HOW INTERACTIONS BETWEEN HUMANITIES AND SCIENCE HAVE SHAPED OUR KNOWLEDGE

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Abstract

The idea that the humanities and the sciences are, and always have been, separate is alive as much as ever. It structures the entrenched organization of the university; it is taken for granted in the everyday thinking of academics. And yet it is wrong. It fails to fit the practice and the organization of scholarship prior to the 19th century. Likewise, it fails to fit what happened in its own time, and what has happened ever since. In this paper, I will discuss shared methods and practices in the humanities and the sciences, and I will show how they have migrated across disciplines. Thus linguists developed grammar formalisms that were used in designing the first programming languages, philologists provided tools for text reconstruction that were applied to DNA analysis, and historians developed source-critical

Rens Bod fotografert under sitt foredrag i Det Norske Videnskaps-Akademi. Foto Thomas Barstad Eckhoff.

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methods that are used in forensic science, evidence-based medicine and other fields. These interactions suggest that we need to rethink the idea of the unity of knowledge-making disciplines.

Introduction

Can we understand the development of science without taking the development of the humanities into account? In this essay I intend to show that we had better not. There is a preconception so deeply rooted in our culture that even scholars seem to believe it. This is the assumption that whatever the humanities do, they do not solve concrete problems, let alone result in technological applications.[2] Nevertheless, a quick glance at the general history of the humanities[3] shows otherwise: Contrary to common wisdom, insights and methods from the humanities did solve concrete problems, and did result in applications that had a profound impact on science and technology. To be sure, such utilizations of humanistic insights and methods sometimes emerged after considerable time. But time after time, methods and theories from the humanities have been picked up and used in science, technology and other disciplines – and indeed vice versa.

It is therefore surprising that overviews of the history of science [4] leave

2 Examples of this preconception can be found in almost any discussion on the humanities, including Martha Nussbaum, *Not for Profit: Why Democracy Needs the Humanities*, Princeton University Press, 2010; Stefan Collini, *What Are Universities For?*, Penguin Books, 2012; Jörg-Dieter Gauger and Günther Rüther (eds.), *Warum die Geisteswissenschaften Zukunft haben!*, Herder, 2007; Stanley Fish, "Will the Humanities Save Us?", *New York Times,* January 6, 2008. Jonathan Bate (ed.), *The Public Value of the Humanities,* Bloomsbury Academic, 2010. For a historical overview, see Helen Small*, The Value of the Humanities*, Oxford University Press, 2013.

3 See e.g. Rens Bod, *A New History of the Humanities: The Search for Principles and Patterns from Antiquity to the Present* (Oxford: Oxford University Press, 2013); James Turner, *Philology: The Hidden Origins of the Modern Humanities* (Princeton: Princeton University Press, 2014). See also the three edited volumes on the comparative history of the humanities: R. Bod, J. Maat and T. Weststeijn (eds.), *The Making of the Humanities, Vol. I: Early Modern Europe*, Amsterdam University Press, 2010; R. Bod, J. Maat and T. Weststeijn (eds.), *The Making of the Humanities, Vol. II: From Early Modern to Modern Disciplines*, Amsterdam University Press, 2012; R. Bod, J. Maat and T. Weststeijn (eds.), *The Making of the Humanities, Vol. III: The Modern Humanities*, Amsterdam University Press, 2014.

4 This is not the place to summarize the historiography of science, but overviews of the history of science are as old as the field itself and continue to be written up to the current day. They include William Whewell, *History of the Inductive Sciences*, 3 volumes,

out the impact from the humanities. In the following I review some of the far-reaching effects of humanistic inquiry and discuss their influence on science and technology, and vice versa. They suggest the need for an integrated view on science and humanities.

