Critical Thinking

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Hypothetical/ Scientific Reasoning

Suppose you get in your car one morning and turn the key in the ignition, and the engine cranks but fails to start.

Conjectures:

- Spark plugs are dirty?
- the ignition coil has shorted?
- the fuel pump has broken?

As you conjecture you begin to form hypotheses, and the reasoning used to produce them is hypothetical reasoning. Each of these hypotheses should have implications. You confirm the hypotheses by testing the implications.

This kind of reasoning is used most often in scientific inquiry. Every scientific theory can be viewed as a hypothesis for unifying and rationalizing events in nature.

Scientific theories:

- Ptolemaic and Copernican theories about the sun and planets.
- Dalton's atomic theory.
- Darwin's theory of evolution.
- Einstein's theory of relativity.

Hypothetical method

Four stages:

1. Occurrence of a problem
2. Formulating a hypothesis
3. Drawing implications from the hypothesis
4. Testing the implications.

Hypotheses

1. Hypotheses are not derived from evidence but are added to evidence. It is a free creation of the mind.
2. The hypothesis directs the search for evidence. All evidence is relevant to the problem until the hypothesis directs the investigator in some way.
3. Hypotheses are tested by modus tollens.

1. Hypotheses are proven by modus tollens. That is, they are proven false, but not proven true.

If H, then I.
I
Therefore, H.

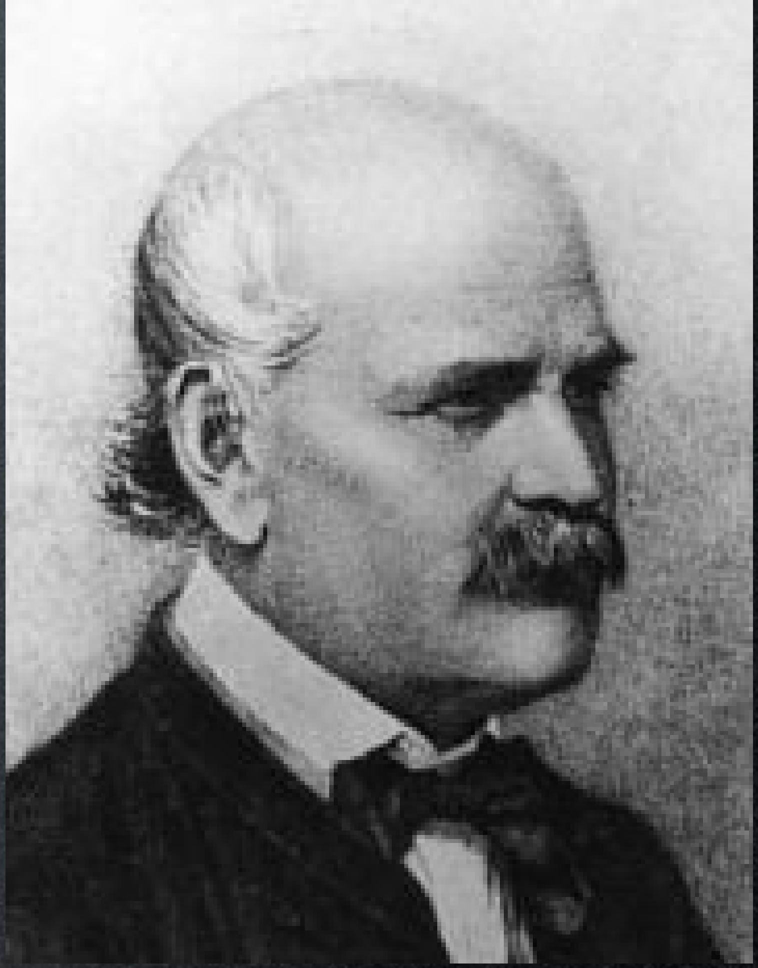
→ Invalid argument form (affirming the consequent)

If H, then I.
Not-I.
Therefore, not-H.

→ Valid argument form (modus tollens)

