The English language uniquely emphasizes the epistemic status of the speaker, according to Anna Wierzbicka's *English: Meaning and Culture*. Speakers of English, very much more than those of every other language,preface their claims with 'I think', 'I guess', 'presumably', and the like; are concerned about the 'reasonableness' of beliefs or courses of action; and use the word 'probably' with a frequency several times that of the corresponding word in other languages. This 'cultural script', Wierzbicka says, can be seen to have developed in English polemical writing in the eighteenth century, and it is clear from the phrases used in the writers of that century that they took on this emphasis on belief and uncertainty from reading John Locke (Wierzbicka 2006: chs 4, 7, 8).

Her emphasis on the role of Locke is correct, but Locke himself was the popularizer of three convergent traditions of thought. One was the legal development of uncertain proofs and the evaluation of the testimony of witnesses; the second, partly built on the first, was the scholastic grading of uncertain or dialectical proofs; and the third was a century of development in which English thought diverged from continental through an increasing attention to reasonableness, reasons, moderation, facts, experiments, and probability.

This chapter begins by surveying the areas in which probabilities were already familiar by 1600, law and moral theology. In those fields, the balancing of reasons, witnesses, and authorities for and against propositions was widely discussed in terms of probability, allowing talk of the strength of reasons on each side. Then the
areas are discussed in which English thinkers, much more than continental ones, developed those resources to discuss reasoning in religion, philosophy, and science. Beginning with Chillingworth, Anglican controversial writers used the language of probability to pursue a middle path in Christian doctrine and to defend the reasonableness of Christianity. Hobbes founded his political theory on the risk of attack. Scientific writers, especially Boyle and Newton, carefully tried to distinguish certainty from probability in the evaluation of scientific hypotheses. Building on all these foundations, Locke then gave a succinct summary of the philosophy of probability and situated it within his theory of ideas. A final section of the chapter considers the most truly original English contribution to probabilistic reasoning, Graunt’s founding of the science of statistics in the sense of inference from quantitative data.

### 15.1 Law and Logic

In the seventeenth century, the language of most serious learning was still Latin, and university education was still based on curricula formed by medieval scholasticism. The writers we now read in vernacular languages, such as Locke, were thus formed in, and wrote in reaction to, a settled body of concepts and distinctions which need to be understood to appreciate the new thinkers’ originality (or otherwise). That is especially true of probability, where an extensive scholastic theory had been built up over several centuries and had become standard in syllabuses in law and logic. Medieval legal theorists had developed a grading of degrees of evidence ranging from ‘indications’ and ‘suspicions’ through ‘half proof’ (semiplena probatio, sufficient to justify interrogation under torture but not conviction) to ‘vehement presumptions’ and finally full proof. Also standard was the distinction between the highest standard of proof, that in mathematics, and the ‘moral certainty’ that was the highest attainable about ordinary matters, sufficient for full confidence in acting. It was appreciated that uncertain reasons, while not strong individually, could combine to produce a highly persuasive argument. Ethical theorists in the sixteenth century advanced the theory of ‘probabilism’, according to which in cases of ethical doubt one might follow an opinion that was merely probable; an opinion could have both ‘intrinsic’ probability (reasons for it) or ‘extrinsic’ (the support of authorities) (Franklin 2001: chs 1–4; Shapiro 1983: chs 1–3).

Continental law and its large treatises on presumptions were not authoritative for English law. But the essential concepts of the grading of evidence were
incorporated into English law by a number of medieval and later legal authorities. Sir Edward Coke, the leading English legal authority of the early seventeenth century, repeated the classical medieval grading of presumptions:

And many times juries, together with other matter, are much induced by presumptions; whereof there be three sorts, viz. violent, probable and light or temerary. *Violenta praesumptio* is manie times *plena probatio*; as if one be runne throw the bodie with a sword in a house, whereof he instantly dieth, and a man is seen to come out of that house with a bloody sword, and no other man was at that time in the house. *Praesumptio probabilis* moveth little but *praesumptio levis seu temeraria* moveth not at all. So it is in the case of a charter of feoffment, if all the witnesses to the deed be dead (as no man can keep his witnesses alive, and time weareth out all men) then violent presumption which stands for a proof is continuall and quiet possession. (Coke 1628: 6b; later in Macnair 1999: 270–5)

The survival of continental ideas on evidence is still clear at the end of the seventeenth century, for example in the remark of the leading authority, Sir Matthew Hale: ‘The evidence at Law which taken singly or apart makes but an imperfect proof, *semiplena probatio*, yet in conjunction with others grows to a full proof, like *Silurus* his twigs, that were easily broken apart, but in conjunction or union were not to be broken’ (Shapiro 1983: 180). The continental system was even stronger in Scotland, where juries were not used and presumptions were discussed using continental authorities (Stair 1981: 548, 1011).

Coke and Hale (and to some degree Bacon) however also stressed the differences between English and continental law, especially in their relation to the contentious concept of experience. They accused continental law of being over-theoretical, axiomatic, and subtle, in contrast to the reliance of English law on the vast experience of precedents, and of jurors on their wide experience of matters of fact. Hobbes took the opposite side in this debate, but Boyle drew on the English legal tradition of respect for experience in emphasizing its role in natural philosophy (Sargent 1995: 42–56).

A small proportion of such theory reached wider university syllabuses through the treatment of the ‘dialectical syllogism’ or ‘probable syllogism’ in logic textbooks (e.g. Crakanthorpe 1622). For example, Blundeville’s 1599 *Arte of Logike* has a short section on ‘Probable Accidents, Coniectures, Presumption, Syngnes, and Circumstances’, illustrated with such arguments as ‘the feast of Bacchus is this day celebrated, ergo there will be many drunken this day’ (Blundeville 1599: 87–8). The 1638 *Logic* of the Jesuit Smiglecki, much used at Oxford, said that multiplying probable reasons can make an opinion ‘infinitely more probable’, but cannot make it certain, any more than making a body ‘infinitely more corporeally perfect’ can make it into a spirit (Smiglecki 1638: 661).
15.2 Testimony

Fully one half of Locke’s definition of probability relied upon testimony to fact, and testimony was the first ground of probability he mentioned: ‘Inducements of Probability, are of two sorts; either concerning some particular Existence, or, as it is usually termed, matter of fact, which falling under Observation, is capable of humane Testimony, or else concerning Things, which being beyond the discovery of our Senses, are not capable of any such Testimony’ (Essay IV. xvi. 5).