Linguistics and the impact of grammar

One of the most salient technological developments during the last century has been the emergence of information technology. While this development is not usually seen as a product of the humanities, it was a humanistic discipline – the study of language – that made information technology possible. A fundamental insight in linguistics is that language can be described by a system of rules, known as a *grammar*. The concept of grammar is older than the first systematic Greek descriptions of language. The first extant grammar is found in the work *Ashtadhyayi* (Eight Books) by the Indian grammarian Panini[5] who lived around 500 BC.[6] The *Ashtadhyayi* contains one of the most complete grammars in existence.[7] Panini developed a set of 3,959 rules that covers all possible sentences of Sanskrit. That is, Panini's grammar can determine whether a given sequence of sounds is a correctly formed sentence in Sanskrit. Panini's grammar is still unsurpassed.[8] After two and a half thousand years, the efficacy of this system of nearly four thousand complex interconnected rules remains undisputed.

Panini was not just a descriptive linguist, however; the underlying formalism he developed is just as interesting. To write down his 3,959 rules,

Parker, 1837; George Sarton, *Introduction to the History of Science,* 3 volumes, Williams and Wilkins, 1931–1947; Stephen Mason, *A History of the Sciences*, Macmillan, 1962; William Dampier, *A History of Science and Its Relation to Philosophy and Religion*, Cambridge University Press, 1966; James McClellan and Harold Dorn, *Science and Technology in World History*, Johns Hopkins University Press, 1999; Frederick Gregory, *Natural Science in Western History*, Wadsworth Publishing, 2007; Patricia Fara, *Science: A Four Thousand Year History*, Oxford University Press, 2009.

5 The transcription from Sanskrit by Indologists is usually Pāṇini, where the accent is on the first syllable ('Pā'). For this paper I will use the more common transcription Panini.

6 Paul Kiparsky, 'Paninian Linguistics', in *The Encyclopedia of Language and Linguistics* (Amsterdam: Elsevier, 1993).

7 For an accessible translation of the *Ashtadhyayi*, with examples and commentaries, see Panini, *The Ashtadhyayi – Translated into English by Srisa Chandra Vasu* (1923; repr., Charleston: Nabu Press 2011).

8 Esa Itkonen, *Universal History of Linguistics* (Amsterdam and Philadelphia: Benjamins, 1991), 12ff.

he used a grammatical system that is nowadays known as *rewrite grammar*.[9] His rewrite grammar consists of rules that indicate how a certain part of a sentence (a 'phrase') can be built up ('rewritten') out of other, smaller phrases and words, provided they appear in a certain combination. In fact not every combination of words or phrases leads to a grammatical sentence. For example, in English there is a rule that states that a nominal phrase can consist of an article and a noun, as in 'the house'. Clearly, these words only form a correct phrase if the article appears before the noun.

Panini's approach in the *Ashtadhyayi* was to make his grammar system explicit and comprehensive. He devised a set of rules that, using a combination of a finite number of lexical units (the *word stems*), could cover all correct Sanskrit utterances.[10] Panini invented an ordered system of rules in order to achieve this goal. His rules are applied in a certain order so as to arrive at a linguistic utterance. This corresponds with the concept of an algorithm: a procedure that generates a result in a finite number of sequential steps. Panini's rules are also *optional*,[11] which means there is always more than one possible choice (otherwise it would only be possible to cover one linguistic utterance). He introduced a metarule in order to make his system consistent: 'If two rules conflict, the last rule prevails.'[12] Panini organized his grammar so that this metarule is always valid.

One of the other influential ideas in Panini's system of rules is that a grammar rule can invoke itself – a given construction can contain another example of that construction. This is known as recursion, in Sanskrit known as *Nyāya*. Recursion occurs for example in the English sentence, 'He was harassed by the individual who was caught by the policeman who was spotted by the photographer'. We can make this sentence longer, indeed as long as we want, by recursively applying the grammatical rule for subordinate clauses in English (and by choosing different words from the lexicon). The use of recursion allowed Panini to describe the unlimited number of Sanskrit sentences with a finite number of rules.

The invention of a precise system of grammar rules together with the concept of recursion makes Panini the most original linguist of antiquity.

