

## Steno, Hooke, and Burnet

### Plus a secondary source: a review of a book on Burnet by Stephen Jay Gould

#### 1. Nicolaus Steno. *The Prodromus*.<sup>1</sup>

Let us consider *Glossopetrae Melitenses* [literally, “tongue-stones of Malta”]. Were these once the teeth of sharks? ...And were other such bodies—similar to marine bodies, and found far from the sea—once produced in the sea?

5 Many other bodies [that bear such resemblances to living things] are also found among the rocks. If one should say that [tongue-stones] were produced by the earth, or by the force of a particular location, one must confess that all the rest were also produced by earth, or by such a force...

10 And so I saw the matter finally brought to the same point that any given solid naturally contained within a solid [e.g., a tongue-stone in a rock] must be examined in order to ascertain whether it was produced in the same place in which it is found. [We must investigate] the character not only of the place where [a body] is found, but also of the place where it was produced....

[Here is what I propose:]

1. A natural body is an aggregate of imperceptible particles...
- 15 2. A solid differs from a fluid in this way: in a fluid, the imperceptible particles are in constant motion, and mutually withdraw from one another, while in a solid, although the imperceptible particles may sometimes be in motion, they hardly ever withdraw from one another so long as that solid remains a solid and intact.
3. While a solid body is being produced, its particles are in motion from place to place.

20 These statements hold true in all cases, whether one considers matter as atoms, or particles changeable in a thousand ways, or the four elements, or whatsoever chemical elements may be assumed to suit the differences of opinion among chemists...

25 These bodies which the earth contains receive from the earth nothing except the place in which they are produced and the matter supplied to them in that place through their pores. These things, which are produced by Nature, receive the determination of their particles from the motion of a penetrating fluid...

In the case of those solids, whether of earth or rock, which completely enclose plants and their parts, bones and the shells of animals, these bodies had already become hard at the time when the earth and rock containing them was still fluid. That is, the earth and rock did not  
30 produce these enclosed bodies... [Indeed, the enclosed bodies existed long before the matter of the earth or rock took the shape of earth or rock.]

If a solid substance is in every way like another solid substance, [not only in its external appearance, but also in the inner arrangement of parts and particles], it will also be like it in the manner and place of production...

35 The strata of the earth, in place and manner of production, are very similar to the strata which can be found wherever muddy water settles in layers.

Bodies dug from the earth, and which are in every way like the parts of plants and animals, were produced in precisely the same manner and place as the parts of the plants and the animals were themselves produced...

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<sup>1</sup> *Nicolaus Steno* (1638-1686): Danish scientist. He published *The Prodromus* in 1669; he intended it as a preliminary work, as its full title reveals: *A preliminary discourse [Prodromus] on a solid body contained naturally within a solid*. The planned later work never appeared. This 1914 translation by John Garrett Winter has been extensively edited by LG.

## 2. Robert Hooke, *Micrographia* (1665).<sup>2</sup>

### Observation XVII: *Of Petrified wood and other Petrified bodies.*

Of this sort of substance, I observed several pieces of very differing kinds... That which I more particular examin'd, was a piece about the bigness of a man's hand, which seemed to have been a part of some large tree, that by rottenness had been broken off from it before it began to be petrified... This *Petrified* substance resembled Wood, in that:

45 First, all the parts of it seemed not at all *dislocated*, or altered from their natural Position, whilst they were Wood, but the whole piece retained the exact shape of Wood, having many of the conspicuous pores of wood still remaining pores, and showing a manifest difference visible enough between the grain of the Wood and that of the bark...

Next..., in that all the smaller and ... *Microscopical* pores of it appear (both when the substance is cut and polished *transversely* and *parallel* to the pores of it) perfectly like the *Microscopical* pores of several kinds of Wood, especially like and equal to those of several sorts of rotten Wood which I have since observed...

It was differing from Wood:

55 First; in *weight*, being to common water as  $3\frac{1}{4}$  to 1, whereas there are few of our *English* Woods, that when very dry are found to be full as heavy as water.