Centuries of reflection on the reliability of witnesses in legal and religious contexts meant that testimony formed a model of the evaluation of uncertain evidence that could be used to understand new forms of evidence, such as experiments and scientific reports (Shapiro 2002; Shapin 1994, ch. 5). Legal thought was based on two brief texts of the Digest, the ancient compendium of Roman law, which called for consideration of the witnesses’ status, character, bias, and responses to examination, the number of witnesses, and how their statements fit with circumstances and common knowledge. Similar statements are standard among legal writers in England (Shapiro 1983: 180–9; Macnair 1999: 254–6; Kassler 2009: 105–8). Coke quotes some Latin legal maxims on testimony: ‘One eye-witness is worth ten by hearsay’, ‘A single voice induces neither proof nor presumption’, ‘When witnesses depose in equal numbers, the more worthy are believed’, ‘On a crime committed in a brothel, frequenters of brothels may be witnesses’ (Franklin 2001: 61). The continental requirement, based on Biblical authority, that conviction for a crime required the concurrent testimony of two witnesses of good character, was not regarded as authoritative in English jury trials, but was well known and sometimes taken seriously (Macnair 1999: 249–54).

Bacon treats of testimony in discussing the too easy crediting of rumours. The ‘facilitie of credite, and accepting or admitting things weakely authorized or warranted’ may apply to ‘a beleefe of Historie, or (as the Lawyers speake, matter of fact)’. He has in mind pious stories of miracles worked by saints, but also writers like Pliny who recount dubious stories of natural history (OFB 4: 26). He does not develop any substantial account of how to evaluate the credibility of testimony, despite its importance in establishing the factual basis of natural history (Serjeantson 1999: 208–11).

The wide knowledge of legal ideas is clear from Boyle’s comment: that

though the Testimony of a Single Witness shall not suffice to prove the accus’d party guilty of Murder; yet the Testimony of two Witnesses, though but of equal Credit...shall ordinarily suffice to prove a Man guilty; because it is thought reasonable to suppose, that, though each Testimony single be but probable, yet a concurrence of such Probabilities...may well amount to a Moral certainty. (Boyle 1675, B 8: 282)

Locke summarized legal thinking on tests for the reliability of testimony: relevant are the number of witnesses, their integrity, their skill in presenting the evidence,
their purpose, the internal consistency of the evidence and its agreement with the circumstances, and the presence or absence of contrary testimony. As ‘the number and credibility of Testimonies, do more or less agree, or disagree with it, so is any Proposition in itself more or less probable’ (Essay IV. xv. 6; Kennedy 2004, ch. 6).

Brief treatments of arguments from testimony were also common in the scholastic logics, but they tended to assimilate testimony to arguments from authority, and hence to rely on a single factor in rendering testimony reliable, the creditworthiness of the witness (Serjeantson 1999: 204–5). An English version of a scholastic logic, by the lawyer Zachary Coke, lists thirteen ‘Canons of human testimony’, beginning with the fact that it does not result in necessary truths and admits of degrees. The canons include:

5. Old testimony is worth more then new.
11. Testimony of a skilfull Artizen, is to be preferred before the testimony of another unskilfull, however famous otherwise. (Coke 1654: 163)

The first of these is certainly not in accordance with the spirit of the age, which came to prefer new observations to old authorities (except in law and religion). The latter advice was taken by the Royal Society’s Georgical Committee in its enquiries to experienced husbandmen on agricultural matters (Lennard 1932); Boyle does however point out that the ‘Logicians Rule, the Skillfull Artists should beCreditied in their own Art’ is taken advantage of by alchemists to impose their misconceptions on the public (Boyle 1661, B 2: 277). Boyle understood that the advance of experimental science needed a clear distinction between authority (old and unreliable) and testimony to experiments (new and reliable when used with care) (Serjeantson 1999: 215–17; Shapiro 2002: 253–4).

Thomas Sprat’s History of the Royal-Society of London (1667) emphasized the communal nature of the establishment of experimental matters of fact, conceiving a crowd present to witness and challenge the repetition of an experiment. Nothing except religious truths could be ‘confirmed by stronger evidence’ than this:

In almost all other matters of Belief, of Opinion, or of Science; the assurance, whereby men are guided, is nothing near so firm, as this. And I dare appeal to all sober men; whether, seeing in all Countreys, that are govern’d by Laws, they expect no more, than the consent of two, or three witnesses, in matters of life, and estate; they will not think, they are fairly dealt withall, in what concerns their Knowledge, if they have the concurring Testimonies of threescore or an hundred? (Sprat 1667: 100; Dear 1985; examples of real public demonstrations of an antecedently unlikely phenomenon in Golinski 1989)

Hooke says likewise, ‘How near the nature of Axioms must all those Propositions be which are examin’d before so many Witnesses?’ (Hooke 1665: sig d1’).

As in law, so in scientific disagreements, conflicting testimony could be a nuisance. When the astronomers Azout and Hevelius referred to the Royal Society their dispute about observations of the comet of 1664–1665, the Society recognized
it as a case of ‘Controversie being about matter of fact, wherein Authority, Number and reputation must cast the Balance’. Wallis, called to investigate, recommended suspending judgement (Shapiro 2002: 256–7; legal discussion of conflicting witnesses in Macnair 1993).

Testimony later seemed to some a natural field for the deployment of the new quantitative ideas arising from the work of Pascal, Fermat, and Huygens on dice. John Craig’s Mathematical Principles of Christian Theology (1699) models the mind as a ‘moving thing’ that is driven by the ‘motive force’ of arguments and testimonies to move through a ‘space’ of degrees of assent. He calculates the degree to which a chain of witnesses attenuates the belief in a proposition that they relay. He concludes that credibility in the Bible will have fallen to zero after 3,150 years, thus requiring the Second Coming before that date (Craig 1699; similar in Hooper 1699; Stigler 1986). The reasons remain unclear as to why ‘applications’ of probability theory to calculating the strength of testimony have all been ridiculous.