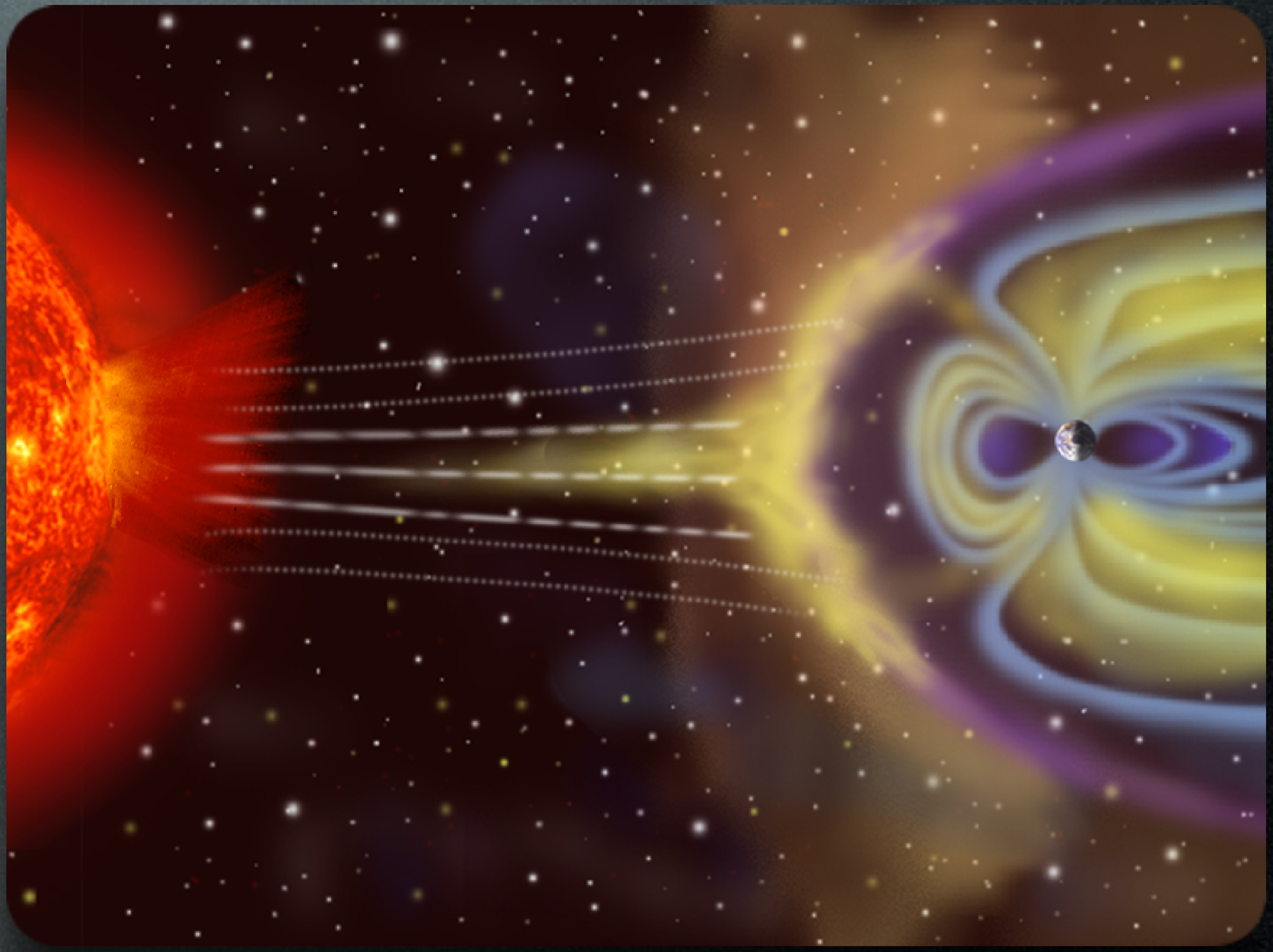
Examples from Science: Semmelweis in the First Maternity Division

"Ignaz Semmelweis...did his work from 1844 to 1848 at the Vienna General Hospital. As a member of the medical staff of the First Maternity Division in the hospital, Semmelweis was distressed to find that a large percentage of the women who were delivered of their babies in that division contracted a serious and often fatal illness known as puerperal fever or childbed fever...



In 1844, as many as 260 out of 3,157 mothers in the First Division (8.2%) died of the disease; for 1845, the death rate was 6.8%, and for 1846, it was 11.4%. These figures were all the more alarming because in the adjacent Second Maternity Division of the same hospital, which accommodated almost as many women as the First, the death toll from childbed fever was much lower: 2.3, 2.0, and 2.7% for the same years...

