# Chapter 10

## The General Spread of the Light of Science

### Evaluating Jefferson as a scientist

> With manners apparently popular and informal, [Jefferson] led a life of his own, and allowed few persons to share it…. The rawness of political life was an incessant torture to him, and personal attacks made him keenly unhappy. His true delight was in an intellectual life of science and art…. He had some knowledge of mathematics, and a little acquaintance with classical art; but he fairly revelled in what he believed to be beautiful… Prone to innovation, he sometimes generalized without careful analysis. He was a theorist, prepared to risk the fate of mankind on the chance of reasoning far from certain in its details. His temperament was sunny and sanguine, and the atrabilious philosophy of New England was foreign to him… He was superficial in his knowledge, and a martyr to the disease of omniscience (Adams 1930: I: 144-6)

Henry Adams, author of that waspish but incisive assessment, was the great-grandson of John Adams, whose atrabilious views of the Enlightenment may have passed down the male line (Haraszti 1952; Spahn 2012). However incisive on Jefferson's unworldliness, Adams seriously underestimated his science.

Jefferson was an outstanding scientist for his time and place, even though his achievements are easily masked by some passages of naked prejudice unsupported by observation. He consistently called what he did 'science', although the Anglophone scientists whom he read still used the archaic term 'natural philosophy' (The senior physics professorships at Glasgow and Edinburgh Universities, endowed in the 18$^{th}$ century, are still called Chairs of Natural Philosophy).

Jefferson’s heroes Sir Francis Bacon and Sir Isaac Newton were his models for inductive and deductive science, respectively. Inductive science builds from observation to generalizable statements. Deductive science starts with pure mathematics and draws valid inferences, which can sometimes be put into practice. Jefferson tried his hand at both. This section considers Jefferson’s work in three areas: taxonomy; natural history; and applied mathematics.

## Taxonomy

Taxonomy is the science of classification. In biology, it involves a hierarchy of classes, from kingdoms at the most general level (e.g., animals, plants, and fungi) down through increasingly specialized divisions to genus and species. In 1735 the Swedish scientist Carl Linnaeus first proposed the binomial nomenclature that has become universal, where the first name (with a capital letter) denotes the genus and the second (all lower-case) denotes the species within that genus. Thus Homo sapiens is one of several distinct species within the genus Homo.

Jefferson had fully absorbed the Linnean system by the time he started to prepare his Notes on Virginia. Most readers probably skip the long lists of plants and birds in Query VI of the Notes, but they are important. They show that Jefferson understood the need for the Linnean system of unique identifiers for each species, especially when North American species (of either plants or animals) are often quite different to European species of the same popular name. His reasons for adopting Linnean notation are interesting, and lead directly to his next innovation in taxonomy: the taxonomy of books.  He wrote:

> his system was accordingly adopted by all, and united all in a general language. it offered the three great desiderata 1. of aiding the memory to retain a knolege of the productions of nature. 2. of rallying all to the same names for the same objects, so that they could

> communicate understandingly on them. and 3. of enabling them, when a subject was first presented, to trace it by it's characters up to the conventional name by which it was agreed to be called…. [I] adhere to the Linnean because it is sufficient as a groundwork; admits of supplementary insertions, as new productions are discovered, and mainly because it has got into so general use that it will not be easy to displace it (TJ to John Manners, Feb. 22 1814, in *PTJ: RS* 7: 207-10.

Jefferson's taxonomy of knowledge has indeed 'got into so general use that it will not be easy to displace it'. He took a scheme that he found in Bacon and adapted it in a way that has become (though few people probably realize it) the basis of every library catalogue in the world. As Jefferson put it at the head of his biggest library catalogue:

> BOOKS may be classed according to the faculties of the mind employed on them: these are –
>
> I. MEMORY II. REASON III. IMAGINATION
>
> Which are applied respectively to –
>
> I. HISTORY. II. PHILOSOPHY. III. FINE ARTS

Just like Linnaeus, he went on to subdivide his three kingdoms. History, for instance, divides first into Civil and Natural. Civil History then subdivides into Civil Proper and Ecclesiastical. Natural History subdivides into Physics, Natural History Proper, and Occupations of Man. At the species level, the kingdom of History finally becomes 15 chapters of knowledge, from Antient History to Technical Arts. Philosophy divides into Moral and Mathematical, and thence into fourteen chapters from Moral Philosophy to Geography. Fine Arts (the easiest for a modern reader to understand) divides into fourteen chapters from Architecture to Languages. Jefferson then adds a final chapter, Polygraphical, for 'Authors who have written on various branches'. This scheme appears in the first printed *Catalogue of the Library of the United States* in 1815 (facsimile in Gilreath and Wilson 1989: ix). It had evolved from Bacon's classification of knowledge, and Jefferson refined it in his successive manuscript library catalogues.

The location of some of his chapters surprises the modern reader:

> To pursue these questions is to confront Jefferson's world…. History … was composed of all known facts about the physical universe. This universe consisted of what could be learned about human activity through time (Civil History) and what had been discovered about the nature of plants, animals, and minerals (Natural History)…. If History dealt with the known world, Philosophy was concerned with the laws that governed those facts – the Moral for human affairs and the Mathematical for the forces of nature (Gilreath and Wilson 1989: 3).