9 Frits Staal, *Universals: Studies in Indian Logic and Linguistics* (Chicago: University of Chicago Press, 1988), 3.

10 Vidyaniwas Misra, *The Descriptive Technique of Panini: An Introduction*, Mouton, 1966, pp. 43ff.

11 Panini's rule 2.1.11 (*vibhasa*) in the *Ashtadhyayi*.

12 Panini's rule 1.4.2 in the *Ashtadhyayi*.

His grammar is regarded as a major monument in human thought.[13] Only towards the end of the eighteenth century was Panini's grammar discovered by European scholars, and it took another century and a half before it was relatively well understood. In the 1950s, the renowned linguist Noam Chomsky based his work on Panini's ideas and called him his spiritual father.[14] Yet it is still an open question whether a finite system of rules can represent a 'complete' grammar of a living language[15] – only for a dead language like Sanskrit does this seem to be beyond doubt.

Nevertheless, the notion of grammar appeared to be exceptionally well suited for describing – and creating – a rather different kind of language: high-level programming languages for computers. In contrast with low-level programming languages, high-level programming languages do not use zeroes and ones or other machine-like codes for programming. Instead they use statements that resemble sentences and phrases in human languages, including recursive structures (which are only in a second stage translated into the underlying machine language and finally into zeroes and ones by a separate algorithm). It was Panini's formalism of grammar with recursion that came to be applied by John Backus to design the full syntax of the first high-level programming language *ALGOL60*. The resulting formalism is also referred to as the Panini-Backus-form.[16] Virtually all current high-level programming languages are written in a formalism that incorporates the linguistic notion of a grammar with recursion.[17] Such a grammar determines whether a given sequence of statements forms a correct expression in a particular programming language. If the statements follow the rules of the grammar, they are correct, which means that they can be processed by the underlying machine language.

The linguistic formalism of rewrite grammar was taken over and reused by computer scientists giving the field of computer science and information technology an unprecedented impulse. In the history of computer science, the history of linguistics plays a key role.[18]

13 Leonard Bloomfield, *Language* (1933; repr., Chicago: University of Chicago Press, 1984), 11.
14 For a discussion of the relation between Panini and Chomsky, see Bod, *A New History of the Humanities*, 290–295.
15 See Rens Bod, *Beyond Grammar* (Chicago: University of Chicago Press, 1998).
16 P.Z. Ingerman, 'Panini-Backus Form Suggested', *Communications of the ACM*, 10(3), 1967, p. 137.
17 See Erol Gelenbe and Jean-Pierre Kahane (eds.), *Fundamental Concepts in Computer Science*, Imperial College Press, 2009, p. 99.
18 See Edwin Reilly, *Milestones in Computer Science and Information Technology*, Green-

Philology and the biological appropriation of text reconstruction techniques

Concepts and methods from the language sciences also found their way into the life sciences. In the course of the 1950s, biologists came to represent organisms and molecules as information systems by using linguistic tropes and textual analogies.[19] The human genome was viewed as a textual information system: the way DNA sequences could be replicated, mutated and contaminated were phrased in terms of philological and computational concepts. These representations of heredity did not arise from the inner logic of DNA genetics. Instead, they had been transported into molecular biology from cybernetics, information theory and computer science[20] who in turn had imported these metaphors from the language sciences, as we discussed above.[21] But while computer scientists had looked mainly at linguistics, molecular biologists (also) looked at stemmatic philology – the theory of text reconstruction that creates a tree of variants (a stemma) of the transmission of a text so as to deduce its presumed archetype.

The way biologists made use of textual concepts in DNA genetics was not just a matter of metaphor or analogy. If we look at the deeper level of formalisms used in philology and DNA genetics, we can discern an equivalence between 19th-century stemmatic philology and 20th-century molecular biology. This equivalence went even further than the one discussed between linguistics and computer science: not only was the formalism of a philological tree of texts (or stemma) taken over by biologists but also several of the rules or operations that philologists had developed to operate on a stemma.