Secondly, in *hardness*, being very near as hard as a Flint; and in some places of it also resembling the grain of a Flint: and, like it, it would very readily cut Glass, and would not without difficulty, especially in some parts of it, be scratched by a black hard Flint. It would also as readily strike fire against a Steel or Flint, as any common Flint.

60 Thirdly, in the *closeness* of it, for though all the *Microscopical* pores of this *petrified* substance were very conspicuous in one position, yet by altering that position of the polished surface to the light, [one could see that the pores were not hollow].

Fourthly, in its *incombustibleness*, in that it would not burn in the fire; nay, though I kept it a good while red-hot in the flame of a Lamp, made very *intense* by the blast of a small Pipe, and a large Charcoal, yet it seemed not at all to have diminished its extension; but only I found it to have changed its color, and to appear of a more dark and dusky brown color...

55 Fifthly, in its *dissolubleness*; for putting some drops of distilled *Vinegar* upon the Stone, I found it presently to yield very many Bubbles, just like those which may be observed in spirit of *Vinegar* when it corrodes *corals*, though perhaps many of those small Bubbles might proceed from some small parcels of Air... driven out of the pores...

60 Sixthly, in its *rigidness*, and *friability*, being not at all flexible but brittle like a Flint, insomuch that I could with one knock of a Hammer break off a piece of it, and with a few more, reduce that into a pretty fine powder.

75 Seventhly, it seemed also very differing from Wood to the *touch, feeling* colder then Wood usually does, and much like other close stones and Minerals.

The Reasons of all which *Phenomena* seem to be:

80 That *petrified* Wood having lain in some place where it was well soaked with *petrifying* water (that is, such a water as is well *impregnated* with stony and earthy particles) [gradually somehow separated] stony particles from the permeating water, which stony particles, being by means of the fluid vehicle *conveyed*, not only into the *Microscopical* pores... but also into the pores or *interstitia*... [They] thereby so augment the weight of the Wood, as to make it above three times heavier then water, and perhaps, six times as heavy as it was when Wood.

Next, they thereby so lock up and fetter the parts of the Wood, that the fire cannot easily make them fly away...

85 By this *intrusion* of the *petrifying* particles, this substance also becomes hard and *friable*; for the smaller pores of the Wood being perfectly wedged, and stuffed up with those stony

<sup>2</sup> Robert Hooke (1635-1703): British scientist with omnivorous interests and talents. Find the original of this text at <http://www.gutenberg.org/dirs/1/5/4/9/15491/15491-8.txt>

particles, the small parts of the Wood have no places or pores into which they may slide upon bending, and consequently little or no flexion or yielding at all can be caused in such a substance...

90 Nor is Wood the only substance that may by this kind of *transmutation* be changed into stone; for I myself have seen and examined very many kinds of substances, and among very credible Authors, we may [read about them]...

[I will] set down some Observation I lately made on several kind of *petrified* Shells... commonly called *Serpentine-stones*. Examining several of these very curiously figured bodies (which are commonly thought to be Stones formed by some extraordinary *Plastick* virtue *latent* in the Earth itself), I took notice of these particulars... [Ed.: *Hooke's investigation is deleted; his conclusions follow.*]

100 ...I cannot but think, that all these, and most other kinds of stony bodies which are found thus strangely figured, do owe their formation and figuration, not to any kind of *Plastick* virtue inherent in the earth, but to the Shells of certain Shell-fishes, which, either by some Deluge, Inundation, Earthquake, or some such other means, came to be thrown to that place, and there to be filled with some kind of Mud or Clay, or *petrifying* Water, or some other substance, which in tract of time has been settled together and hardened in those shelly moulds into those shaped substances we now find them... that these Shells... have in tract of time rotted and moldered  
105 away, and only left their impressions, both on the containing and contained substances... That others of these Shells, according to the nature of the substances adjacent to them, have, by a long continuance in that posture, been *petrified* and turned into the nature of stone...

And he that shall thoroughly examine several kinds of such curiously formed stones, [will reach the same conclusions]. For it seems to me quite contrary to the infinite prudence of Nature, which is observable in all its works and productions, to design every thing to a determinate end...  
110 that these prettily shaped bodies should have all those curious Figures and contrivances... generated or wrought by a *Plastick* virtue, for no higher end, then only to exhibit such a form... It were therefore very desirable that a good collection of such kind of figured stones were collected; and as many particulars, circumstances, and informations collected with them as could be  
115 obtained, that from such a History of Observations well [arranged], examined and digested, the true original or production of all those kinds of stones might be perfectly and surely known...