In other words, History was the basis of inductive (Baconian) knowledge, while Philosophy was the basis of deductive (Newtonian) knowledge. And of course for Jefferson the architect, wine-lover, and musician, the Fine Arts were just as important.

Within each of his 44 chapters, Jefferson arranged the books in an order which he called 'sometimes analytical, sometimes chronological, & sometimes a combination of both' (TJ to George Watterston Mar. 2 1816, in *PTJ: RS* 9: 532). He explained his cataloguing principles:

> I have preferred arrangement according to subject; because of the peculiar satisfaction, when we wish to consider a particular one, of seeing at a glance the books which have been written on it, and selecting those from which we expect most readily the information we seek. on this principle the arrangement of my library was formed, Of the

> Advancement and Proficiencie of Learning: or the Partitions of Sciences and I took the basis of it's distribution from Ld Bacon's table of science, modifying it to the changes in scientific pursuits which have taken place since his time, and to the greater or less extent of reading in the several sciences which I proposed to myself…

He went on to explain that because he was a specialist in law and politics, he required more subdivisions in those subjects, whereas "a physician or theologist would have modified differently the chapters sections and paragraphs of a library adapted to their particular pursuits".

The final element of his scheme was that:

> I have generally, but not always, collocated distinctly the folios, 4tos 8vos & 12mos placing with the last all smaller sizes. on every book is a label, indicating the chapter of the catalogue to which it belongs, and the order it holds among those of the same format. so that, altho' the Nos seem confused on the catalogue, they are consecutive on the volumes as they stand on their shelves & indicate at once the place they occupy there. (All quotations in this paragraph are from TJ to George Watterston, May 7 1815. *PTJ: RS* 8: 473-4).

To Jefferson's great annoyance (although, typically, he concealed his anger from Watterston), the latter ignored the analytical/chronological arrangement of the books in Jefferson's catalogue. Only its reconstruction in the Trist catalogue, and its discovery and publication by Gilreath and Wilson (1989), enables us to see Jefferson's Baconian taxonomy as he intended. For instance the Ethics chapter begins, chronologically, with the Greeks, but then goes analytically from the more general to the more particular. A set of books on slavery, including Condorcet's, comes right at the end, befitting the discussion of the ethics of a particularly difficult issue (Gilreath and Wilson 1989: 52-56).

Jefferson's scheme has all the essential features of the two main library classification systems in use world-wide, one of them instituted by the Library of Congress itself and the other the Dewey Decimal system. The Library of Congress (LC) system superseded the Jefferson system, beginning in 1897, but using the same principle of infinitely expandable subject divisions (Library of Congress 2020). The rival system was proposed in 1876 by Melvil Dewey, librarian at Amherst College. A Wikipedia entry, current on Nov. 17 2023, states that "One of the innovations of the Dewey Decimal system was that of positioning books on the shelves in relation to other books on similar topics". That shows why nobody should ever trust Wikipedia as a source. The innovation is clearly set out in Jefferson's letters to Watterston, half a century earlier.

Another important aspect of Jefferson's fascination with taxonomy was his work on weights and measures, which led to a politico-scientific dispute with Condorcet. Jefferson had long been fascinated by the idea of a uniform system of measurement, and it must have been much pleasanter for him than his monumental fight with Alexander Hamilton to have been asked as Secretary of State to report to Congress on unification of measures. The fundamental need was for a basis for all measurements that would be invariable throughout the world, irrespective of temperature, air pressure, latitude, longitude, or any other confounding factor. Jefferson knew that his hero Sir Isaac Newton had proposed that the invariable basis should be the length of a pendulum oscillating once per second at a given latitude. In the first draft of his report to Congress he proposed that the fundamental unit of length should be derived from "'the Double length of a rod or Treble length of a Pendulum vibrating seconds". This would then define a new decimal set of lengths – an inch, a foot of ten inches, and so on up to a mile of 10,000 inches. Measures of area and volume would then be, respectively, squares and cubes of these units. The volumetric measures, based on the cubic inch, would be named after the measures actually used, to standardize them. So, for instance, a cubic foot (= 1000 cubic inches) would define the units 'bushel' and 'firkin', which at the time denoted different volumes in different places. For the fundamental unit of mass, "Let Rain water, as the most homogeneous substance, be referred to as the standard for weights, and a cubic [inch] of that be called an Ounce". On the same decimal basis, ten ounces would make a pound, ten pounds a stone, and 100 stone a Demi-Tun. The system would extend to currency by fixing the dollar as a set weight of silver. (All quotations and numbers in this paragraph are from "First State of the Report on Weights and Measures", [Apr. 1790] in *PTJ* 16: 624-7).