The history of the notion of stemma has been investigated at various places. Robert O'Hara draws attention to the presence of "trees of history" glossed as "branching diagrams of genealogical descent and change" in a

wood Publishing Group, 2003, pp. 43ff; Martin Davis, Ron Sigal, and Elaine Weyuker, *Computability, Complexity, and Languages: Fundamentals of Theoretical Computer Science*. Academic Press, Harcourt, Brace, 1994, p. 327.

19 See Henry Hoenigswald and Linda Wiener, *Biological Metaphor and Cladistic Classification: An Interdisciplinary Perspective*, University of Pennsylvania Press, 1987. See also Lily Kay, *Who Wrote the Book of Life?: A History of the Genetic Code*, Stanford University Press, 2000, pp. 2–3.

20 Steve J. Heims, *The Cybernetics Group*, MIT Press, 1991; Lily Kay, "Cybernetics, Information, Life: The Emergence of Scriptural Representations of Heredity", *Configurations* 5.1 (1997) 23–91.

21 The prime example in information theory was language – see Claude Shannon and Warren Weaver, *The Mathematical Theory of Communication*, University of Illinois Press, 1949.

large variety of disciplines: textual criticism, evolutionary biology, historical linguistics and information science.[22] The first ever stemma seems to have been produced for Swedish legal manuscripts by Carl Johan Schlyter in 1827.[23] It predates the use of the first genealogical trees in linguistics by August Schleicher in 1850 and evolutionary biology by Charles Darwin in 1859. It was the philologist Karl Lachmann (1793–1851) who in 1850 spelled out the rules that applied to a philological stemma of texts and how they could be used in reconstructing the original text from hereditary copies in the family tree.[24] While the origins of this technique of text reconstruction are much older – it can be traced back to the early humanists, in particular to Angelo Poliziano [25] – only in the nineteenth century this humanistic practice was turned into a more or less orderly set of rules. These rules were further refined and mathematically formalized in the early twentieth century,[26] which resulted in several formal rules or operations for describing the 'errors' in variants due to copying mistakes, such as rules for *substitution*, *deletion* and *insertion* of elements.[27]

These operations of substitution, insertion and deletion turned out to be applicable both to sequences of lexical elements and to sequences of DNA elements – thus independent of whether these elements were due to *scribal alterations* arising over successive generations of recopied manuscripts or due to *genetic mutations* in DNA molecules occurring through successive

22 Robert O'Hara and Peter Robinson, "Computer-Assisted Methods of Stemmatic Analysis", *Occasional Papers of the Canterbury Tales Project,* 1, 1993.

23 Schlyter's stemma was added in the appendix (ill. 2) of Carl Johan Schlyter and Hans Samuel Collin (eds.) 1827. *Westgöta-lagen*, vol.1, Häggström, 1827. See also Britta Olrik Frederiksen,"Stemmaet fra 1827 over Västgötalagen – en videnskabshistorisk bedrift og dens mulige forudsætninger." *Arkiv för nordisk filologi*, 124, 2009, pp. 129–150.

24 SebastianoTimpanaro, *La genesi del metodo del Lachmann*, Liviana, 2nd ed., 1981, pp. 5–13. Translation by Glenn Most, *The Genesis of Lachmann's Method*, University of Chicago Press, 2005.

25 Angelo Poliziano, *Miscellanea*, 1489. For the origins of formal text reconstruction, see Anthony Grafton, *Defenders of the Text* (Cambridge, MA: Harvard University Press, 1991), 56ff. See also See Glenn Most, "*Quellenforschung*", in R. Bod, J. Maat and T. Weststeijn (eds.), *The Making of the Humanities, Vol. III: The Modern Humanities*, Amsterdam University Press, 2014, pp. 207–218.

26 See Walter Greg, *The Calculus of Variants: An Essay on Textual Criticism* (Oxford: Oxford University Press, 1927); For an overview, see Vinton Dearing, *Principles and Practice of Textual Analysis* (Berkeley: University of California Press, 1974).