### 15.3 Moral Doubts and Probabilism

A substantial part of seventeenth-century discussion of uncertainty and probability, both on the Continent and in England, took place in moral theology. Catholic moral thought, with a bias towards practical advice for confessors, developed an elaborate discipline of casuistry with a detailed study of ‘cases of conscience’. As the confessional was seen as resembling a miniature court of canon law, legal concepts were applicable. A standard problem was what is permitted to a doubting conscience. In reaction to strict medieval opinions that one must always follow the safer path in case of doubt, Catholic and especially Jesuit moralists of the late sixteenth and early seventeenth centuries defended probabilism, the doctrine that one might follow an opinion that had some probability, for example the approval of several learned doctors, even if the opposite, more strict opinion, were more probable. Probabilism was held up to caricature by Pascal in his Provincial Letters in the 1650s (Franklin 2001, ch. 5).

The determination of mainstream Anglicanism to maintain a position between Catholic and Calvinist created special problems in moral theology. A church in schism could hardly have the same respect for authorities, especially recent ones, as Catholics. So English casuistry avoided probabilism in the sense of reliance on the opinions of doctors, and gave greater weight to the reasons for and against opinions. ‘Trust neither me, nor the adverse part, but the Reasons’, says John Donne (Donne 1930: 30). Donne complains that probabilism indulges the human propensity to intellectual laziness: ‘To which indisposition of ours the casuists are
so indulgent, as that they allow a conscience to adhere to any probable opinion against a more probable, and do never bind him to seek out which is the more probable, but give him leave to dissemble it and to depart from it, if by mischance he come to know it' (Gosse 1899, I: 174).

The word 'dissemble' here alludes to the notorious views of the Jesuits on the permissibility of equivocation and mental reservation. The Jesuits were committed to the view that an outright lie was intrinsically wrong, and hence never permissible. But they did regard it as allowable, for sufficient cause, to give answers that were deliberately ambiguous, or to give only part of an answer, 'mentally reserving' a continuation of the sentence that would change its meaning. The case for the permissibility of these practices was argued in the Treatise of Equivocation of Henry Garnett, the superior of the English Jesuits in the dangerous years around 1600. Admitting that not all doctors approve of mental reservation, he calls the doctrine of probabilism in his support: where there are two probable opinions, 'A man may without sinne follow either, if it may be done without prejudice of our neighbour; and if one be lesse probable than the other, yet so long as it is within ye compasse of probability, he may do it if the consequences require it (Zagorin 1990: 195). He means that one may balance a lesser probability of the doctrine of mental reservation against the harm that will follow from answering truly such questions as whether there is a priest hidden in one's home.

Father Garnett evaded capture for many years, but fell into the hands of the authorities after the Gunpowder Plot. Coke achieved his conviction of complicity in the plot (possibly wrongly), claiming to offer, in the continental phrase, proofs luci clariores (clearer than light) of his guilt.

Who was lax and who strict became curiously reversed in the case of the Oath of Allegiance controversy. After the Gunpowder Plot, James I imposed the Oath to distinguish between loyal Catholics and traitorous ones. Many Catholics complied, but were forbidden to do so by the Pope. Donne suggested that Catholics might like to apply probabilism to the case, and conclude that obedience to the King may be legitimately preferred to obedience to the Pope (Donne 1610: 230–1; Malloch 1962).

The high point of Anglican casuistry actually appeared after Pascal's Provincial Letters, and bears no evidence of being affected by Pascal's ridicule of casuists. Bishop Jeremy Taylor's Doctor dubitantium (1660) includes some colourful praise of probable arguments:

Probable arguments are like little stars, every one of which will be useless as to our conduct and enlightening; but when they are tied together by order and vicinity, by the finger of God and the hand of an angel, they make a constellation, and are not only powerful in their influence, but like a bright angel, to guide and to enlighten our way. And although the light is not great as the light of the sun or moon, yet mariners sail by their conduct; and though with trepidation and some danger, yet very regularly they enter into the haven. This heap of probable inducements, is not of power as a mathematical and physical demonstration,
which is in discourse as the sun is in heaven, but it makes a milky and a white path, visible enough to walk securely. (Taylor 1822, 12: 36–7)

On the issue of the doubting conscience, Taylor is firmly against probabilism, laying down the rule, 'The greater probability destroys the less'.

# 15.4 Hobbes and the Risk of Attack

A standard case of conscience is the allowability of violence in self-defence when in fear of one’s life. Hobbes’ political theories were, in a sense, entirely founded on the concept of risk, or danger, although he does not exactly express himself in those terms. The famous phrase in *Leviathan* about the life of man in a state of nature being ‘nasty, brutish and short’ occurs in a paragraph that attributes that condition to lack of certainty about the effects of actions:

In such condition, there is no place for industry; because the fruit thereof is uncertain: and consequently no culture of the earth; no navigation... no art; no letters; no society; and, which is worst of all, continuall feare, and danger of violent death; And the life of man, solitary, poore, nasty, brutish and short. (Lev. 13: 89)

The remedy is the removal of ‘just suspicions’ of being attacked. That is a main reason for replacing the state of nature with a compact of civil society under a powerful sovereign.

If a Covenant be made, wherein neither of the parties performe presently, but trust one another; in the condition of meer Nature, (which is a condition of Warr of every man,) against every man, upon any reasonable suspition, it is Voyd: But if there be a common Power set over them both, with right and force sufficient to compell performance; it is not Voyd. For he that performeth first, has no assurance the other will perform after... But in a civill estate, where there is a power set up to constrain those that would otherwise violate their faith, that feare is no more reasonable; and for that cause, he which by the Covenant is to perform first, is obliged so to do. (Lev. 14: 96)

The more elaborate *De cive* at the corresponding place emphasizes even more the concept of the reasonableness of the evaluation of risk: ‘for it suits not with reason, that any man should perform first, if it be not likely that the other will make good his promise after; which, whether it be probable or not, he that doubts it must be judge of’ (EW 2: 21).

