table 2. Lead concentration of port in crystal decanters

Pb concentration in Port μg/L	PbO content of glass %
2161	24
3061	32
5331	32

The original lead content of the port was 89 mg/L. The concentrations listed above were reached after four months storage in the decanter.[5]

Table 3. Lead concentration in assorted spirits kept in crystal decanters

Alcoholic beverage	Storage period (years)	Pb concentration (μg/L)
Port	0.5–1	203
Armagnac	0.5–1	203
Whiskey	over 3	2,587
Brandy	5	7,746
Madeira	5	1,402
Brandy	over 5	19,920
Brandy	over 5	21,530

Assorted vessels in the homes of colleagues of the investigators.[5] Additional analyses were carried out for liquors stored for periods of 0.5–2 years in antique American decanters; these uniformly showed much lower lead concentrations, from 13–300 mg/L.[5] These vessels may predate the use of lead in American crystal manufacture.

Gout and Superintelligence

In current times a high frequency of gout has been reported[6] for an association of individuals called Mensa, who have proclaimed themselves superintelligent. (Members of Mensa are in an economic class that does not drink moonshine, and any modern port they imbibe has low lead content.) In addition to gout, Sofaer and Emery[6] found that myopia was twice as common among members of Mensa as among a control group of individuals.

These investigators attributed the correlations to genetic factors, specifically suggesting that the genes producing gout and myopia also affect mental functions. A skeptical wit, W. H. James,[7] wondering about the possible nonrepresentativeness of Mensa members in their admissions of people with "high IQ" suggested that individuals who wear eyeglasses might be more likely to join Mensa than those who do not. He cited the observation of Dorothy Parker, in a different context, that:

> Men don't make passes at girls who wear glasses.

Metabolic Chemistry of Uric Acid

Lead poisoning of urinary excretion of uric acid is very uncommon nowadays, so the biochemical origin of most gout must be traced back to the production of uric acid.

This substance is the end product, in human beings, of the metabolism of purines (Fig. 1), essential constituents of DNA. For example, adenine goes through the following transformations:

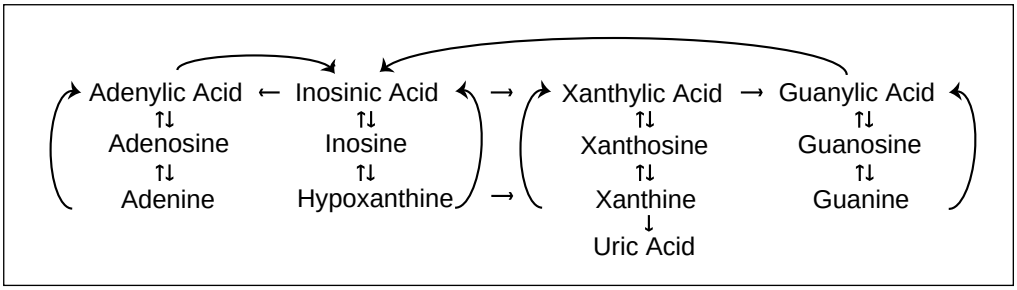


Fig. 1. Pathways of purine metabolism.

adenine∅hypoxanthine∅xanthine∅uric acid

Each of these steps is controlled by an enzyme. Gout is not present in most animals because uric acid is converted to allantoin, which has a much higher solubility in aqueous media. However, man lacks the enzyme, uricase, needed for this metabolic transformation, even though it is found in essentially all mammals. Evidently, a few million years ago a gene governing the synthesis of uricase was knocked out in an early anthropoid ancestor of ours. It has even been suggested (E. Orowan[8]) that the large development of the brain in man and higher apes was a consequence of the stimulation of the cortex by uric acid. Orowan pointed out that the molecular structure of uric acid is similar to that of caffeine, a stimulant, and others have claimed that caffeine is known to facilitate thinking. On the other hand, one should not ignore the fact that birds also have high uric acid levels and are not particularly "brainy."

The cellular production of enzymes is controlled by genes, and thus by heredity. Aberrations in the intrinsic activity of enzymes involved in purine metabolism (Fig. 1) can affect the production of uric acid. For example, it has been established that one of the enzymes, phosphoribosylpyrophosphate synthetase, which controls an alternate path of hypoxanthine metabolism, has abnormally high activity in a family with genetically transmitted gout. Furthermore, individuals afflicted with the genetic defect causing Lesch-Nyhan disease, in which uric acid levels may be as high as 24 mg/100 mL, are mentally retarded and show self-destructive behavior. Likewise, another genetic disease, Down's syndrome, or mongolism, is associated with high uric acid levels.

It has also been known for decades that allopurinol, a drug that blocks the activity of the enzyme xanthine oxidase which controls the conversion of xanthine to uric acid, decreases the uric acid content in blood and alleviates gout.