27 For a history of these copying rules in stemmatic philology, see Kari Kraus, "Conjectural Criticism: Computing Past and Future Texts", *Digital Humanities Quarterly*, 3(4), 2009 (no page numbers).

generations.[28] At the level of the formalism used and (several of the) operations applied, there is not just analogy but equivalence between philology and genetics![29] That is, both in philology and genetics a sequence (be they words in the case of a manuscript, or nucleotides in the case of DNA) is copied on the basis of the same operations. When changes occur, textual changes and DNA mutations are described by the same system of rules or operations. For example, the operation of substitution of one word for another (in text copying) is equal to the substitution of a nucleotide for another (in DNA copying). The elements differ, but the abstract rule or operation is the same. And the operation of insertion or deletion of words is formally equal to the rule of insertion and deletion of nucleotides. Even philological contamination, whereby pieces from several manuscripts are combined, follows the same formal rule in DNA genetics, known as genetic recombination.[30]

Thus the formalism and rule system from the discipline of textual philology were decontextualized and next recontextualized in the new field of genetics. We cannot really grasp the history of science, in this case 20th-century genetics, if we neglect the long-term history of its methods, some of which originate in the humanities, in this case 19th-century stemmatic philology. But the opposite also holds. In fact, the story does not finish here. Over the last few decades, stemmatics in biology has led to the new field of *cladistics* which has turned into a highly sophisticated computer-assisted methodology for creating history trees in biology. Although originating in philology, cladistics has now influenced philology and historical linguistics again, not only technically but also conceptually.[31] Cladistic software is currently applied to stemmatic philology to derive highly sophisticated trees of texts that lead to new questions in philology.[32] Thus the interaction between human-

28 See Willi Hennig, *Phylogenetic Systematics*, University of Illinois Press, 1966.

29 See Don Cameron, "Problems in Manuscript Affiliation", in Hoenigswald, Henry, and Linda F. Wiener, *Biological Metaphor and Cladistic Classification: An Interdisciplinary Perspective*, University of Pennsylvania Press, 1987, p. 302.

30 See Kari Kraus, *ibidem*, 2009. See also Caroline Macé, Philippe Baret, Andrea Bozzi and Laura Cignoni, (eds.), "The Evolution of Texts: Confronting Stemmatological and Genetical Methods", *Proceedings of the International Workshop held in Louvain-la-Neuve on September 1–2, 2004*, Istituti Editoriali e Poligrafici Internazionali, 2006.

31 See N. Platnick and H. Cameron, "Cladistic methods in textual, linguistic, and phylogenetic analysis", *Systematic Zoology*, 1977, 26, pp. 380–385. For an overview of cladistics and other methods in philology, see Macé et al., *ibidem,* 2006.

32 See e.g. N. Cartlidge, "The Canterbury Tales and cladistics", *Neuphilologische Mitteilungen*, 102, 2001, pp. 135–150; Heather Windram, Prue Shaw, Peter Robinson and Christopher Howe, "Dante's *Monarchia* as a test case for the use of phylogenetic methods in

istic and scientific disciplines is a highly dynamic one; it is rarely a one-way transfer: formalisms and rule systems from philology first entered biology and next came back to philology in computational form. The same happened with linguistics and computer science: the linguistic notion of grammar was first transferred to computer science, from which the notion of computational grammar came back to linguistics, leading to the field of computational linguistics.

The effectiveness of historical source criticism

One might object that linguistics and stemmatic philology, with their formalized methods, do rather belong to the sciences than to the humanities – it is actually the historical disciplines that are the real backbone of humanistic research. Historiography, as the German philosopher Wilhelm Dilthey put it, is not concerned with explaining events but with understanding them, as illustrated by the German word *verstehen*.[33] In the view of the Neo-Kantians, rather than aiming at finding general rules or regularities (nomothetic), as linguistics and stemmatic philology do, historiography focuses on the specific (idiographic).[34] Yet it is also the discipline of historiography that developed the general and widely applicable method of *source criticism*. This method is used not only in historical research but also in other disciplines for critically evaluating sources especially in forensic science, evidence-based medicine and jurisprudence.[35] It is, for instance, used at the International Court of Justice and at the International Criminal Court to determine whether a source is authentic or whether it has been forged.

stemmatic analysis", *Literary and Linguistic Computing,* 23, 2008, pp. 443–463.