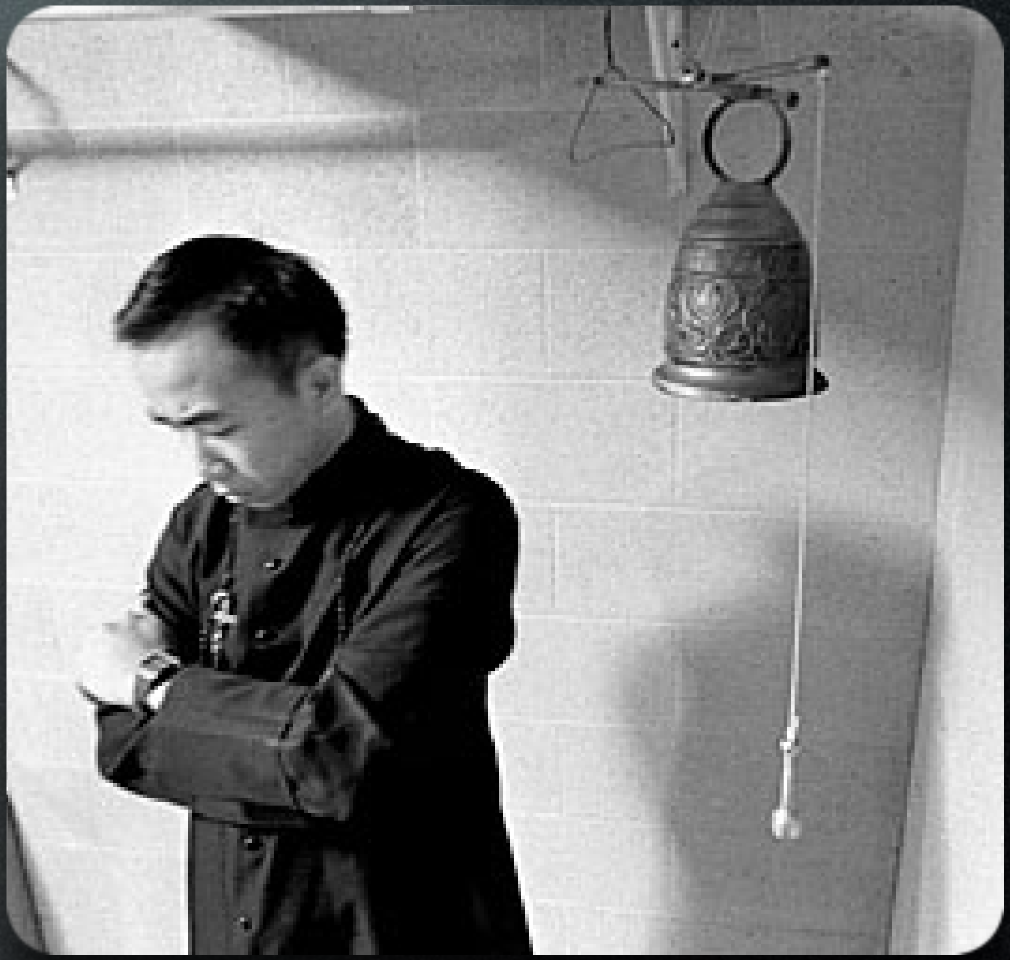
One widely accepted view attributed the ravages of puerperal fever to 'epidemic influences', which were vaguely described as 'atmospheric-cosmic-telluric changes' spreading over whole districts and causing childbed fever in women in confinement. But why wouldn't this effect the Second Division? Why wouldn't this effect women who didn't deliver in the hospital?



On another view, overcrowding was a cause of mortality in the First Division. But Semmelweis points out that in fact the crowding was heavier in the Second Division. He also rejects two similar conjectures that were current, by noting that there were no differences between the two Divisions in regard to diet or general care of the patients.

In 1846, a commission that had been appointed to investigate the matter attributed the prevalence of illness to injuries resulting from rough examination by the medical students... Semmelweis notes that the injuries resulting naturally from the process of birth are much more extensive than those that might be caused by rough examination; the midwives examined their patients in much the same way; when the number of medical students was halved, the mortality rose to higher levels than ever before.

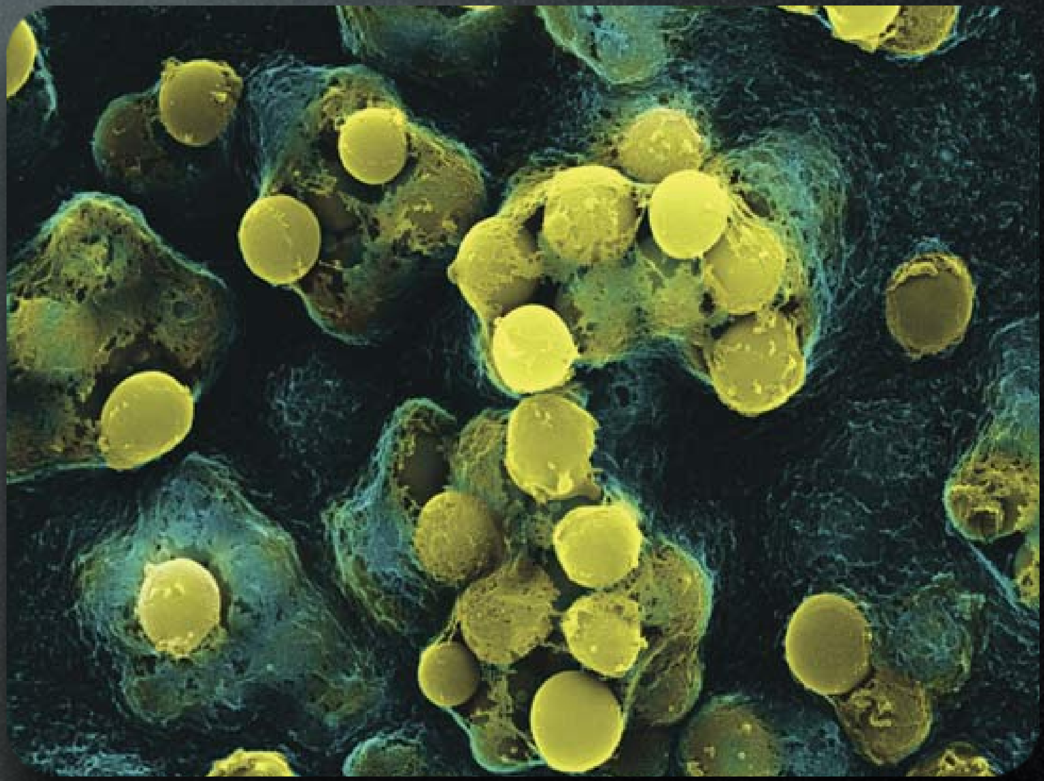
Another conjecture was that a priest bearing the last sacrament to a dying woman had to pass through five wards before reaching the sickroom: the appearance of the priest, preceded by an attendant ringing a bell, was held to have a terrifying effect upon the patients in the wards and thus make them more likely victims of childbed fever. In the Second Division the priest could go directly to the sickroom. Semmelweis tested this by rerouting the priest without the bell, but there was no change in mortality.