The same reasoning, according to Hobbes, is behind the law’s forbidding of pre-emptive first strikes: ‘Nature gave a Right to every man to secure himselfe by his own strength, and to invade a suspected neighbour, by way of prevention: but the Civill Law takes away that Liberty, in all cases where the protection of the Law
may be safely stayd for’ (Lev. 26: 200). Hobbes is less than clear on what is to be done when one does reasonably fear that the sovereign lacks the power to protect, or when the protection of the law may not be ‘safely stayd for’. A sovereign without power, it seems, has no claim to allegiance; a consequence which was the source of not a little ill feeling between Hobbes and the Royalist exiles in Paris during the Commonwealth. The situation was all the more awkward because the Commonwealth’s propagandists were using exactly the same argument. Marchamont Nedham, first a defender of Parliament, then a Royalist, later a Cromwellian, in 1650 rested the case for the Commonwealth on two theses: ‘That the Power of Sword is, and ever hath been, the Foundation of all Titles to Government’, and, that there was a great improbability of any of the Commonwealth’s adversaries, whether Royalists, Scots, Presbyterians or Levellers, ever succeeding in their designs. He estimates it at ten to one against any Royalist attempt to regain power succeeding. The second edition of Nedham’s book includes an appendix delightedly quoting Hobbes, whose arguments about the need for a strong ruler, Nedham suggests, could hardly apply to the ‘King of Scots’ or ‘any other Power beside the present’ (Nedham 1650: 6, 109).

The language of odds, such as ‘ten to one’, is used by Hobbes in his brief discussion of induction. Bacon had made much of a method of induction as a cure for the scholastics’ hasty generalizations in science, but his induction is not a probabilistic method of inference from particulars to general truths of the kind later discussed by Hume, such as the inference from ‘All observed ravens are black’ to ‘All ravens are black’. It is instead an essentially deductive method like Mill’s Methods, which relies on a large range of carefully collected instances to rule in or out laws connecting properties (Carlin 2009: 24–8; Malherbe 1996). The problem of induction in Hume’s sense, of asking for the justification of pure inductive inferences such as that involving ravens, was not considered in seventeenth-century British philosophy (though known on the Continent; Franklin 2001: 222–4). Hobbes however does recognize such arguments as probabilistic and goes so far as to assign some of them, in a very casual way, numerical odds: ‘experience concludeth nothing universally. If the signs hit twenty times for one missing, a man may lay a wager of twenty to one of the event; but may not conclude it for a truth’ (Human Nature, Hobbes 1839, 4: 18).

15.5 THE REASONABLENESS OF ANGLICAN CHRISTIANITY

Religious controversy in the post-reformation period was the setting for many of the applications of probability in the two countries that attempted a moderate course in matters of religion, England and Holland. It was in this context that
English thought began to take on its typical and much celebrated cast of 'reasonableness', 'compromise', and 'practicality'. Seventeenth- and eighteenth-century English thought takes many of its assumptions from a stream of works on the 'reasonableness of Christianity', a topic central to the concerns of the most influential writers.

There are some historical causes of this development, such as the long reign of Elizabeth I with her determination to avoid extremes. But its intellectual origins are to be found principally in Hooker's Laws of Ecclesiastical Polity of 1594 (Quinton 1978). What was especially important for later developments was Hooker's concentration on questions of the sources of knowledge. That was an especially difficult problem for the Church of England, which was searching for a middle way between the authority of 'Scripture alone' and that of authoritative Roman tradition. Hooker's solution was to rely on 'reasonableness' and 'tradition', except where modification was manifestly necessary. 'The ground of credite', he writes, 'is the creditilitie of thinges credited; and things are made crediblie, eyther by the knowne condition and qualitie of the utterer, or by the manifest likelihood of truth which they have in themselves' (Hooker 1593: 102). The relationship to later English conservative thought is clear. There is also a relationship to the past, since 'reasonableness' and 'tradition' are the same as the scholastics' notions of intrinsic and extrinsic probability.

He classifies the grades of assurance as the scholastics did, and insists many times that assent should be proportioned to evidence: 'perswasions grounded upon reason are either weaker or stronger according to the force of those reasons whereupon the same are grounded' (Hooker 1593: 16).

The greatest assurance generally with all men is that which we have by plaine aspect and intuitive beholding. Where we cannot attayne unto this, there what appeareth to be true by strong and invincible demonstration, such as wherein it is not by any way possible to be deceived, thereunto the mind doth necessarily assent, neyther is it in the choyce thereof to do otherwise. And in case these both do flyle, then which way greatest probability leadeth, thether the mind doth evermore incline... Now it is not required or can be exacted at our hands, that we should yeeld unto any thing other assent, than such as doth answere the evidence which is to be had of that we assent to.

Hooker very cunningly suggests that the Calvinists' fervour stems from their mistake on this point. Their zeal is a cover for their lack of evidence: 'whereas the truth is, that how bold and confident soever we may be in words, when it commeth to the point of tryall, such as the evidence is which the truth hath eyther in it self or through proofe, such is the hearts assent thereunto, neither can it be stronger, being grounded as it should be' (Hooker 1593: 117).

The Low Countries were responsible for early work on the 'reasonableness of Christianity', with its characteristic reliance on design arguments for the existence of God, arguments on the historicity of the Gospels, and rational comparisons
between different versions of Christianity. Two of the major writers, the Antwerp Jesuit Leonard Lessius and the Dutch Protestant Hugo Grotius, were translated into English (Franklin 2001: 244–6). The ideas of Grotius’ On the Truth of the Christian Religion found their most influential support in England, at least in the longer term. A circle of Anglicans, meeting at Great Tew in the 1630s, maintained the ideas of Hooker and Grotius, of moderate scepticism, toleration, and political conservatism. Though dispersed during the troubled times of the Civil War, their surviving members were influential in the thought of the Restoration church (Beiser 1996, ch. 3). The central writer of the circle was William Chillingworth, whose The Religion of Protestants a Safe Way to Salvation, of 1638, is one of the most acute works of Catholic–Anglican controversy. Chillingworth had been converted briefly to Catholicism, and had studied at the Jesuit College at Douai before returning to Oxford and preferment in the Anglican Church. His book, though of course largely taken up with particular points of doctrine, is at bottom an attack on the notion of infallibility, based on considerations about the logic of certainty and probability. Chillingworth argues, like Hooker, that the correct degree of belief in a proposition is the degree proportional to the reasons for it, and that God cannot require more:

God desires only that we believe the conclusion, as much as the premises deserve, that the strength of our faith be equal or proportionable to the credibleness of the motives to it. Now, though I have and ought to have, an absolute certainty of this thesis—all which God reveals for truth, is true… yet of this hypothesis—that all the articles of our faith were revealed by God—we cannot ordinarily have any rational and acquired certainty, more than moral, founded upon these considerations; first, that the goodness of the precepts of Christianity, and the greatness of the promises of it, show it, of all other religions, most likely to come from the Fountain of goodness. And then, that a constant, famous, and very general tradition, so credible, that no wise man doubts of any other which hath but the fortieth part of the credibleness of this; such and so credible a tradition tells us, that God himself hath set his hand and seal to the truth of this doctrine, by doing great, and glorious, and frequent miracles in confirmation of it. Now our faith is an assent to this conclusion, that the doctrine of Christianity is true; which being deduced from the former thesis, which is metaphysically certain, and from the former hypothesis, whereof we can have but a moral certainty, we cannot possibly by natural means be more certain of it than of the weaker of the premises; as a river will not rise higher than the fountain from which it flows. (Chillingworth 1840: 81)

God is not even morally permitted to require certainty of belief where it is not to be had.