33 Wilhelm Dilthey, *Einleitung in die Geisteswissenschaften: Versuch einer Grundlegung für das Studium der Gesellschaft und der Geschichte*, 1883, pp. 29ff. For an English translation, see Wilhelm Dilthey, *Selected Works,* Volume I, translated and edited by Rudolf Makkreel and Frithjof Rodi, Princeton University Press, 1991.

34 Wilhelm Windelband, *Geschichte und Naturwissenschaft*, 3rd edition, Heitz, 1904. The discussions by Dilthey and Windelband are more subtle than summarized here. See Bouterse and Karstens, this Focus section, for more details.

35 See Richard Riegelman, *Studying a Study and Testing a Test: How to Read the Medical Evidence*, Lippincott Williams and Wilkins, 2004. See also Charles Bazerman, *The Informed Writer: Using Sources in the Disciplines*, Houghton Mifflin, 1995; Lawrence McCrank, *Historical Information Science: An Emerging Unidiscipline*, Medford, N.J., Information Today, 2002.

The notion of source criticism itself has a notable history. It can already be found in Herodotus who compared contradicting sources in terms of plausibility.[36] It developed via Thucydides who only accepted sources based on eyewitness accounts,[37] and Polybius who stressed personal experience as the most reliable source,[38] into the more textual approach to historical source criticism that we find in the Roman republic and onwards, where written sources were regarded as the most reliable.[39] Unlike oral sources, written sources guaranteed some level of verifiability, but the problem of contradictory sources remained, and thus factors such as the authority of a written source played a fundamental role in determining whether to accept it as a reliable witness.

Usually, the nineteenth-century historian Leopold von Ranke (1795–1886) is credited with the invention of a systematic source criticism that aims to determine whether a document corresponds to historical reality.[40] Both the content of the source and its external facets, such as the form and the carrier, were subjected to a critical analysis. Yet, a very similar kind of source criticism had already been practiced several centuries before, first by early humanists, and later during the heyday of humanist historiography in the sixteenth and seventeenth century. One of the most illustrious examples of early source criticism is Lorenzo Valla's famous rebuttal of the document known as the *Donatio Constantini* in 1440.[41] As is well known, the *Donatio* stated that the emperor Constantine had transferred authority over the Western Roman empire to Pope Sylvester I. It gave a justification for the church's worldly power. Although others had suggested earlier that the document was a forgery,[42] it was Valla who convincingly showed that indeed the document could not have been written in the fourth century during the reign of Constantine. By combining the methods of historical, lexical and logical criti-

36 Herodotus, *Histories*, 7.139.

37 Thucydides, *History of the Peloponnesian War*, 1.22.

38 Polybius, *Histories*, 1.1–4.

39 See Bod, *A New History of the Humanities*, 24–26. See also G.E.R. Lloyd, *Disciplines in the Making* (Oxford: Oxford University Press, 2009), 67–70.

40 See Kasper Eskildsen, 'Leopold Ranke's Archival Turn: Location and Evidence in Modern Historiography', *Modern Intellectual History* 5 (2008): 425–453. See also Lorraine Daston, "Objectivity and Impartiality: Epistemic Virtues in the Humanities", in R. Bod, J. Maat and T. Weststeijn (eds.), *The Making of the Humanities, Vol. III: The Modern Humanities*, Amsterdam University Press, 2014, pp. 27–42.

41 Riccardo Fubini, 'Humanism and Truth: Valla Writes against the Donation of Constantine', *Journal of the History of Ideas* 57 (1996): 79–86.