The system would have had huge benefits to science and to commerce. Jefferson's final report tweaked the science. He had realized that the pendulum would be too much subject to heat expansion or contraction and to air pressure variation, so he now proposed a vibrating cylindrical rod, kept in a cellar to minimize expansion and contraction, at latitude 45 degrees North. The last was a concession to Condorcet, who was working on the same subject in France, and who had pointed out that the truest measure would be at latitude half way between the equator and the pole. However, Jefferson had also realized that there was pushback against his decimalization scheme, and he offered Congress two options, the first of which was merely to tidy up and standardize the existing non-decimal measures. He then re-proposed his decimal system as before, proposing to deal with the pushback as follows:

> After a given term, for instance, it might begin in the Custom houses, where the merchants would become familiarised to it. After a further term, it might be introduced into all legal proceedings, and merchants, and traders in foreign commodities, might be required to use it in their dealings with one another. After a still further term, all other descriptions of people might recieve it into common use.—Too long a postponement on the other hand, would increase the difficulties of it's reception, with the increase of our population. ("Final State of the Report on Weights and Measures", [Jul. 4 1790]. In *PTJ* 16: 650-673, quoted at p. 665):

In parallel with Jefferson, Condorcet and colleagues at the Academy of Science were working on a comparable scheme. As already noted, on getting news of the Condorcet plan Jefferson adapted his in one respect, by substituting 45 degrees for his previously proposed reference latitude of 38 degrees.

In July 1791 he received – and fluently translated – Condorcet's report. Having discussed the pros and cons of the pendulum standard, Condorcet's committee preferred a division of a meridian of longitude that passed through 45 deg. Latitude. A convenient one was

> an arc of the meridian from Dunkirk to Barcelona, comprising … more than nine degrees and an half…. The choice of the forty fifth degree of Latitude was not determined by the position of France, it is not here considered as a fixed point of the meridian, but only as that to which the mean length of the pendulum, and the mean length of a given division of that circle correspond: in fine we have chosen the only meridian wherein an arc can be found terminating at both it's extremities at the level of the ocean, and cut by the mean parallel without being of too great extent, which would render it's actual mensuration too

> difficult. There is nothing here then which may give the smallest pretence for reproaching us with an affectation of pre-eminence. (Borda, Condorcet, Laplace, Lagrange and Monge, Report to the Academy of Sciences on a Unit of Measure, March 1791, translated by TJ. *PTJ* 20: 354-60).

Jefferson's reaction was sharp:

> Candor obliges me to confess that it is not what I would have approved. It is liable to the inexactitude of mensuration as to that part of the quadrant of the earth which is to be measured, that is to say as to one tenth of the quadrant, and as to the remaining nine tenths they are to be calculated on conjectural data, presuming the figure of the earth which has not yet been proved. It is liable too to the objection that no nation but your own can come at it; because yours is the only nation within which a meridian can be found of such extent crossing the 45th. degree and terminating at both ends in a level. (TJ to Condorcet, Aug. 30 1791. *PTJ* 22: 98).

Jefferson and Condorcet were far from the only scientists working on uniformity of weights and measures. Jefferson was largely working on his own, with help from the indefatigable (but not particularly mathematical) James Madison. Condorcet's committee included both of the other most eminent mathematicians of his day, P.-S de Laplace and J.-L. Lagrange. As anybody realizes who buys a quart of milk or a gallon of gasoline in the USA, Jefferson failed where Condorcet posthumously succeeded. In 1799, France adopted a metric system with the base units of a meter and a kilogram, with the latter defined, similarly to Jefferson's proposal, as the mass of a liter of water. The system gradually expanded to include other base and derived units, and is now used universally by scientists (but not by the American lay public, nor, sufficiently, by rocket scientists) as *SI* (Système International). Jefferson's and Condorcet's shared dream has been realized.

Another work of taxonomy is Jefferson's *Manual of Parliamentary Practice* (Jefferson 1837; Howells 1988). .It drew on a manuscript *Parliamentary Pocket-book* that he had been working on since his commonplacing days as a student in Williamsburg. This is really a fourth commonplace book to add to his Literary, Legal, and Equity Commonplace books and has been at the Massachusetts Historical Society since 1898 (Howells 1988: 41). Jefferson observed the need for a taxonomy of parliamentary rules from early in his career. Writing to his childhood friend John Page in 1766, he reported on a visit to the Maryland legislature in Annapolis:

> The first object which struck me after my entrance was the figure of a little old man dressed but indifferently, with a yellow queüe wig on, and mounted in the judge's chair. This the gentleman who walked with me informed me was the speaker…. At one end of the justices' bench stood a man …, reading a bill then before the house with a schoolboy tone and an abrupt pause at every half dozen words. This I found to be the clerk of the assembly. The mob (for such was their appearance) sat covered on the justices' and lawyers' benches, and were divided into little clubs amusing themselves in the common chit chat way. I was surprised to see them address the speaker without rising from their seats, and three, four, and five at a time without being checked. When [a motion was] made, the speaker instead of putting the question in the usual form only asked the

> gentlemen whether they chose that such or such a thing should be done, and the rules and precedents governing the proceedings of deliberative assemblies and other organizations be divided, they never would go to the trouble of dividing the house, but the clerk entered the resolutions, I supposed, as he thought proper. In short every thing seems to be carried without the house in general's knowing what was proposed (TJ to John Page, May 25 1766. *PTJ* 1: 19-20. Words in square brackets supplied by editors of *PTJ*).

Jefferson's concern for parliamentary order never left him. When serving as Vice-President from 1797 to 1801, he decided that he needed to work his manuscript notes up for publication. The result was his *Manual*, first published in 1801, and republished with Jefferson's revisions in 1812. I use an edition easily available online, and the modern scholarly edition (Jefferson 1837; Howells 1988).