A new idea was suggested to Semmelweis by the observation that in the First Division the women were delivered lying on their backs; in the Second Division, on their sides. Though he thought it unlikely, he decided to test whether this difference in procedure was significant. Again, the mortality remained unaffected.

At last, early in 1847, an accident gave Semmelweis the decisive clue for his solution to the problem. A colleague of his, Kolletschka, received a puncture wound in the finger, from the scalpel of a student with whom he was performing an autopsy, and died after an agonizing illness during which he displayed the same symptoms that Semmelweis had observed in the victims of childbed fever. Although the role of microorganisms in such infections had not yet been recognized at the time...

…Semmelweis realized that "cadaveric matter" which the student's scalpel had introduced into Kolletschka's blood stream had caused his colleague's fatal illness. This led Semmelweis to conclude that his patients had died of the same kind of blood poisoning: he, his colleagues, and the medical students had been the carriers of the infectious material, for he and his associates used to come to the wards directly from performing dissections in the autopsy room, and examine the women in labor after only superficially washing their hands.



Semmelweis put his hypothesis to a test. He reasoned that if he were right, then childbed fever could be prevented by chemically destroying the infectious material adhering to the hands. He therefore issued an order requiring all medical students to wash their hands in a solution of chlorinated lime before making an examination. The mortality from childbed fever promptly began to decrease, and for the year 1848 it fell to 1.27% in the First Division compared to 1.33% in the Second.

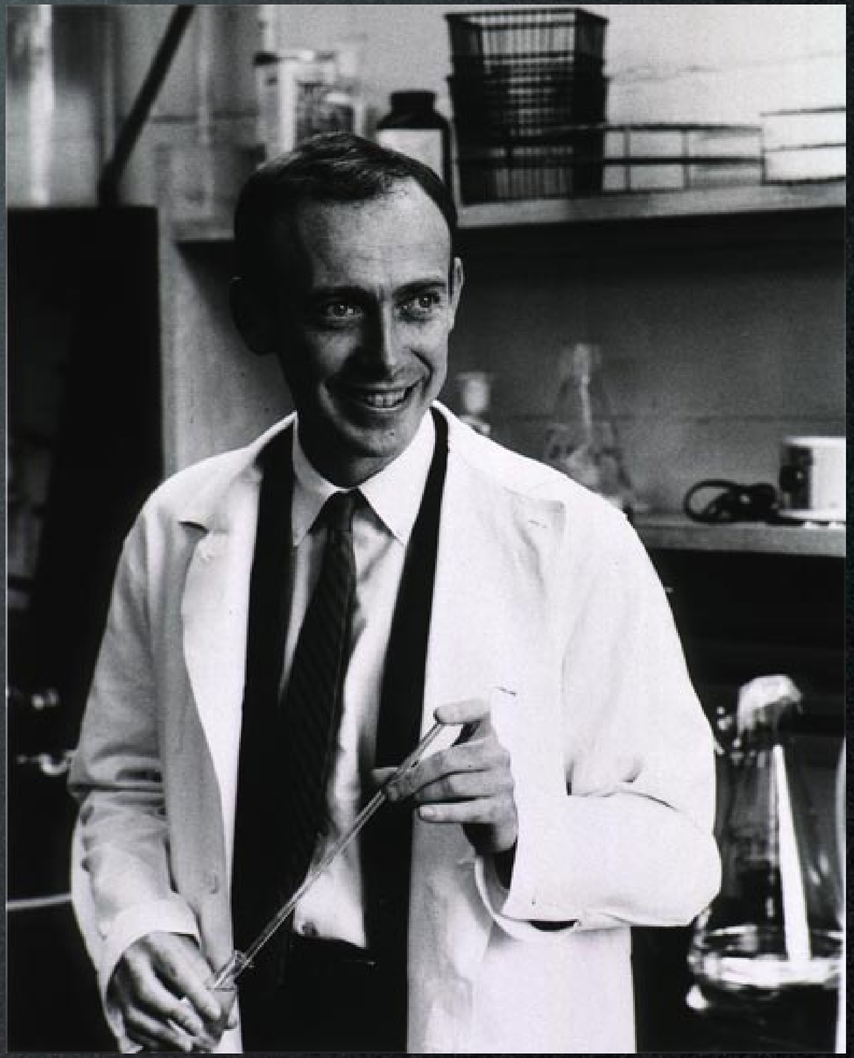
In further support of this hypothesis, Semmelweis notes that it accounts for the fact that the mortality in the Second Division consistently was so much lower: the patients there were attended by midwives, whose training did not include anatomical instruction by dissection of cadavers.