42 E.g. Nicholas of Cusa in his *De concordantia catholica*, 1433.

cism, Valla showed that a number of events, words and phrases in the document were of medieval origin and that part of the discourse was in fact logically inconsistent. Valla's demonstration was so convincing that it was immediately accepted – even (initially) by the pope – until it was used by reformers like Martin Luther in their arguments against the church, and then placed on the Index.[43]

While Valla's impact was impressive, source criticism probably had its greatest impact on early modern thought through the work of Joseph Scaliger (1540–1609) who was active at the University of Leiden in the late sixteenth and early seventeenth century.[44] Scaliger aimed at unifying all ancient histories (Graeco-Roman, Babylonian, Egyptian, Persian and Jewish) so as to create the definitive historical chronology from the earliest era to his own time.[45] In doing so, Scaliger not only had to compare many different calendar systems but a very large number of historical sources too. Scaliger therefore critically compared various historical texts, among them Manetho's list of Egyptian dynasties. Using the information from these sources, particularly about the duration of the different dynasties, Scaliger was able to date the beginning of the first Egyptian dynasty to 5285 BCE. To his dismay this date was nearly 1300 years before the generally accepted day of Creation, which according to biblical chronology had to be around 4000 BCE. However, Scaliger did not draw the ultimate conclusion from his discovery, which would have meant that either the Bible or his own method was wrong. In order to 'save the phenomena', Scaliger introduced a new time pattern – the *tempus prolepticon* – a time before time.[46] He placed every event that occurred before the Creation, such as the early Egyptian kings, in this proleptic time. Clearly, for a Protestant around 1600 it was inconceivable to cast doubt on the Bible. Yet Scaliger was too consistent to give up on his critical method just like that.

But Scaliger's discovery appeared to be a time bomb. Only a couple of generations later, an increasing number of scholars – from I. Vossius to

43 For further background on Valla, see Lodi Nauta, 'Lorenzo Valla. Italian Humanist', in *The Classical Tradition: A Guide*, ed. Anthony Grafton, Glenn Most and Salvatore Settis (Cambridge, MA: Harvard University Press, 2010).

44 For an in-depth biography of Joseph Scaliger and discussion of his works, see Anthony Grafton, *Joseph Scaliger: A Study in the History of Classical Scholarship*, 2 vols. (Oxford: Oxford University Press, 1983–1993).

45 Anthony Grafton, *Joseph Scaliger: A Study in the History of Classical Scholarship*, 2 volumes, Oxford University Press, 1983, 1993.

46 Joseph Justus Scaliger, *Thesaurus temporum*, Joannem Janssonium, 1658 [1606], p. 278.

Spinoza – realized that the only possible interpretation of Scaliger's result was that the earliest Egyptian kings had actually lived before the Biblical date of the Creation. This meant that the Bible could not be taken seriously as a historical source. Scaliger's pattern of world history conflicted with biblical chronology, and this triggered a chain of biblical criticism that resulted in the early Enlightenment.[47]

The interactions between other humanistic disciplines and the sciences

The examples of the impact of the humanities on science and technology discussed so far are by no means exhaustive. A fuller account of the impact of the humanities should certainly also mention Leon Battista Alberti's work *De pictura* (1435), which provided the first theoretical description and analysis of linear perspective. Alberti developed a completely articulated method for the illusionistic reproduction of three-dimensional objects on a two-dimensional surface (the discovery of which he attributes to the sculptor and architect Filippo Brunelleschi). This method and its impact on painting literally changed our view of the world. It not only led to a revolution in European painting and art theory, but also to entirely new design techniques in architecture which were inconceivable without the use of linear perspective.[48]

Neither should an overview of the impact of the humanities on the sciences overlook the exploration of musical dissonance and consonance by early humanists. The humanistic study of harmony revealed the synergetic interaction between theory and empiricism, which was passed on to the 'new scientists' of the seventeenth century, who elaborated it again in their own way.[49] This has in particular been studied in the relation between Vincenzo Galilei and his son Galileo Galilei. Vincenzo was a humanist, composer and music theoretician performing, among other things, experiments with the monochord. He experimented with strings of different lengths, materials and

47 At various places it has been shown that there is a direct line running from Scaliger via Saumaise and Isaac Vossius to Spinoza. See e.g. Jonathan Israel, *Radical Enlightenment*, Oxford University Press, 2002, and Eric Jorink, *Reading the Book of Nature in the Dutch Golden Age, 1575–1715*, Brill, 2010.

