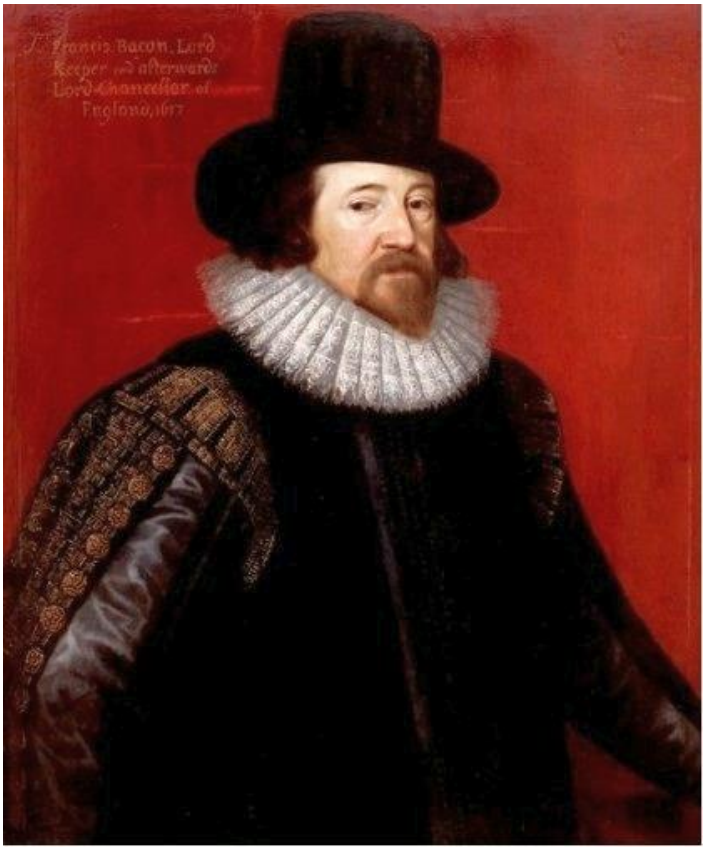
3. The Scientific Method

The scientific method was more or less invented by Sir Francis Bacon, an Elizabethan, who lived from 1561 to 1626. He was a pioneer in the use of *Inductive*



Source: Wikipedia article on Francis Bacon

Reasoning, which is moving from individual bits of knowledge, observations, to more general conclusions; that is from the specific to the general. For example: We have followed the action of two hundred individual bees, each of which is collecting nectar from flowers and bringing it back to the hive.

Our conclusion, subject, of course to further testing, is that, most simply, the hive must be full of nectar. More complex conclusions could be that nectar collection plays an important role in the operation of the hive, and that nectar production may be involved in the production of honey. The *Scientific* or *Empirical Method* uses inductive reasoning. And it's an important way of knowing…of learning things about our universe.

Deductive reasoning is moving from the general to the specific. Thus we learn general rules and apply them to various specific situations in our lives. For example: All bees gather nectar. Freddie is a bee. Therefore she gathers nectar. Or: All men die; Aristotle is a man; therefore Aristotle will die.

Note that the first premise, in each case of deductive reasoning, is an hypothesis. So "All men die," or "all bees gather nectar" are hypotheses since we have not observed the death of each and every man or the actions of each and every bee. And, as it turns out, all bees don't gather nectar, just the worker bees. Or, there might be immortal humans who we haven't happened to observe.

In a similar sense, "All crows are black" is a hypothesis. In fact, if we examine enough crows we will find an

albino crow, which disproves our hypothesis. In the case of "All men die," we would need to find an immortal person, but we cannot say for sure that one doesn't exist.

There is also a third form of reasoning called *abductive reasoning*. In abduction, data is collected and the best model to explain it is accepted; more complex or less satisfactory models are discarded. Abduction is sort of a more advanced form of induction.

So, for example, our inductive example of bees makes a prediction that nectar is important in the life of the hive. Further observations and inductions will lead us to notice different classes of bees besides workers, production of honey, construction of the hive, defense of the hive, care of the Queen's eggs, and so on.

Abduction might say: "Nectar is important in the life of the hive, and more data collection is required before we can induce the role of nectar in the hive."

Doctors use abduction when making a diagnosis based on test results and observations. Jurors use abduction to render verdicts based on evidence presented. Sherlock Holmes used abduction to lead him from precise observations to competing theories.