### 3. Thomas Burnet, *The Theory of the Earth*<sup>3</sup>

#### BOOK I: Concerning the Deluge, and the Dissolution of the Earth.

##### CHAPTER I. Introduction

... We have... designed in this Work to give an account of the Original of the Earth, and of all the great and general changes that it hath already undergone, or is hence forwards to undergo, till the Consummation of all things. For if from those Principles we have here taken, and  
120 that Theory we have begun in these two first Books, we can deduce with success and clearness the Origin of the Earth, and those States of it that are already past; Following the same Thread, and by the conduct of the same Theory, we will pursue its Fate and History through future Ages, and mark all the great Changes and Conversions that attend it while Day and Night shall last; that is, so long as it continues an Earth.

125 By the States of the Earth that are already past, we understand chiefly Paradise and the Deluge; Names well known, and as little known in their Nature. By the Future States we understand the Conflagration, and what new Order of Nature may follow upon that, till the whole Circle of Time and Providence be completed. As to the first and past States of the Earth, we shall have little help from the Ancients, or from any of the Philosophers, for the discovery or  
130 description of them; We must often tread unbeaten paths, and make a way where we do not find

<sup>3</sup> Thomas Burnet (1635?-1715): royal chaplain to William III of England, and author of this landmark work in geology. Find the original at <http://www.uwmc.uwc.edu/geography/burnet/burnet.htm>

one; but it shall be always with a Light in our hand, that we may see our steps, and that those that follow us may not follow us blindly. ...

‘Tis the Sacred writings of Scripture that are the best monuments of Antiquity, and to those we are chiefly beholden for the History of the first Ages, whether Natural History or

135 Civil...there may be providentially conserved in them the memory of things and times so remote, as could not be retrieved, either by History, or by the light of Nature; and yet were of great importance to be known...Such points may be, Our great Epochs or the Age of the Earth, The Origination of mankind, The first and Paradisiacal state, The destruction of the Old World by an universal Deluge, The longevity of its inhabitants, The manner of their preservation, and of their  
140 peopling the Second Earth; and lastly, The Fate and Changes it is to undergo. These I always looked upon as the Seeds of great knowledge, or heads of Theories fixed on purpose to give us aim and direction how to pursue the rest that depend upon them. But these heads, you see, are of a mixed order, and we propose to our selves in this Work only such as belong to the Natural World; upon which I believe the trains of Providence are generally laid; And we must first consider how  
145 God hath ordered Nature, and then how the Economy of the Intellectual World is adapted to it; for of these two parts consists the full System of Providence. In the mean time, what subject can be more worthy the thoughts of any serious person, than to view and consider the Rise and Fall, and all the Revolutions, not of a Monarchy or an Empire, of the Grecian or Roman State, but of an entire World.

150 The obscurity of these things, and their remoteness from common knowledge will be made an argument by some, why we should not undertake them; And by others, it may be, the very same thing will be made an argument why we should; for my part I think There is nothing so secret that shall not be brought to Light, within the compass of Our World; for we are not to understand that of the whole Universe, nor of all Eternity, our capacities do not extend so far; But  
155 whatsoever concerns this Sublunary World in the whole extent of its duration, from the Chaos to the last period, this I believe Providence hath made us capable to understand, and will in its due time make it known. ...

...There is no Chase so pleasant, methinks, as to drive a Thought, by good conduct, from one end of the World to the other; and never to lose sight of it till it fall into Eternity, where all  
160 things are lost as to our knowledge.

This Theory being chiefly Philosophical, Reason is to be our first Guide; and where that falls short, or any other just occasion offers itself, we may receive further light and confirmation from the Sacred writings. Both these are to be looked upon as of Divine Original. God is the Author of both; He that made the Scripture made also our Faculties, and ’twere a reflection upon  
165 the Divine Veracity, for the one or the other to be false when rightly used. We must therefore be careful and tender of opposing these to one another, because that is, in effect, to oppose God to himself...