The first surprise comes in Jefferson's preface. He explains that his manual is based on the rules for proceedings in the UK Parliament, because

> [i]ts rules are probably as wisely constructed for governing the debates of a considerative body, and obtaining its true sense, as any which can become known to us[.] (Jefferson 1837: iv-v)

So influential has Jefferson been in this regard, that the very meaning of the word 'parliamentary' and its cognates has diverged between British and American English. In British English, the primary meaning of the word, attested from 1616, is "Enacted, ratified, or established by Parliament or a parliament" (*OED* online, consulted Feb. 4 2024). The American English usage of *parliamentary law* to mean "the rules and precedents governing the proceedings of deliberative assemblies and other organizations" (Merriam-Webster, consulted Feb. 4 2024) is unknown to speakers of British English, to whom titles like Senate Parliamentarian ("an expert in the rules and usages of a deliberative assembly (such as a parliament)" - Merriam-Webster) are mysterious. Thus Jefferson, who detested the British system of government, and detested Hamilton for his supposed reverence for it, so admired British parliamentary procedure that he changed the meaning of a word.

The *Manual*, then, has its origins early in Jefferson's career, and its rehearsal of English precedent fits in the first of his three Baconian categories, 'Memory'. But Jefferson brought 'Reason' to this taxonomic task as well. The first scholar to draw attention to the Condorcet-Jefferson connection in the context of parliamentary rules was a law professor at Mr Jefferson's university, Saul Levmore (Levmore 1989). He begins with *Robert's Rules of Order* (Robert 1971). This is the established 'parliamentary' text in the USA in the sense initiated by Jefferson. In other words, all sorts of bodies use it to draw up their own rules of procedures. It is culturally predominant. In the UK, a similar role was once played by Walter Citrine, a former general secretary of the Trades Union Congress, (Citrine 1982), but its cultural prominence has faded. *Robert's Rules* in turn drew heavily on Jefferson's Manual, and so the shadow of Jefferson still looms large in American parliamentarism.

All parliamentarians including Jefferson and Robert, stress that deliberative procedures must be *binary*. At any one time there is one motion before the house, which faces an up-and-down vote.

It may be amended, and both Jefferson and Robert lay out sequencing rules for voting on amendments, amendments to amendments; motions that the motion be now put, motions that the motion be tabled (not put), and so on. Binary procedures always produce a clear result. Do they guarantee that the majority will is carried out? No, because of the omnipresent possibility of the cycling that Condorcet discovered. A manipulator of parliamentary procedure can, for instance, arrange for the motions to be put in such an order that the cycle stops where the manipulator wants it. Riker (1986) gives a number of examples. Some of them have been challenged, e.g., by Mackie 2003, but some survive unscathed.

Given Jefferson's closeness to Condorcet, how aware was he of cycling and paradox, and is that reflected in the text of the *Manual*? Levmore (1989) does not speculate, but McLean and Urken (1992) tested the hypothesis by various searches, including in Jefferson's own copy of the first (1801) edition of the *Manual* which he marked up for his revisions to the second edition. We had to conclude that we found no positive evidence that Jefferson understood cycling, either from his annotations or for the way he structured his proposed sequencing of binary motions. Others (notably Schofield 2006) nevertheless continued to argue that Jefferson, or Madison, or both, understood the single most revolutionary discovery in eighteenth-century social science.

## Natural History

The indirect invitation from Marbois, an associate of Buffon, to compile *Notes on Virginia* gave Jefferson the opportunity to contest Buffon's natural history at length. As described elsewhere in this book, Buffon and his school believed that the North American climate caused species to degenerate, becoming smaller and weaker. Although Buffon himself never applied this claim to Homo sapiens, some of his followers did. In riposte, Jefferson was as good an observational scientist as his mentor Bacon, who reportedly died of a chill caught from seeing if stuffing a hen with snow would preserve it (an anecdote told by Thomas Hobbes, a friend of Bacon, to the gossip John Aubrey: Aubrey 1898: 299-300). To confute Buffon, Jefferson went to extraordinary efforts to get a moose skeleton shipped to Buffon in Paris. The story is set out in his letters and told entertainingly by Dugatkin 2009.

We have already discussed the relationship between Jefferson and Buffon (above, Chapter 6). This section discusses the quality of Jefferson's scientific work as a natural historian and anthropologist. In geology, he accepted the view of Buffon and French naturalists that, whatever the origin of fossils, they did not come from Noah's ark. The *Notes* contain some geological observations but nothing systematic. Notably, his rapture for the Natural Bridge, a property he owned in today's Rockbridge County, comes over all Romantic and overblown rather than much of an attempt to explain how the formation might have occurred. It is hard to blame Jefferson for this. Modern geology began with the Scottish Enlightenment scientist James Hutton, who after many years' thought finally published his *Theory of the Earth* in 1788. Jefferson did not own a copy. Nor, to state the blindingly obvious, was he familiar with Darwinian evolution (Darwin 1859), nor Mendelian genetics (Mendel 1865), nor plate tectonics (Wegener 1912).