Hyperuricemia and Superintelligence

The idea that superintelligence is a manifestation of hyperuricemia is so appealing to some individuals that attempts have been made repeatedly to demonstrate epidemiological-type correlations. The contradictions to this concept cited above do not necessarily rule it out because, as is often true in science, apparent discrepancies may be resolved in time, as secondary factors and perturbations are elucidated.

Uric Acid Assays

Assays for blood uric acid are unequivocal chemical tests, subject to a certain amount of experimental error. In modern times they are carried out easily and quickly by automated instruments. The validity of the assays can always be checked by taking a sample of certified-pure uric acid out of a bottle.

The generally used assays for intelligence are IQ tests, but they are harder to validate because we do not have access to bottles of pure intelligence. So one can be swallowed up in the bottomless quicksand of controversy about just what is measured in IQ tests. Interestingly, the most brilliant

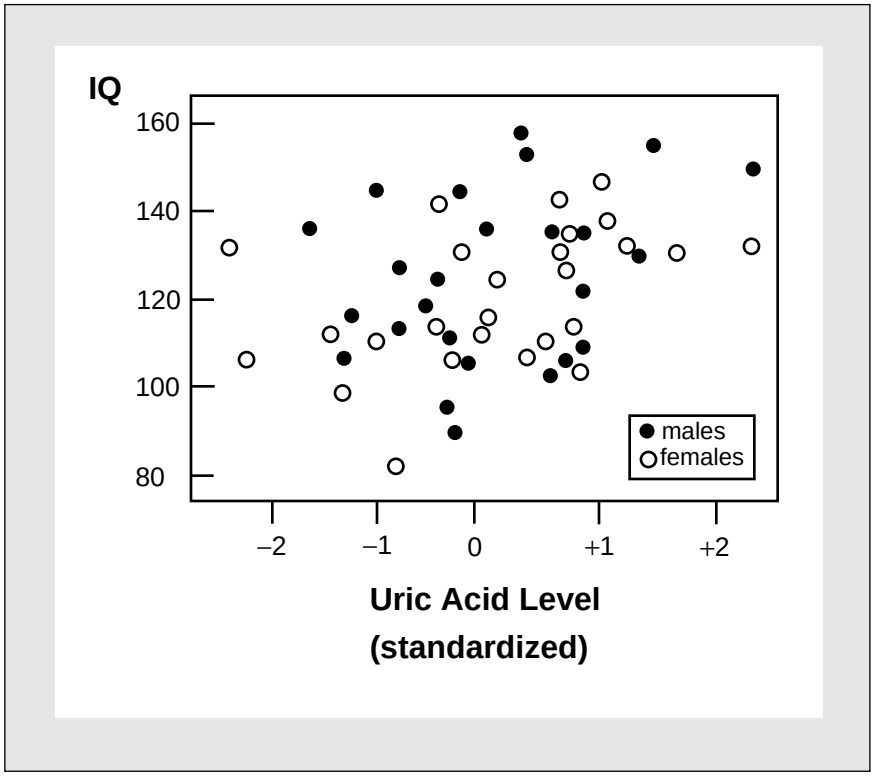


Fig. 1. Pathways of purine metabolism.

and creative physicist of the second half of the 20th century, Richard Feynman, once took a standard IQ test[9] and scored 125, a number far too low to rank him among the superintelligent, let alone geniuses.

Superintelligence and IQ Tests

Large-scale IQ testing began in the United States during World War I. A compendium and analysis of the earliest results, with Army recruits, was published by C. C. Brigham,[10] and it represented the views of the dominant American psychologists of the time. Only a few years later, however, in a remarkable mea culpa, Brigham himself sank the entire magnum opus with his confession[11] that

"One of the most pretentious of these comparative racial studies—the writer's own—was without foundation . . . that study with its entire hypothetical superstructure of racial differences collapses completely."

Since then there have been continual refinements of IQ tests and ceaseless arguments about their significance. Many of these have been analyzed by S. J. Gould.[12] We shall circumvent the uncertainties by pretending that they don't exist, and we shall look at data of coupled IQ and uric acid tests published by four different groups.

D. W. Stetten and J. Z. Hearon[13] carried out a number of statistical treatments of information collected by the U.S. Army, long after World War II, for a large group of trainees inducted at a training base in New Jersey. These recruits were given the Army battery of intelligence and aptitude tests, and in their medical examinations a sample of blood was collected routinely, so a uric acid assay was also carried out. The statistical parameters derived indicated a low level of correlation between the score in the Army intelligence/aptitude test and the concentration of uric acid in the blood. However, the correlation was not strong enough to warrant speculation on a causal relationship.