In thinking about inductive reasoning, Bacon took note of what he called “idols,” which introduce problems to human reasoning.

1. *Idols of the Tribe* are deceptive beliefs inherent in the mind of humans. For example, most people think that a slot machine which has just paid out a jackpot should be abandoned because a new jackpot from the same machine will not occur any time soon. This is a false belief. It’s like abandoning a flipped penny because it produced a head and you want another head. The slot machine is simply a many sided penny, and the possibility of a jackpot on each pull is equal.
2. *Idols of the Cave* arise within the mind of an individual. Thus a chemist sees chemistry in all things. Or a hateful person sees everyone as out to get him. Or very religious people see God’s involvement throughout life.
3. *Idols of the Marketplace* are errors arising from the use of words without attention to their true meaning. Thus something is not a “fact” just because a particular politician says so. Philosophers, by the way, point out that there is

only one fact, which is that there are no facts! But, of course if there are no facts, how could there be one fact?

4. *Idols of the Theater* are due to sophistry and false learning. For example a man is saved from a ship wreck and now prays to god, not doubting his grace. What about the people who died and were also praying? Maybe they weren't!

Let's take a look—hopefully a review—of the steps of the scientific method.

1. Pose a question.
2. Collect relevant data. The data must consist of accurate observations and be related to the question.
3. Develop a hypothesis or hypotheses to explain data.
4. Test the hypothesis or hypotheses with an experiment.
5. Test results will support or not support a particular hypothesis.
6. If the data do not support the hypothesis, revise the hypothesis, and test again.

7. If the data do support the hypothesis, carry out additional testing, or advance the hypothesis to the level of a theory.

So, considering Climate Change and Global Warming:

1. Is global warming occurring and do humans cause it? That's the question.
2. To answer the question, we'll collect data on whether warming is occurring or not; collect data on which human activities—such as burning fossil fuel—might cause the warming.
3. Then we'll develop a hypothesis: Humans burn vast quantities of fossil fuels, which increases the CO_2 concentration in the air. CO_2 in the atmosphere traps heat that would otherwise radiate away from earth. This greenhouse effect causes global warming.

   A second hypothesis: Global warming is responsible for all sorts of problems including rising sea levels, droughts in some places, floods in others, more severe weather worldwide.
4. The big arguments nowadays are whether the evidence was collected accurately and whether the evidence supports the hypothesis or not. For

example, calculating accurate average world temperature turns out to be extremely complicated just in the present and even more complicated in the distant past.

5. Some people say the available data support the hypotheses; others disagree.

A few comments on observations and data and on scientists:

1. Observations may be inaccurate. For example a mirage is not really a lake in the desert. A picture of your brother and Elvis by the Eiffel Tower may be fake. Elvis is dead, well probably, and your brother has never been there, with or without Elvis. Equipment that records data such as temperature, CO_2 concentration, and the like may not work properly. A faulty thermometer or one placed in direct sun does not collect accurate data about the air temperature. Can we compare a thermometer used in 1750 to one used today in terms of accuracy and particularly if the 1750 thermometer is no longer available to us.
2. Scientists are humans. In arriving at and testing a hypothesis they may ignore some accurate data or accept inaccurate data. Or, the testing may be

flawed in some way because equipment didn't work or because the experiment was set up or carried out incorrectly.

3. Their preconceived ideas about what is happening may influence their interpretation of results. Gregor Mendel's results are much more accurate than chance would predict. For example his 3:1 ratio of tall and short pea plants is much better than chance would predict. If you toss a coin 100 times, will you get 50 heads and 50 tails? Of course not, and a standard curve will predict the likelihood of various result.

   So Mendel "improved his results" somehow—this is called "cooking the data"—probably by putting plants (actually his assistants probably did this) that were neither short nor tall into the pile that he thought needed strengthening in order to meet the hypothesis. Or maybe, since Mendel was a monk, he had God on his side, and therefore got better results.

4. The accuracy of their science may be influenced by money or by political views. We'll see quite a lot of this one as we investigate climate change and global warming.

The Scientific Method does work, and it's one of our best ways of learning and knowing. Making it work is not necessarily simple and easy. And, some scientific questions are more complex than others. Questions about climate change and global warming are complex at best.