In the course of arguing that fallible beliefs are sufficient for action, Chillingworth gives the essentials of Pascal’s wager, in considering the balance of an infinite future happiness and the present inconveniences necessary for attaining it:

For who sees not that many millions in the world forego many times their present ease and pleasure, undergo great and toilsome labours, encounter great difficulties, adventure upon
great dangers, and all this not upon any certain expectation, but upon a probable hope of some future gain and commodity, and that not infinite and eternal, but finite and temporal? Who sees not that many men abstain from many things they exceedingly desire, not upon any certain assurance, but a probable fear, of danger that may come after? What man ever was there so madly in love with a present penny, but that he would willingly spend it upon any little hope, that by doing so he might gain a hundred thousand pounds? And I would fain know, what gay probabilities you could devise to dissuade him from this resolution. And if you can devise none, what reason then or sense is there, but that a probable hope of infinite and eternal happiness, provided for all those that obey Christ Jesus, and much more a firm faith, though not so certain, in some sort, as sense or science, may be able to sway our will to obedience, and encounter with all those temptations which flesh and blood can suggest to avert us from it? (Chillingworth 1840: 430–1)

He argues too that the Catholic doctrine of infallibility is logically incoherent, since, being not fully evident from scripture, it needs to be supported by reasoning drawn from scripture and tradition which is not itself certain. He argues that Catholics in any case make salvation rest on fallible grounds, since they require that one receive the sacraments from priests, who are real priests only if descended by a chain of valid ordinations from the apostles. That this is so is uncertain; Chillingworth employs some sophisticated probabilistic argument:

In fine, to know this one thing you must first know ten thousand others, whereof not any one is a thing that can be known, there being no necessity that it should be true, which only can qualify any thing for an object of science, but only, at the best, a high degree of probability that it is so. But then, that of ten thousand probables, no one should be false; that of ten thousand requisites, whereof any one may fail, not one should be wanting, this to me is extremely improbable, and even cousin-german to impossible. So that the assurance hereof is like a machine composed of an innumerable multitude of pieces, of which it is strangely unlikely but some will be out of order; and yet if any one be so, the whole fabric of necessity falls to the ground: and he that shall put them together, and maturely consider all the possible ways of lapsing, and nullifying a priesthood in the church of Rome, I believe will be very inclined to think, that is a hundred to one, that amongst a hundred seeming priests, there is not one true one: nay, that it is not a thing very improbable, that amongst those many millions, which make up the Romish hierarchy, there are not twenty true. (Chillingworth 1840: 131–2)

In the course of exposing the contradiction between Catholic demands for infallibility in one place with its reliance on probabilities when convenient, Chillingworth makes an original use of numerical odds as a metaphor for the varying strengths of probabilities:

you take occasion to ask, ‘shall I hazard my soul on probabilities, or even wagers?’ As if whatsoever is but probable, though in the highest degree of probability, were as likely to be false as true! Or, because it is but morally, not mathematically, certain, that there was such a woman as Queen Elizabeth, such a man as Henry VIII, that is, in the highest degree probable, therefore it were an even wager there were none such! By this reason, seeing the truth of your whole religion depends finally upon prudential motives, which you do but
pretend to be very credible, it will be an even wager that your religion is false. And, by the same reason, or rather infinitely greater, seeing it is impossible for any man (according to the grounds of your religion) to know himself, much less another, to be a true pope, or a true priest; nay, to have a moral certainty of it; because these things are obnoxious to innumerable secret and indiscernible nullities, it will be an even wager, nay, (if we proportion things differently), a hundred to one, that every consecration and absolution of yours is void...you have confounded, and made all one, probabilities, and even wagers. Whereas any ordinary gamester can inform you, that though it be a thousand to one that such a thing will happen, yet it is not sure, but very probable. (Chillingworth 1840: 295–6)

Chillingworth’s skill in argument caused some apprehension even among his own party. Locke suggested every gentleman should read him to learn the principles of correct reasoning (Locke 1989: 320–1). The essentials of such ideas on probability became a staple of moderate English natural theology in such influential authors as John Wilkins and John Tillotson (Shapiro 1969: 229–34; Ferreira 1986, ch. 2; Reedy 1993: 90–2).

15.6 Scientific Hypotheses: Certain or Probable?

The new experimental paradigm of scientific research, pursued especially in England, posed a number of problems for the probability of the knowledge arising. Medieval science had relied on confronting theory with generally known and widely accessible experiences, such as that heavy bodies fall. That was satisfactory for those sciences where conceptual analysis dominated, such as geometry, the mathematics of motion, and economic analysis. It meant however that medieval and Renaissance science was weak in such areas as chemistry and the physics of fluids, where there is little progress without precision measurement and controlled experiment. In arguing from the highly contrived experiments needed in those sciences, scientists like Boyle and Newton faced three logical problems. The first was that the reliability of testimony came to the fore, since an experiment is a particular historical occurrence, not easily and cheaply repeated, which has to be reliably reported on so as to found knowledge solidly. Like a marvel but unlike common experience, it needs credible testimony to support it, though unlike a marvel it is repeatable. The second is that experiments, being particular, create a problem as to their inductive generalizability: having observed a consistent effect several times, what is the reliability of the belief that the same will be observed under the same conditions again, perhaps in distant times and places? Thirdly, having established such generalizations, what is their relation to the postulation of
hidden causes such as atoms or mechanisms to explain them? Are those hypotheses on unobserved causes established, probable, or beyond our knowledge? Those three problems threatened, individually and collectively, to render science merely probable, and posed the problem of explaining why, if they implied that science was not fully certain, they did not imply further that it was completely uncertain.