The Mentos Case

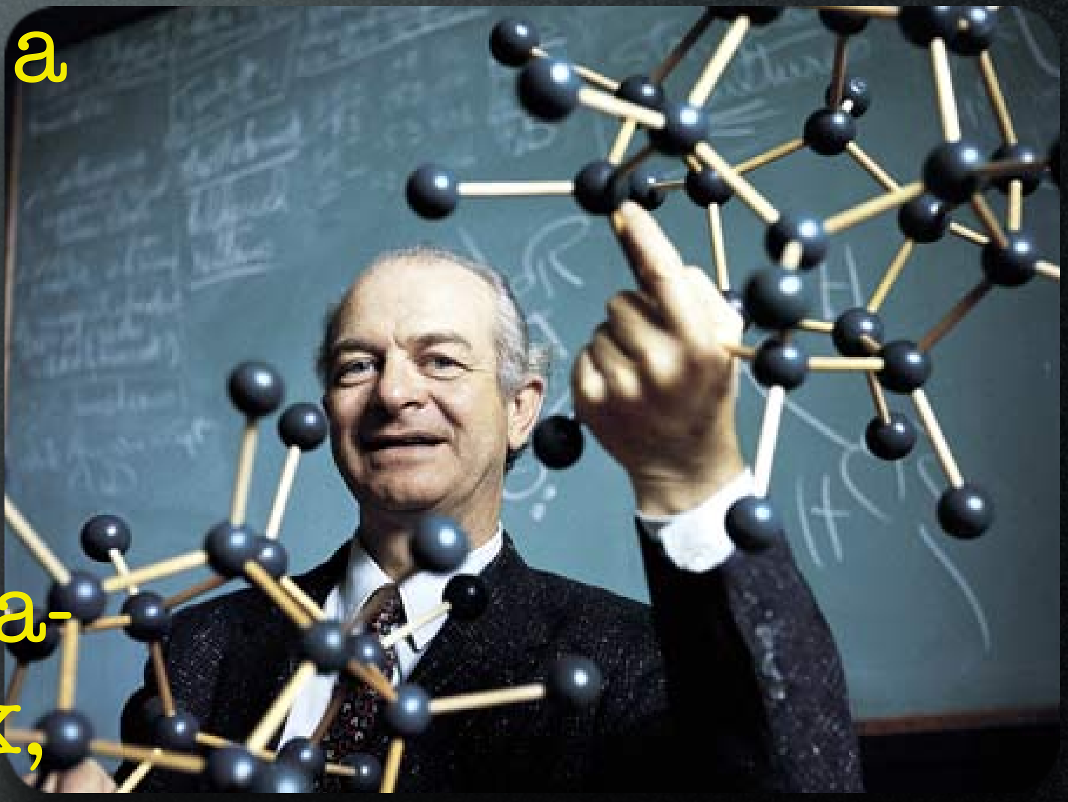
- In the video, how is the hypothetical method used?
- What are the necessary and sufficient conditions for the reaction?
- Are any of Mill's methods used to test the phenomena?

Examples from Science: Watson, Crick, and the Double Helix

In the fall of 1951, a 23 year old named Jim Watson arrived at the Cavendish Laboratory in Cambridge, England. The state of knowledge in 1951 concerning the makeup of DNA was that a DNA molecule was thought to consist of one or more nucleotides, called polynucleotides. Each individual molecule consists of a sugar molecule, a phosphate molecule and a base...Such chains of nucleotides were thought of as consisting of a backbone which supports the sequence of bases.