In natural history, as already noted, Jefferson understood and used the Linnean classification system, and persuasively argued for it (TJ to Dr John Manners, Feb. 22 1814: *PTJ: RS 7:* 207-211). He was a field naturalist on his own account and eagerly collected the discoveries of others. He was a highly active President of the American Philosophical Society (a post to which he seems to have devoted more energy than the vice-presidency of the United States). He chaired a committee inviting naturalists to submit their discoveries of, *inter alia*, mammoth skeletons, Native American tumuli, and morphological changes in mountains, encouraging them to look in particular at the Great Salt Lick in Ohio (Jefferson 1799a). He deposited the bones of a prehistoric sloth, found in present-day West Virginia, with the Society (Jefferson 1799b; Wistar 1799). This has become the type specimen of the species named *Megalonyx jeffersonii* in 1822. Jefferson the classicist himself coined the name *Megalonyx* (Greek, ‘great claw’).

Many aspects of Jefferson’s life are completely outside the scope of this book. These include his opportunistic doubling of the size of the USA, while President, through the Louisiana Purchase from France in 1803, of the land west of the Mississippi then claimed by France (viz., the whole of present-day Louisiana, Arkansas, Missouri, Kansas, Iowa, South Dakota, and Oklahoma, plus parts of Texas, Minnesota, North Dakota, Montana, Wyoming, Colorado, and New Mexico). The purchase involved several of Jefferson’s French contacts, including his friend Dupont de Nemours, and the same Marbois who had commissioned the *Notes*, who was by 1803 Napoleon’s finance minister.

What is relevant to this book is the scientific opportunities the Purchase provided. Jefferson commissioned Meriwether Lewis and William Clark to explore the NW of the new territory by going up the Missouri until they found a west-flowing river that would debouch into the Pacific. Remarkably, they succeeded, losing only one member of their Corps of Discovery (to appendicitis). They departed from near St Louis in May 1804, reached the Pacific at the mouth of the Columbia River in November 1805, and arrived back in St Louis in September 1806 (Lewis and Clark 1814).

The expedition had been long in planning, going back to Jefferson’s Paris days. His scientific commission is noteworthy. The Corps of Discovery was to report on:

> the soil & face of the country, its growth & vegetable productions … the mineral productions of every kind; but more particularly metals, limestone, pit coal, & saltpeter; salines & mineral waters, noting the temperature of the last, & such circumstances as may indicate their character; volcanic appearances; … climate, as characterized by … the proportion of rainy, cloudy, & clear days, by lightning, hail, snow, ice, by the access & recess of frost, by the winds prevailing at different seasons, the dates at which particular plants put forth or lose their flower, or leaf, times of appearance of particular birds, reptiles or insects. TJ to Meriwether Lewis Jun 20 1803. In *PTJ* 40: 176-181.

All of which they did, in a tribute to three remarkable naturalists: Jefferson, Lewis, and Clark.

As already noted, Jefferson's attitude to Native Americans was curiosity-driven and mostly respectful. Not so his attitude to Blacks. Look again at the most difficult passage in *Notes.*

> Whether the black of the negro resides in the reticular membrane between the skin and scarf-skin, or in the scarf-skin itself; whether it proceeds from the colour of the blood, the colour of the bile, or from that of some other secretion, the difference is fixed in nature, and is as real as if its seat and cause were better known to us…. their own judgment in favour of the whites, [is] declared by their preference of them, as uniformly as is the preference of the Oran-ootan for the black women over those of his own species *(Notes on Virginia,* Query XIV, see Documentary Appendix)

Jefferson had seen Black blood. How can he have believed that it might be a different color to White blood? As to Oran-ootans, a first point for clarification is that in Jefferson's time the name was applied to all apes and monkeys. One may regard the fascination of the Enlightenment with the closeness of apes and humans (cf, e.g., Sebastiani 2019) in two lights: showing that apes were almost human and showing that (some) humans were almost ape-like. The ethical implications of the two perspectives differ. But this section is about Jefferson's science rather than his ethics. He owned one of the earliest comparative anatomy texts, viz., Tyson 1699. Tyson's 'Pygmie' was actually a chimpanzee that he dissected, and he concluded that chimpanzees were anatomically closer to humans than to monkeys. Needless to say, Tyson, a good experimental scientist, said nothing about sex between chimpanzees and humans. That fantasy came from the travelers' tales that, in other contexts such as his struggle with Buffon, Jefferson was the first to denounce. For whatever reason, his powers of classification, analysis, and evaluation of evidence deserted him at this crucial point.

## Applied Mathematics

In this section, we need to bear in mind that Jefferson probably had little or no mathematical education except, conjecturally, from William Small. That the amateur scientist Jefferson could propose a mathematically sound system of weights and measures which bore comparison with the system proposed by a French committee including three of the greatest mathematicians of their day speaks volumes. It is also noteworthy that Jefferson could accept from Condorcet a modification of the base latitude for his system from 38 degrees North to 45 degrees North. The former better fitted the geography of the USA and the latter better fitted the geography of France, as Jefferson pointed out. But in this case he was prepared to let mathematics triumph over national pride. Two other examples of Jefferson's mathematical aptitude should be considered: his invention of a 'mouldboard of least resistance' and his calculation of actuarial probabilities.