**4. Secondary source:** from “The Metaphor and the Rock,” a review by Frank J. Sulloway<sup>4</sup> of Stephen Jay Gould’s *Time’s Arrow, Time’s Cycle* (1987)

a. The Discovery of Deep Time.

Geological time is so immense compared with the human experience of time that we can only hope to grasp it dimly through analogies. “Consider the earth’s history,” Gould suggests, “as  
170 the old measure of the English yard, the distance from the king’s nose to the tip of his outstretched hand. One stroke of a nail file on his middle finger erases human history.” This discovery of “deep time,” which involved abandoning Biblical standards of time for nearly incomprehensible eons, Gould ranks with the monumental intellectual revolutions associated with Copernicus and Darwin. He has picked three major figures in the history of geology, one

<sup>4</sup> [http://www.stephenjaygould.org/reviews/sulloway\\_sjgould.html](http://www.stephenjaygould.org/reviews/sulloway_sjgould.html)

175 traditional villain (Thomas Burnet) and two traditional heroes (James Hutton and Charles Lyell),  
to illustrate the nature of this discovery.

Standard textbook accounts of the achievements of these three figures have long provided what Gould describes as a “self-serving mythology.” These flimsy “cardboard” accounts vaunt the superiority of empiricism and inductivism over the scientific nemesis of religious bigotry.

180 *According to the textbooks*, geology remained in the service of the Mosaic story of creation as long as armchair geological theorists refused to place fieldwork ahead of scriptural authority. Thomas Burnet, author of the *Sacred Theory of the Earth* (1681–1689), was just such an archetypal spokesman for religious interests. A century later the Scottish geologist James Hutton finally broke with this biblical zealotry by arguing that geological evidence must rest upon a solid empirical foundation... [Thus the textbooks argue.]

185 Other historians of geology, Gould acknowledges, have refuted this textbook mythology, and he claims no originality in this respect. But he does believe that the real sources of inspiration in the discovery of deep time have not been properly understood. It is this aspect of the story that he sets out to rectify, and he does so with imagination and flair. In this respect Gould should be seen as part of the generation of historians who have been affected by T.S. Kuhn’s *Structure of Scientific Revolutions* (1962). Kuhn argued, in part, that science is a social activity and that theories are intellectual constructions imposed on data, not demanded by them. The views of Kuhn and other philosophers and sociologists of science have helped historians of science to recognize, as Gould emphatically does, that mental constructs (metaphors, analogies, personal philosophies, imaginative leaps)—not empirical discoveries—are what bring about scientific advance. “Facts” are so embedded in theory that they simply do not have the kind of independent probative power they were once supposed to possess.

190 Thus what underlies the discovery of deep time is by no means fieldwork, as the myths of geology textbooks would have us believe. Rather, Gould pinpoints a powerful pair of metaphors—time’s arrow and time’s cycle—by which humankind has always tried to grasp the concept of time. Time’s arrow captures the uniqueness and distinctive character of sequential events, whereas time’s cycle provides these events with another kind of meaning by evoking lawfulness and predictability. Gould notes that this metaphorical pair is common not only in the thinking of ancient and preliterate peoples but also in the Judeo-Christian tradition, in which time’s arrow nevertheless began to predominate. More importantly, this metaphorical pair of ideas was essential to the thinking of Gould’s three geological protagonists; and the paired concepts therefore offer the key, now obscured by textbook mythology, to unlocking their thinking about time.