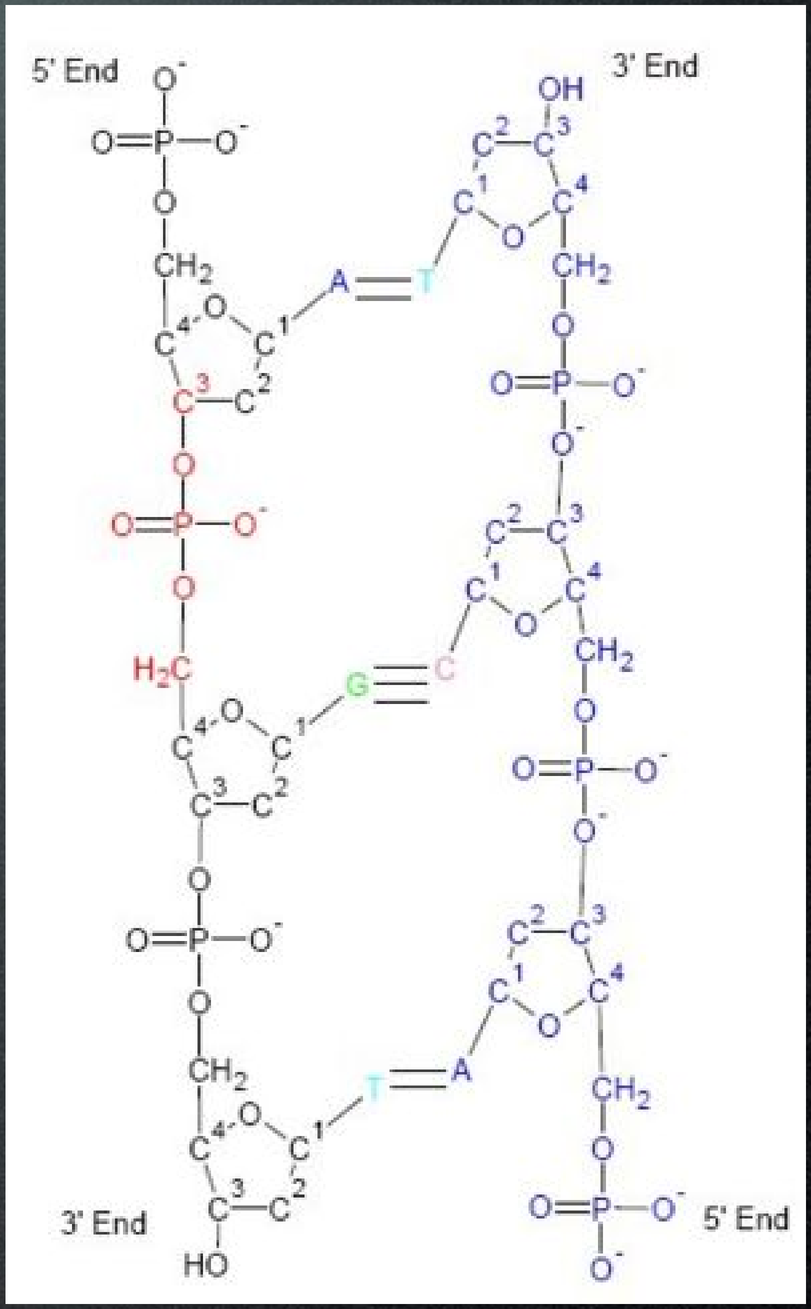


What no one understood is how all these pieces fit together in three-dimensional space. While visiting a friend, Watson learned that the world's greatest living physical chemist, Linus Pauling, had just discovered the structure of a significant protein molecule, alpha-kerotin. The structure was a helix, and Pauling had discovered it by building a physical model of the molecule, using information obtained from x-ray photographs.

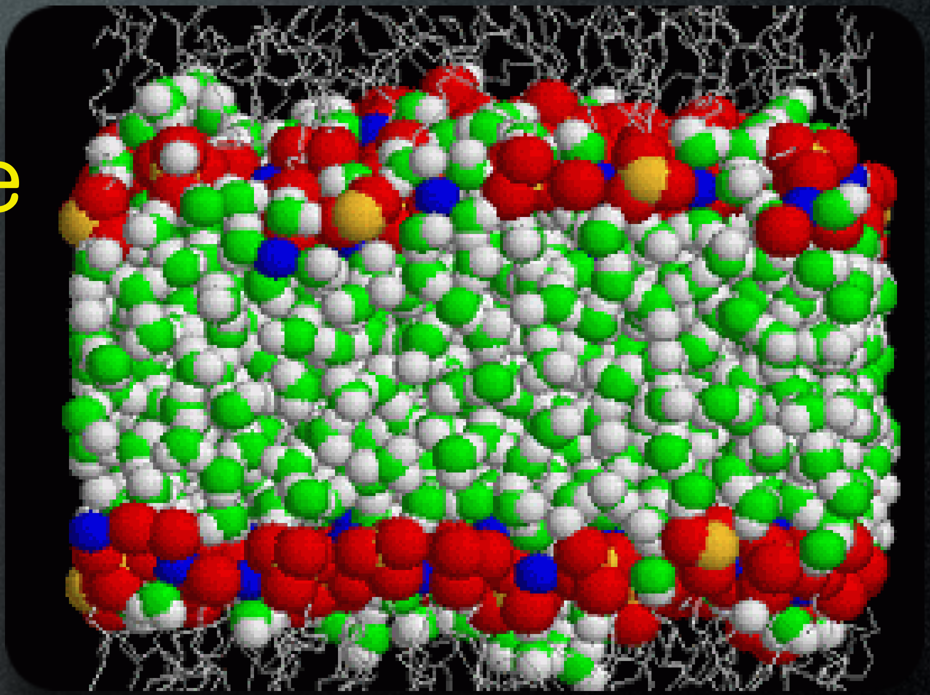


At the Cavendish laboratory, Watson met Francis Crick. Crick soon provided a major contribution to the project by developing a theoretical account of how x-rays are diffracted by helically shaped molecules. Since Francis and Crick needed more information about x-ray photographs of DNA, they asked for help from the scientist Rosalind Franklin. They determined that there could be only a few possible helical structures for DNA molecules. It should consist of at least two, but not more than four, polynucleotide chains.