A mo[u]ldboard is the part of a plow that turns over the sod after it has been cut from underneath by the metal cutter (or ‘share’ in Jefferson’s description) in front. Jefferson was very proud of his mouldboard of least resistance. On a tour of the Netherlands, the Rhineland, and eastern France in 1788, Jefferson noted that plows in the Nancy area were very inefficient:

> The awkward figure of their mould board leads one to consider what should be it’s form. The offices of the mouldboard are to receive the sod after the share has cut under it, to raise it gradually and reverse it. The fore end of it then should be horizontal to enter under the sod, and the hind end perpendicular to throw it over, the intermediate surface changing gradually from the horizontal to the perpendicular. It should be as wide as the furrow, and of a length suited to the construction of the plough. The following would seem a good method of making it. Take a block whose length, breadth and thickness is that of your intended mouldboard, suppose 2½f. long and 8I. broad and thick. Draw the lines a. d. and c. d. With a saw, the toothed edge of which is straight, enter at, a, and cut on, guiding the hind part of the saw on the line a. b. and the fore part on the line a. d. till the saw reaches the points b. and d. Then enter it at, c. and cut on, guiding it by the lines c. b. and c. d. till it reaches the points b. and d. The quarter a. b. c. d. will then be completely cut out, and the diagonal from d. to b. laid bare. The peice may now be represented as in fig. 2. Then saw in transversly, at every 2. inches, till the saw reaches the line c. e. and the diagonal b. d. and cut out the peices with a chissel. The upper surface will thus be formed. With a gage opened to 8.I. and guided by the line c. e. scribe the upper edge of the board from d. to b. Cut that edge perpendicular to the face of the board and scribe it of the proper thickness. Then form the under side by the upper, by

> cutting transversely with the saw, and taking out the peices with a chissel. As the upper edge of the share fin rises a little, the fore end of the board b. c. will rise as much from a strict horizontal position, and will throw the hind end a. d. exactly as much beyond the perpendicular so as to ensure the reversing of the sod. (TJ, 'Memorandums on a tour from Paris to Amsterdam, Strasburg and back to Paris', spring 1788, entry for April 19. *PTJ:* 13: 27.)

Next to this diary entry, he sketched a drawing of the cuts necessary to produce the desired shape (Fig 10.1):

[Fig. 10.1 here]

Once back, Jefferson had a model made which his son-in-law 'admired so much at Monticello' (T. M. Randolph to TJ, Apr 23 1790, in *PTJ* 16: 370). He described it in various letters (e.g., to John Taylor of Caroline, Dec. 29, 1794, in *PTJ* 28: 234: *I have imagined and executed a mould-board which may be mathematically demonstrated to be perfect, as far as perfection depends on mathematical principles. And one great circumstance in it's favor is that it may be made by the most bungling carpenter, and cannot possibly vary a hair's breadth in it's form, but by gross negligence*), and most fully to Sir John Sinclair:

> [A]n experience of 5. years has enabled me to say it answers in practice to what it promises in theory. the mould board should be a continuation of the wing of the ploughshare, beginning at it's hinder edge and in the same plane. it's first office is to recieve the sod horizontally from the wing, to raise it to a proper height for being turned over, & to make in it's progress the least resistance possible, & consequently to require a

> minimum in the moving power. were this it's only office, the wedge would offer itself as the most eligible form in practice. but the sod is to be turned over also. to do this, the one edge of it is not to be raised at all: for to raise this would be a waste of labor. the other edge is to be raised till it passes the perpendicular, that it may fall over with it's own weight. and that this may be done, so as to give also the least resistance, it must be made to rise gradually from the moment the sod is recieved. (TJ to Sir John Sinclair Mar 23 1798 in *PTJ* 30: 197-206).

Jefferson's moldboard won prizes from British, French, and Italian agricultural improvement societies. But its role in actually improving arable farm productivity was small. His example of 1794 was in wood, but innovators elsewhere had already made them in iron. Not until May 1814 did Jefferson commission a casting from his model:

> I send you the model of the mouldboard of a plough of a form of my own, and ask the favor of you to cast me two dozen in iron. I presume you will preserve the mould, as I shall probably call annually for a supply. I will thank you to have them ready as soon [a]s you can, and I will direct them to be called for. they had better be tied together manageable bundles by bits of nailrod passing thro' their holes (TJ to John Staples, May 4 1814, in *PTJ: RS* 7 346-7).

Jefferson was not the only moldboard improver. He was preceded by James Small (1740-93) (Sinclair 1813: 84; Brown 2004): Small was a Scots smith, who visited Yorkshire in his teens to work for a wheelwright near Doncaster and observed what was called the 'Rotherham plough' in use in that area. On returning to the Scottish Borders in 1763, he worked on the same project as Jefferson was to stumble on 25 years later: devising a mouldboard of least resistance, so that it required the minimum horse-power achievable for a given acreage of plowing. He devised a wooden one in 1763, a model of which is in the Royal Scottish Museum. He went on to improve it by substituting a cast-iron mouldboard, made in Scotland's leading foundry of the day, the Carron Ironworks, in 1779. Encouraged by his local patron and luminaries of the Scottish Enlightenment including Lord Kames and Sir John Sinclair, he wrote a *Treatise of Ploughs and Wheel-Carriages*. (Small 1784) which became a standard text. Jefferson may have already arrived in Paris when Small's book was published, so he may have overlooked it. There is no record of it being in any of Jefferson's libraries.