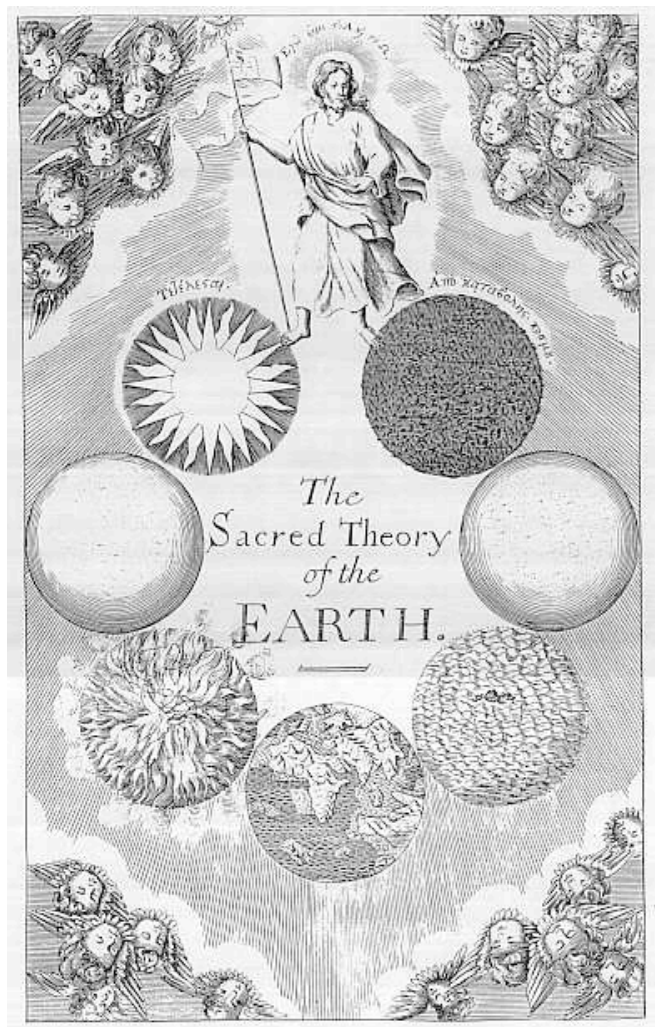
#### b. Burnet and Newton.

210 The frontispiece to Thomas Burnet’s *Sacred Theory of the Earth* [see next page] embodies the essence of his argument. Christ, at the top, has his left foot on the earth as it was in the beginning of the creation (“without form and void”). Earth history moves clockwise, recording the perfect (featureless) earth of Eden, the Flood (with Noah’s ark floating just above the center), the present state of the earth, the coming conflagration that shall consume and purify the earth once more, and finally the earth transformed into a star after the righteous have ascended to heaven. Above Christ is the inscription from the Book of Revelation, “I am the alpha and omega,” that is, the beginning and the end. (See illustration on next page.)

215 Burnet’s theory illustrates the metaphors of time’s arrow and time’s cycle in unmistakable form. His is a one-cycle theory in which biblical narrative (time’s arrow) runs its course within a wider conception of “the great year” and “great circle of time and fate” that bring about the return of Paradise. It is precisely this literal belief in Scripture that has made Burnet a pariah in the history of geology. Yet Burnet, Gould demonstrates, was hardly the religious fanatic he is supposed to have been when he is placed within the context of contemporary scientific thought. Compared with the textbook legend, Burnet was, ironically, **adamant about explaining the history of the earth as recorded in Scriptures entirely within the frame of natural science,**

225 devoid of all appeals to miracles or divine intervention. Whereas his contemporaries had to call  
 upon God to create new and vast sources of water for the Flood, for example, Burnet tried to  
 avoid such external interventions by positing an underground source of water released onto the  
 earth's surface through a fault in the crust. Similarly, Burnet believed that Vesuvius and Etna  
 230 would provide the sources of fire that would ultimately consume and purify the world prior to the  
 second coming of Christ.

In a revealing exchange, Burnet in 1681 argued with Isaac Newton over the length of the  
 original "days" of creation. Newton saw a way out of the difficulty of assuming God had made  
 the world in a week. He believed that the "days" of Genesis might have been much longer than  
 present ones, and that God, when the job was finally done, intervened in order to speed up the  
 235 earth's rotation. Burnet regarded such a theory as totally unacceptable precisely because it  
 required divine intervention. Thus the "bad guy" of geological textbook history was actually more  
 devoted to rational, miracle-free science than was the greatest scientist of his age.



<sup>5</sup> This image can be found at <http://www.uwmc.uwc.edu/geography/burnet/burnet.htm>. See the full text of Burnet's work at <http://www.sacred-texts.com/earth/ste/index.htm>