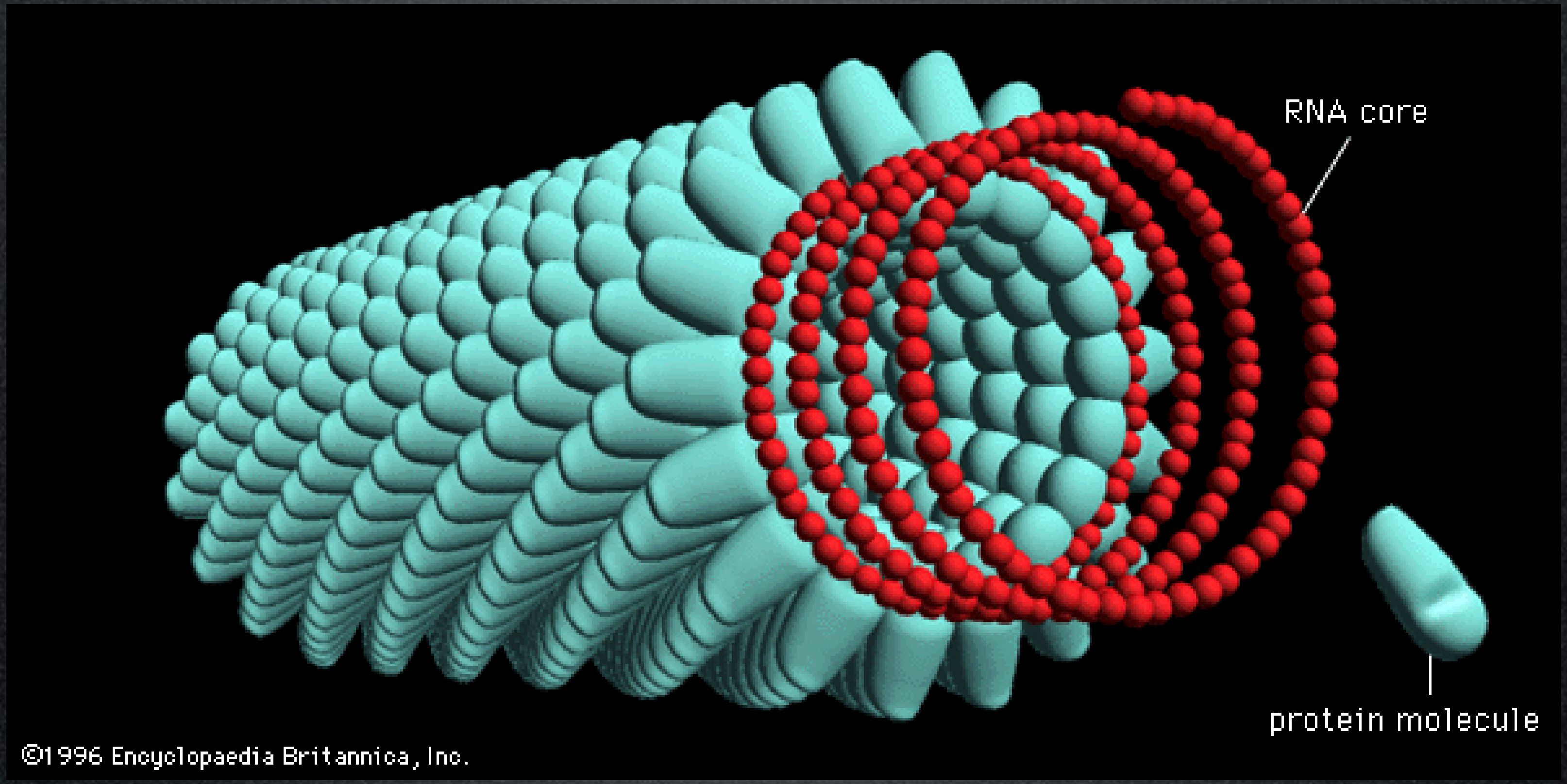
They decided to try a model with three chains. The next big question concerned the position of the sugar phosphate backbones relative to the bases. There were only two major alternatives: put the intertwined backbones in the center and let the bases hand out on the outside, or put the backbones on the outside and try fitting the bases inside. Fitting the bases inside seemed too complicated, so they decided to try building a model with the bases on the outside.