Sinclair (1754-1835; Mitchison 2004) is a key figure in the Scottish Enlightenment. In his youth he was befriended by Adam Smith, who is said to have assisted with Sinclair's *History of the Public Revenue of the British empire* (Sinclair 1785).Jefferson owned a copy. Smith's most thorough biographer relates that

> One day Sinclair brought Smith the news of the surrender of Burgoyne at Saratoga in October 1777, and exclaimed in the deepest concern that the nation was ruined. "There is a great deal of ruin in a nation," was Smith's calm reply (Rae 1895: 365).

Sinclair later became critical of what he saw as Smith's inadequate knowledge of Scottish agriculture. Having inherited an estate in Caithness, in the windblown north-eastern corner of the

Scottish mainland, he threw himself into agricultural improvement, and many other projects, such as correspondence with Jefferson and others about agricultural improvements in America.

His greatest achievement was to produce the *Statistical Account of Scotland* (Sinclair 1799; cf MacDonald 2023). In 1790 he persuaded the General Assembly of the Church of Scotland to let him send a circular to every parish minister asking for statistics (a new word, of which Sinclair's was one of the first usages in English) of the economy, population, and education in their parish. So effective was Sinclair's badgering that in the end he got a response from all bar twelve parishes in Scotland. He wrote the return for Thurso himself; Edinburgh was covered (very badly) by his publisher, and 'the final twelve recalcitrant parishes were covered by the editorial staff' (Mitchison 2004.)

The *Statistical Account*, now known as the *Old Statistical Account* (OSA) to distinguish it from two later efforts, is like a multi-author *Notes on Virginia* but on a heroic 21-volume scale. Jefferson never acquired a set, but he did own two of Sinclair's spin-offs. These were a 55-page *Specimen of the statistical account of Scotland : drawn up from the communications of the ministers of the different parishes* (1791: one of Sinclair's devices to persuade recalcitrant or lazy ministers to complete their write-ups), and a book-length *Specimens of statistical reports* (1793: published before the OSA was complete).

A search for the strings "mould board" and "mouldboard" on the OSA database at https://stataccscot.edina.ac.uk/static/statacc/dist/home reveals that 28 parish ministers commented on improvements in the mouldboard, with the general tone being that Small's invention was vastly better than the old Scotch plow but that pig-headed farmers had not always adopted it.

What did Sinclair really think about the Jefferson and Small mouldboards? He had known Jefferson since they met in Paris in 1786. When Sinclair received Jefferson's enthusiastic letter in 1798 he already knew that plows with the Small geometry were being cast at the Carron ironworks and that Small had gone on tinkering with his model for the rest of his life (see Sinclair 1813). He does not seem to have ever told Jefferson that he had been scooped. They renewed their correspondence in 1815 after the end of the War of 1812, and in 1817 Sinclair wrote to Jefferson:

> I have not neglected to mention, in the Section on Implements of Husbandry, your ingenious improvement on the construction of the plough. I inclose a proof sheet, just received from the Printers containing the notes (see p. 105), in which that subject is mentioned.

The proof sheet (from Sinclair 1817, p. 105) states:

> An improvement in the plough-ear, or mould-board, of swing ploughs, has been recommended by the celebrated Jefferson, formerly President of the United States of America, who has cultivated the mechanical branches of agriculture with much success. (*PTJ : RS*: 11: 381-2).

Should we then regard Jefferson's moldboard as a heroic failure? That would hardly be fair. There was no Internet in 1788. Jefferson was a keen collector of books on all sorts of subjects including agricultural improvements, but he missed the publication of Small's book. His Scottish Enlightenment contacts were from earlier generations, including the unrelated William Small. Sinclair seems never to have told Jefferson that his invention had been made 25 years earlier. We should regard the optimal moldboard as a case of near-simultaneous invention, based on sound mathematical theory in both cases. Decades of experiments on both Atlantic coasts after Small and Jefferson showed that different forms of plow worked best in different kinds of soil. As his agricultural prizes show, Jefferson made a real contribution to this effort, even though he never put hand to plow himself.

We have already discussed Jefferson's adaptation of Condorcet on actuarial science in his famous 'Earth belongs in usufruct to the living' letter, analysed above. Taking it together with the various pieces of work discussed in this chapter, it is fair to conclude that Jefferson was a remarkably talented self-educated mathematician and scientist.

## Dissemination

The University of Virginia stands at the apex of Jefferson's scientific activities. It was a lifelong project, built on Jefferson's realization that the College of William & Mary was in the wrong place (too many mosquitoes, too many Tidewater planters) and had an inadequate curriculum. Other colleges were springing up (Washington College – now Washington & Lee University - in Lexington; Hampden-Sydney College in its eponymous village). But none of these fitted Jefferson's vision. All were denominational (Episcopal or Presbyterian). None was close to Monticello. So the meeting at Rockfish Gap in August 1818 was a crucial moment.