Two decades later a study by E. Inouye, K, S. Park, and A. Asaka[14] presented individual IQ/uric acid points graphically (Fig. 2). Although the scatter of the data might not convince a casual reader, the authors claim that a linear regression analysis yields the equation

IQ = 123 + 5.56 (uric acid, normalized)

and that the correlation coefficient between the two variables is 0.3343 (note four significant figures). Such a value implies that the probability that the correlation is pure chance is less than 0.02. These investigators, more confident than Stetten and Hearon,[13] suggest that common genes, controlling enzymes in purine metabolism (Fig. 1), are determinants of both IQ and uric acid levels.

Inserting actual uric acid readings (instead of normalized, i.e., actual minus mean value) into the equation of Inouye, et al., one finds that

$IQ_{female} = 99 + 5.56$ (uric acid)
$IQ_{male} = 92 + 5.56$ (uric acid)

Thus, for any given blood uric acid level, females are more intelligent than males. That opens up an interesting biological question: What in the genetics or physiology of females contributes the extra IQ advantage at a given uric acid assay?

S. V. Kasl, A. W. Brooks and W. L. Rodgers[15] carried out a broad study of a large group of male high school students, looking for correlations between blood uric acid levels and a wide range of achievement indices: grades, test scores, educational goals beyond high school, extracurricular activities, dating behavior, etc. These investigators concluded from their own and previous studies that the correlation between IQ scores and serum urate levels in unselected boys is too small to be of practical significance.

One interesting by-product of the last study was a comparison of the grades reported by students on their questionnaires and those listed in high school records. This revealed that subjects with low uric acid levels and high cholesterol levels were more likely to claim that their grades were higher than those actually found on their records.

Other interesting correlations found by Kasl, Brooks, and Rodgers (15) include the following:

- Students with high grade-point averages showed higher uric acid levels.
- Students who dated frequently had high uric acid levels.
- Students who admitted to quarreling with their parents had higher uric acid levels.

Extending the many-faceted investigations of relationships between uric acid levels and behavioral variables, K, F. Kennett and A. J. Cropley[16] gave a group of about 100 male college students a double battery of examinations, one set being a test of conventional, "convergent thinking" and the other of "divergent thinking." According to these investigators, convergent thinkers show high ambition, accept conventional goals, and exhibit strong drives toward achievement. In contrast, divergent thinkers are relatively unconcerned about adherence to rules and tend to be unconventional in outlook. They are impulsive and playful, possess a good sense of humor and are willing to take risks. They are more likely to be intellectually creative. (This is a good description of Richard Feynman.)

Statistical analysis of the results showed a significant inverse correlation between uric acid level and divergent thinking, but no significant correlation with convergent thinking.

Factors Influencing Blood Uric Acid Levels

In an atmosphere in which allusions to cognitive capacities continue to crop up, inevitably comparisons will be made between different groups or "races." One such study is that of I. F. Duff, et al.,[17] who have assembled data for uric acid levels in Oriental and Caucasian populations. Some of their results are listed in Table 4.

If blood uric acid level is a measure of cognitive abilities or intelligence, then we reach the following conclusions from Table 4:

- American Caucasians (at least those from Tecumseh, MI) must have lower IQ's than all the Orientals examined except those of a "primitive" New Guinea group and the Chinese in Taiwan.

• With one exception, the Salatas, women always score lower than men. The Salatas present a very intriguing enigma.

• Rural Malays, men or women, are superior to all other groups.

• The Chinese of Malaysia score much better than those of Taiwan.

Other studies show that Filipinos in Hawaii and in parts of the continental United States have higher uric acid levels than those in the Philippine Islands. Studies among Polynesians reveal that the Maoris of the Cook Islands have high uric acid levels, as do the Chamorros and Carolinians in the Mariana Islands, but pure Hawaiians do not.

Are these differences inherent in the genetics of the populations? Published studies reveal that many factors may influence serum uric acid levels in human beings:[18, 19]

- sex
- age
- height
- weight
- diet
- alcohol
- drugs
- medication
- exercise
- family
- race, ethnic, or cultural group
- geographical location.

Thus, many variables must be accounted for in population studies.

These present formidable obstacles to designing tests to isolate the contribution of each factor that influences uric acid levels. In addition these factors may be coupled. For example, one could probably recruit a group of volunteers to go on a diet containing large daily portions of liver, sweetbreads, and shrimp with copious quantities of beer; IQ tests could be administered during this regimen. However, this diet probably would be accompanied by weight gain, so any increase in intellective abilities may be a consequence of the latter influence. Perhaps weight gain could be circumvented by direct ingestion of pills of uric acid, just as one takes vitamin pills daily.

Conclusion

Perhaps the most trenchant conclusion one can reach from all of the studies of hyperuricemia and superintelligence, or of gout and genius, is that of J. S. Fuerst[20] expressed in his whimsical limerick (somewhat modified):

> Now leadership, achievement, drive and IQ
> Correlate with uric acid, is one view,
> But there seems to be room for doubt,
> For those researchers themselves have gout.