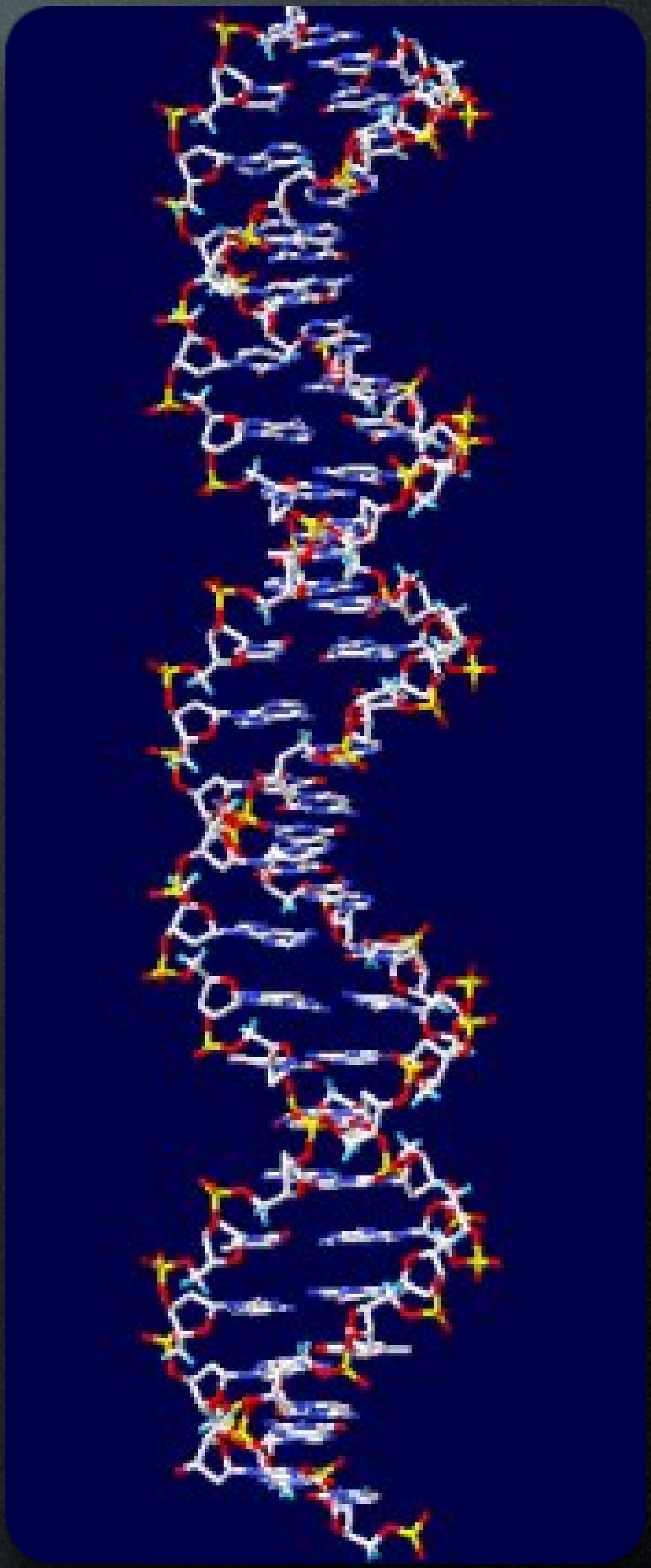
They assembled this model, and invited Franklin and another scientist to see their work. Franklin immediately discovered a flaw in the model: natural DNA is surrounded by water, which is loosely bound to the molecule. Watson and Crick's three-chain model left far too few places for water molecules to hook onto the DNA.



Next, Watson took up learning how to take x-ray pictures of the tobacco mosaic virus. He was not wasting his time because this virus should have a helical structure. Several months later he got a good photograph of the helical structure of the virus. In September 1952 Watson turned his attention to the idea that bacteria come in male and female pairs. If true, this meant that the genetics of bacteria are much more like that of higher organisms than had earlier been thought.



Although Franklin did not want to work with Watson and Crick, they did get to see a picture she had taken of “B-form” DNA and realized that it was much simpler that any they had seen before. They still had questions: How many chains are there? Are the bases outside or inside? If the bases are inside, how are they arranged? This time, Watson decided they should try two-chain models, appealing to the general idea that biological entities come in pairs.



Seeing that they were getting nowhere with base-outside models, they decided to have a go at models with the bases on the inside. The idea was that a base attached to one sugar phosphate backbone should bond with a base on the opposing sugar backbone, thus forming a kind of miniature spiral staircase. Watson and Crick formed bases out of cardboard and began toying with different combinations to build a spiral staircase with a uniform diameter. They found that their combinations would in fact work to explain the bonding between the molecules.

They quickly realized that in this model they had found the “secret of life.” They wrote a 900 word paper published in the journal Nature that began, “We wish to suggest a structure for the salt of deoxyribose nucleic acid (D.N.A.).”