The first two problems were generally run together. Locke for example maintains that concurrent reliable testimony is sufficient to establish with the ‘highest degrees of probability’ both particular matters of fact (‘Thus, if all English-men, who have occasion to mention it, should affirm that it froze in England the last Winter, or that there were Swallows seen there in the Summer, I think a Man could almost as little doubt of it as that Seven and Four are Eleven’) and generalizations (‘the regular proceedings of Causes and Effects in the ordinary course of Nature’ subject to constant observation, such as that iron sinks in water and swims in quicksilver) (Essay IV. xvi. 6).

Hypotheses as to hidden causes—whether atoms, Aristotelian essences, or occult qualities—were another matter entirely. Boyle puts the logical difficulty clearly with Descartes’ example of different arrangements of clockwork lying behind the same visible phenomenon: ‘For as an Artificer can set all the Wheels of a Clock a going, as well with Springs as with Weights... So the same Effects may be produc’d by divers Causes... and that it is a very easie mistake for Men to conclude, that because an Effect may be produc’d by such determinate Causes, it must be so, or actually is so’ (B 3: 255–6; Schoen 2002; van Leeuwen 1963: 94–5). In addition there was a need to distinguish science based on experiment from the ‘speculative’ philosophy of nature of the scholastics (Anstey 2005). Any inference to unseen hypotheses risked falling back into the bad old days of purely speculative ‘science’.

Locke took a generally negative view of hypotheses concerning causes. He does speak somewhat positively of the corpuscularian theory in view of its explanatory success—it ‘is thought to go farthest in an intelligible Explication of the Qualities of Bodies; and I fear the Weakness of humane Understanding is scarce able to substitute another’—but even that is in the context of the general impossibility of assurance about hidden causes (Essay IV. iii. 16; Farr 1987; Halabi 2005). Locke expresses a generalized scepticism about, if not all scientific hypotheses in principle, at least actually existing ones: ‘probable hypotheses’ may have their uses, for example as aids to memory, but ‘take care that the Name of Principles deceive us not, nor impose on us, by making us receive that for an unquestionable Truth, which is really, at best, but a very doubtful conjecture; such as are most (I had almost said all) of the Hypotheses in natural Philosophy’ (Essay IV. xii. 13; for Locke’s restriction of science to natural history and practicalities, see IV. xii. 10 and Anstey 2003).

Newton draws a sharp division between scientific knowledge and speculation at the same place as Locke. Induction from experiment, observation, and measurement may establish such general truths as the elliptical paths of planets and the
inverse square law of gravitation. But attempts to find the cause of gravity, such as an ether pressing inwards, though possibly worth pursuing amount only to hypotheses (Newton 1952, Query 21: 350–2). Similarly with light: there are the established generalizations about, for example, the different degrees of refraction of different colours, expressible in mathematical terms, and then there are the several uncertain hypotheses that might explain them:

But I knew, that the Properties, which I declar’d of Light, were in some measure capable of being explicated not only by that [corporeal hypothesis], but by many other Mechanical Hypotheses. And therefore I chose to decline them all, and to speak of Light in general terms, considering it abstractly, as something or other propagated every way in straight lines from luminous bodies, without determining, what that Thing is. (Newton 1958: 118–19; van Leeuwen 1963: 110–13)

Yet scientists found themselves unable to give up entirely the search for real insight into the hidden springs of nature, at least with a high degree of probability. Boyle states his aim ‘to make it Probable to you by Experiments... That allmost all sorts of Qualities... may be produced Mechanically... the Doctrine (or rather the Hypothesis), which is to be Collated with, and to be either Confirmed, or Disproved by, the Historick Truths, that will be deliver’d concerning Particular Qualities (& Forms)” (B 5: 302–5). Signs of an excellent hypothesis include sufficient grounds, auxiliary proofs, simplicity and the lack of alternatives, and successful predictions (S: 119).

As might be expected from one with an unrivalled insight into nature, Newton was not prepared to concede much to uncertainty. His considered view on the question is that in a paragraph of the celebrated Query 23, appended to the second (1706) edition of his Opticks. Centuries of debate as to Newton’s views in the Query have been occasioned, in part, by an ambiguity as to what sort of scientific theory about causes can be established conclusively—whether theories previously thought speculative causal hypotheses might actually be capable of proof. Newton begins with an assertion (“it seems probable to me”) that much of physics is rightly explained by supposing matter composed of tiny solid massy impenetrable and indestructible particles endowed with gravitational force and other principles as necessary to explain other properties such as cohesion. The causes of their having such properties remain unknown, but ‘I scruple not to propose the Principles of Motion above-mention’d, they being of very general Extent, and leave their Causes to be found out’. He then launches into a methodological comment:

As in Mathematicks, so in Natural Philosophy, the Investigation of difficult Things by the Method of Analysis, ought ever to precede the Method of Composition. This Analysis consists in making Experiments and Observations, and in drawing general Conclusions from them by Induction, and admitting of no Objections against the Conclusions, but such as are taken from Experiments, or other certain Truths. For Hypotheses are not to be regarded in experimental Philosophy. And although the arguing from Experiments and
Observations by Induction be no Demonstration of general Conclusions; yet it is the best way of arguing which the Nature of Things admits of, and may be looked upon as so much the stronger, by how much the Induction is more general. And if no Exception occur from Phaenomena, the Conclusion may be pronounced generally. But if at any time afterwards any Exception shall occur from Experiments, it may then begin to be pronounced with such Exceptions as occur. By this way of Analysis we may proceed from Compounds to Ingredients, and from Motions to the Forces producing them; and in general, from Effects to their Causes, and from particular Causes to more general ones, till the Argument end in the most general. This is the Method of Analysis: And the Synthesis consists in assuming the Causes discover’d, and establish’d as Principles, and by them explaining the Phaenomena proceeding from them, and proving the Explanations. (Newton 1717, Query 31: 380–1; related texts discussed in McGuire 1970)

It is clear that Newton believes ‘analysis’ delivers well-established general conclusions, including conclusions about causes (and without the need for any further confirmation by their predictions). What is less clear is whether that extends to causes as hidden as corpuscles, or whether it is restricted to more evident and measurable causes such as gravity (as distinct from any further causes of gravity). The impression Newton leaves, in the context, is that it does so extend. But the ambiguity as to whether it does is—it may be suspected—deliberate. That impression is confirmed by Newton’s several changes of mind in draft when he, following Boyle, tackles the awkward question of what properties of macroscopic bodies can be extrapolated to the sub-microscopic world: why should the corpuscles be conceived to possess extension but not colour (Anstey 2000: 54–8; Shapiro 1993: 42–6)?