Rockfish Gap is a col in the Blue Mountains that separate central Virginia from the Shenandoah Valley. Jefferson's trip there, and onwards to Warm Springs in the Alleghenies (the latter leg in a vain search for a health cure) was the longest that he made after his retirement. The meeting was a mini-Constitutional Convention. Like Washington in Philadelphia in 1787, Jefferson was the non-speaking presiding officer. Like Madison at Philadelphia, however, Jefferson had a plan, which he had been preparing for months. As at Philadelphia, the delegates agreed to stay in the inn, which was high and remote, until they had made a plan. Three venues for the new university were proposed – Charlottesville, Lexington, and Staunton. The delegates moved fast, choosing Charlottesville by 16 votes against three for Lexington and two for Staunton. Jefferson quickly produced a copy of his plan, which became the blueprint for the University of Virginia. (All details in this paragraph are from the editorial note in *PTJ: RS* 13: 179-181, See also Addis 2012).

Jefferson's draft report said that the criteria for the site were to be "the healthiness of the site, the fertility of the neighboring country, and it's centrality to the white population of the whole state" – a set of criteria which conveniently excluded Williamsburg, Norfolk, Richmond, Petersburg, and Alexandria. It proceeded to do its sums based on the Census of 1810, and, miraculously, to conclude that Charlottesville was more central than Lexington or Staunton.

So far, so clientelistic. But Jefferson's report for the Commissioners is a revealing extension of his system of knowledge. The University was to have ten professors, and the report goes into some detail about why the Commissioners (read: Jefferson) selected these subjects, and not others.

The ten professorships were to be:

1. Languages Antient (Greek, Latin, and Hebrew);
2. Languages Modern (French, Spanish, Italian, German, and Anglo-Saxon);
3. Mathematics Pure;
4. Physico-Mathematics;
5. Physics or Natural Philosophy, Chemistry, and Mineralogy;
6. Botany and Zoology;
7. Anatomy and Medicine;
8. Government, Political Economy, Law of Nature and Nations, and History;
9. Law Municipal
10. Ideology, General Grammar, Ethics, Rhetoric, Belle [sic] Lettres and the Fine Arts.

The first thought that comes to mind is that each of these ten people must be remarkable polymaths, even by Enlightenment stands: even by Jefferson's standards. The next thought is that the list is very Scottish. Notice, for instance, the headings 'Law of Nature and Nations', and 'Belle[s]-Lettres'. These reflect the titles of Scottish chairs and the writings of the Scottish Enlightenment. The Regius Chair of Public Law and the Law of Nature and Nations at Edinburgh was endowed by Queen Anne immediately after the Union of 1707. The title reflects the book studied by all Scottish jurists, and by Jefferson: Samuel Pufendorf's *Law of Nature and Nations* (Pufendorf 1703). Jefferson owned two copies, one in French and one in English. Millicent Sowerby's detective work shows that when he quoted Pufendorf in an opinion for President Washington in 1793, he translated from the French, rather than use an extant English edition (Sowerby 1952, II: 68-70). As for Rhetoric and Belles-Lettres, that was the title of Adam

Smith's lectures delivered in Edinburgh (Smith 1985). These were unpublished in Smith's lifetime, but gave rise to an identically-titled book by Hugh Blair (Blair 1784), of which Jefferson owned two copies. Blair was a friend of Smith and Hume who became Professor of Rhetoric and Belles-Lettres in Edinburgh in 1762. He came to Jefferson's notice early on, as the debunker of the supposed Gaelic originals of the poems of 'Ossian' (James Macpherson), whose authenticity Jefferson believed in (Sowerby 1952: IV. 464). Like other Scottish Enlightenment titles, Blair's *Lectures* were very widely read, and republished, in the new republic. One of Jefferson's sets was published in Philadelphia in 1784.

Some Jeffersonian obsessions emerge from the Rockfish Gap report. The chair of Modern Languages was to include Anglo-Saxon (can he really have expected the professor to be fluent in all five languages listed?) because of "the great instruction which may be derived from it towards a full understanding of our Antient common Law on which as a stock our whole System of Law is engrafted" (*PTJ: RS* 18: 217). The Report goes on to explain two important omissions from the professoriate. One is practical:

> Medecine, where fully taught, is usually subdivided into several professorships. but this cannot well be without the Accessory of an hospital, where the Student can have the benefit of attending Clinical lectures, & of assisting at operations of Surgery. with this Accessory, the seat of our University is not yet prepared, either by it's population, or by the numbers of poor who would leave their own houses, and accept of the charities of an hospital. for the present therefore we propose but a single Professor for both Medicine and Anatomy….
>
> In conformity with the principles of our constitution, which places all sects of Religion on an equal footing, with the jealousies of the different sects in guarding that equality

> from encroachment and surprise, and with the sentiments of the legislature in favor of freedom of religion manifested on former occasions, we have proposed no Professor of Divinity; and the rather as the proofs of the being of a god, the creator, preserver, and supreme ruler of the universe, the Author of all the relations of morality, and of the laws and obligations these infer, will be within the province of the Professor of Ethics; to which adding the developements of these general principles of morality of those in which all sects agree a basis will be formed common to all sects. proceeding thus far without offence to the constitution, we have thought it proper to leave every sect to provide, as they think fittest, the means of further instruction in their own peculiar tenets. (*PTJ: RS* 13: 197-8).

There are now enough poor people in central Virginia for the University of Virginia to have a large medical school. True to its Jeffersonian principles, to this day it has no professional school of divinity, although there is a Religious Studies program, founded in 1967, in the College of Arts and Sciences. Jefferson’s strictures about freedom of religion link his first tombstone achievement to his last.