15.7 Locke on Probable Opinion

For Locke, probability is crucial because of the narrow compass of what can be known with certainty: ‘So in the greatest part of our Concernment, [God] has afforded us only the twilight, as I may so say, of Probability, suitable, I presume, to that State of Mediocrity and Probationership, he has been pleased to place us in here’ (Essay IV. xiv. 2; Ashcraft 1969).

Locke’s Essay concerning Human Understanding contains a short chapter on probability, followed by a longer one on the degrees of assent. The distinction between the two is clear: degrees of assent are psychological entities, probabilities are objective reasons for beliefs, and the relation between the two is that ‘Our Assent ought to be regulated by the grounds of Probability’ (IV. xvi. 1; alleged confusions in this distinction in Wolterstorff 1996: 48–50). Locke’s account of both probability and assent is generally traditional. The basic ground of probability is that expressed in the Aristotelian phrase, what happens ‘for the most part’; even the
reliability of testimony depends on it, as when we believe what a geometer tells us about a result whose proof we do not understand because he is not ‘wont to affirm anything contrary to, or besides his Knowledge’ (IV. xv. 1). The grounds of probability are two: ‘The conformity of anything with our own Knowledge, Observation and Experience’, and testimony (IV. xv. 4). ‘Conformity’ means similarity to other observed cases: ‘if another tells me he saw a Man in England in the midst of a sharp Winter walk upon Water harden’d with cold; this has so great conformity with what is usually observed to happen, that I am disposed by the nature of the thing itself to assent to it’. But a King of Siam, told by a Dutch ambassador that water in his country froze, refused to believe it; on Locke’s account, reasonably (IV. xv. 5). The mere opinion of others, though often influential, is not a genuine ground of probability.

Locke situates probabilistic as much as demonstrative reasoning in his theory of ideas, by emphasizing that both concern the agreement or disagreement of ideas rather than the syllogistic following of chains of propositions. Probabilistic reasoning, which requires the balancing of intuitively felt reasons for and against the agreement of two ideas, is particularly unsuited to formal syllogistic reasoning (IV. xvii. 4, 5, 16).

As was also traditional, Locke graded the degrees of assent rather finely, but qualitatively: ‘such different Entertainment, as we call Belief, Conjecture, Guess, Doubt, Wavering, Distrust, Disbelief, etc.’ (IV. xvi. 9). Reaching the correct degree on the evidence is not easy, even with goodwill and a desire to know, because it involves balancing the often numerous reasons for and against. And in addition, there is the threat of further yet unknown relevant evidence: ‘in matters of Probability,’ tis not in every case that we can be sure, that we have all the Particulars before us, that any way concern the Question; and that there is no evidence behind, and yet unseen, which may cast the Probability on the other side, and out-weigh all, that at present seems to preponderate with us’ (IV. xvi. 3). The most genuinely difficult cases for evaluating probability, however, are two: firstly, where evidence conflicts, for example where testimony contradicts common experience (IV. xvi. 9) and secondly, where we make conjectures about matters beyond observation and hence not supportable by testimony, such as whether there is life on other planets or hypotheses about unseen causes, where we must rely on very fallible though not useless arguments from analogy (IV. xvi. 12).

Locke does go beyond the tradition in one respect: in discussing whether belief in a probable opinion is voluntary. That in turn raises moral problems of uncertain belief (Ayers 1994, 1: 106-10). In principle, and for clear cases, Locke holds that assent is involuntary: ‘As Knowledge, is no more arbitrary than Perception: so, I think, Assent is no more in our Power than Knowledge... and what upon full Examination I find the most probable, I cannot deny my Assent to’ (IV. xx. 16). In practice, however, where there is some balance in the reasons for and against a proposition, and there is reason to believe one is not in command of all the relevant
evidence, 'there Assent, Suspense, or Dissent, are often voluntary Actions' (IV, xx. 15). From a moral perspective, there is then scope for criticism of those who stop enquiry into the reasons on both sides too early, and of those who give undue weight to slight grounds for doubt (IV, xx. 14).

On the other hand, one may excuse those who have genuine difficulties finding the truth, given the difficulties of evaluating probabilities in many cases. Toleration of the opinions of others is therefore indicated. Given that one must have opinions without indubitable proofs of them, and that one should not give up an opinion merely because one learns of a contrary argument that one cannot immediately answer, one should extend peace and friendship to those who persist in what one takes to be errors: 'At least those, who have not thoroughly examined to the bottom all their own Tenets, must confess, they are unfit to prescribe to others; and are unreasonable in imposing that as Truth on other Men's Belief, which they themselves have not searched into, nor weighed the Arguments of Probability' (Essay IV, xvi.4; Rogers 1992; similar ideas less explicitly in the Letters on Toleration: Owen 2007) But those with unreasonable and dangerous opinions, such as Catholics and atheists, are excluded from toleration (Schulman 2009).

On questions of faith, Locke follows Chillingworth's distinctions: 'I crave leave to say with Mr. Chillingworth, "that I do heartily acknowledge and believe the articles of our faith to be in themselves truths as certain and infallible, as the very common principles of geometry and metaphysics. But that there is not required of us a knowledge of them, and an adherence to them, as certain as that of sense or science"' (Locke 1823: 4. 275; Helm 1973; Snyder 1986; Wolterstorff 1996: 118–33).

In the fourth edition of the Essay (1700), Locke added a new chapter attacking 'Enthusiasm'. Like Hooker, he diagnoses a failure to proportion assent to probability in uncertain matters. Thus some psychological explanation of an enthusiast's fervour in his belief is called for: 'whatsoever degrees of Assent he affords it beyond the degrees of that Evidence, 'tis plain all that surplusage of assurance is owing to some other Affection, and not to the Love of Truth'. Where Hooker had suggested doubt in his own salvation as the explanation, Locke prefers too great self-esteem, enthusiasts having 'often flatter'd themselves with a persuasion of an immediate intercourse with the Deity'. Naturally, having deliberately distorted their own belief, enthusiasts are keen to impose their opinions on others (Essay IV, xix. 1, 2, 5).

Not everyone was happy with the rising tide of probabilities. One of the victims of the intolerance of Catholics approved by Locke was the Aristotelian John Sergeant, Secretary of the Catholic Chapter in London, who several times had to hide and flee abroad. Against Locke and the other Anglican 'Probability Men', he vigorously defended demonstrative certainty in philosophy and infallibility in religion. He attacked 'Books of Philosophy, nay, Volumes, blown up to a vast Bulk with Windy and Frothy Probabilities, and petty inconclusive Topicks; which, like Rank Weeds, have over-run that Rich Soil where Science ought to have been Sown' (Sergeant 1697: Preface, sig. a6). He is sarcastic at the idea of a merely morally
certain rule of faith (Krook 1993: 9, 85, 123). Probabilities, he alleges, 'are not capable of any [right measure]; but, like desultory Ignis-fatui, whiffle now to this side, now to that... so that none can take their just Dimension, or Proportion' (Sergeant 1697: 451; Krook 1993: 124). History was not on his side.

15.8 Mathematics of Dice and Bills of Mortality

The significance of the mathematical results on dice of Pascal, Fermat, and Huygens in the 1650s (the latter translated in Arbuthnot 1692) took some time to become clear. Historians of mathematics see a ‘dark ages of (mathematical) probability’ from the time of those initial discoveries till the publication of major treatises after 1700, particularly Bernoulli’s Ars conjectandi. In that period, combinatorial results on dice were largely taken to be curiosities of recreational mathematics, of little significance for understanding uncertainty in general. Newton answered a dice problem posed by Pepys—not entirely correctly (Stigler 2006; some probabilistic reasoning by Newton on biblical chronology in Sheynin 1971)—while Thomas Strode’s 1678 Short Treatise of the Combinations, Elections, Permutations and Composition of Quantities improved in some respects on Pascal’s combinatorial results (Strode 1678; Stigler 1988). One writer who saw some possibilities in using the new results on dice as a model for uncertainty was Richard Cumberland, who argued that while the selfish strategy he attributed to Hobbes might succeed occasionally, it would not do so in the majority of cases, just as a man who wagers to throw two sixes on the first throw of two dice might succeed, but would have odds of 35 to 1 against doing so (TLN; Stigler 1988).

Of much greater interest is the work of Graunt, Petty, and Halley on bills of mortality, which initiated the science of statistics as opposed to probability—in this context, probability refers to inference from causes to observations (for example from biases in dice to expected relative frequencies in series of throws), while statistics means the reverse, inference from observations to causes (for example, from sample to population proportions in opinion polling).

The Baconian ideal of practical knowledge based on observation and experiment could lead, in one direction, to careful scientific experiments and the collection of natural history observations from distant places. But if one were to pursue philosophy ‘like a Lord Chancellor’, as Harvey said of Bacon (Aubrey 2000: 143), one would be just as interested in enquiries on the management and reform of society based on inferences from the kind of data now called statistical and economic. The lack of understanding of such possibilities meant that there was little data collected
in the early seventeenth century, and hence few opportunities for analysis. A vision of what might be done was promoted by William Petty, who after exposure while young to the advanced Dutch economy and contact with Hobbes, was given charge of the information management aspects of Cromwell’s plundering of Ireland. Besides massively enriching himself, he completed a large survey of Ireland which convinced him of the necessity of statistical information for making governmental decisions (Fox 2009; Stone 1997, ch. 1; Mykkänen 1994). He recognized the need for the information to be quantitative, writing in his Political Arithmetick (1676, published 1690):

The Method I take...is not yet very usual; for instead of using only comparative and superlative Words, and intellectual Arguments, I have taken the course (as a Specimen of the Political Arithmetick I have long aimed at) to express myself in Terms of Number, Weight, or Measure; to use only Arguments of Sense, and to consider only such Causes, as have visible Foundations in Nature. (Petty 1690: sig. a3v–a4r)

On the basis of partial records for poll and other taxes he attempted to reach estimates for such quantities as the population of Ireland. The amount of extrapolation and guesswork is excessive and his conclusions sometimes fanciful, but the demonstration of what might be reached on the basis of sound data was convincing. Equally valuable was his attempt to use the data to investigate causal questions of economics, such as why Irish agricultural labour was less productive than English although there was more land per person. Work of a similar nature was undertaken by Gregory King in the 1690s in his estimates of national wealth and population, by which time there was more data to hand but still no serious investment in the collection of reliable and complete statistics (Taylor 2005; Stone 1997, ch. 3).

A more critical approach to inference from statistical data was taken by Petty’s associate John Graunt in his investigation of the London bills of mortality. Graunt shared with Petty a Baconian perspective and a determination to reach reasonable conclusions from imperfect data (Kreager 1988), but had a better appreciation of the pitfalls, and a conception of how to avoid them by bringing different data to bear on the same conclusion. The data available to him consisted of weekly figures on deaths in London from 1603, classified by causes of death as estimated by ‘ancient matrons, sworn to their office’. For the later part of the period there were also records of burials and christenings (Church of England only) for each sex, and some comparative bills of mortality for a few country parishes. He begins by printing yearly tables of the data. The tabular form and the reduction of data to summary figures are both substantial advances in allowing data to be understood. He understands that there are problems with the reliability of the data, for example the underreporting of deaths from syphilis because of the shame of the disease, but he attempts to allow for data problems and investigate such hypotheses as ‘that the more sickly the year is, the less fertile of births’. He recognizes that a major problem
lies in the lack of knowledge of the size of the population of London, complicated by the fact that it was increasing strongly in the period 1603–1660 and was affected by temporary emigration in plague years. He estimates the population of London by three methods: from Christenings, from burials, and from multiplying the area of a map of London by estimates for the number of houses per unit area and the number of people per house; he finds (suspiciously close) agreement among the three methods (Graunt 1662; Hald 1990: chs 7–8).

Contemporaries were particularly interested in Graunt’s attempt to construct from the information on mortality (which did not record age of death) a life table (that is, a table of the average ages of people’s deaths or probability of death, as is needed to base life insurance premiums on data). The project was completed more successfully in 1693 by Edmond Halley, who had available mortality data from Breslau that did include age of death (Halley 1693; Hald: 131–41). The foundations were laid for the slow progress of statistical methods.

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