48 See Bod, *A New History of the Humanities*, 211–216.

49 Penelope Gouk, 'The Role of Harmonics in the Scientific Revolution', in *The Cambridge History of Western Music Theory*, ed. Thomas Christensen (Cambridge: Cambridge University Press, 2002), 223–245.

tensions, and aimed to refute some of the most influential musical theorists of his day (Gioseffo Zarlino) not just by theoretical considerations but by experiment. Galileo seems to have applied his father's empirical methodology to his own experiments with balls rolled down an inclined plane. This intricate connection between music and nature was not new, as music theory had been treated as a matter of cosmological importance ever since Pythagoras.[50] What was new, though, was that the humanists employed a strongly empirical method for the study of their subject matter (music, but also texts), in which empiricism was to have the last word, no matter how fine the underlying theory was. And in doing so these early humanists created – or should we say, 'discovered' – the synergy between theory and empiricism. They did so well before the 'new scientists' of the seventeenth century applied the empirical approach to the study of nature and brought it to great heights.[51]

The examples given so far are the tip of the iceberg. We can remind ourselves how the nineteenth-century discovery of the Indo-European language family – which at the time was called 'comparative philology' – defined our view of the relationships between peoples, for better and worse. Among other things, this discovery gave a boost to scientific racism, in particular to the hypothesis of the existence of a 'pure' Aryan race, a theory which would be taken over much later by the National Socialists.[52] This shows that the impact of the humanities is not necessarily positive. The claim that the humanities are essential to a critical mentality and democracy (as Martha Nussbaum contends[53] may deserve a more nuanced discussion. For nineteenth-century scholars like Friedrich Max Müller and Christian Lassen it was straightforward that the linguistic evidence for an ur-language meant that there was a pure Aryan race and that some other races were endlessly mixed and impure.[54] Some of the most critical linguists and philosophers of the time ac-

50 H. Floris Cohen, 'Music as Science and as Art: The 16th/17th-Century Destruction of Cosmic Harmony', in R. Bod, J. Maat and T. Weststeijn (eds.), *The Making of the Humanities, Vol.1: Early Modern Europe,* Amsterdam University Press, 2010, pp. 59–71.

51 See Stillman Drake, 'Renaissance Music and Experimental Science', *Journal of the History of Ideas* 31 (1970): 483–500. But see also H. Floris Cohen, *Quantifying Music: The Science of Music at the First Stage of the Scientific Revolution*, *1580–1650* (Boston: Reidel Publishing Company, 1984).

52 Stefan Arvidsson, *Aryan Idols: Indo-European Mythology as Ideology and Science* (Chicago: University of Chicago Press, 2006), 241ff.

53 Martha Nussbaum, *Not for Profit: Why Democracy Needs the Humanities*, Princeton University Press, 2010.)

54 See Georges Vacher de Lapouge, 'Old and New Aspects of the Aryan Question', *The American Journal of Sociology* 5, no. 3 (1899): 329–346.

cepted this view. If we want to describe the history of scientific racism, we cannot leave out the history of comparative philology.

We can also add some examples from the more recent humanities disciplines such as film studies and television studies. Fundamental insights from such disciplines include an analysis of the medium of television indicating that viewers are captured through 'flows' – i.e. non-stop streams of information, advertising, entertainment and trailers – whose purpose is to keep the viewer tuned to a particular channel.[55] And what to think about the disturbing discovery that the TV series *Crime Scene Investigation*, which has dragged on for years, consists of only eight narrative building blocks that are endlessly reshuffled?[56] Time will tell whether these insights and discoveries will have applications in science or technology, but they are in any event sensational.

Conclusion

My review of the history of interactions between humanities and science has only scratched the surface, but it has made clear that insights from the humanities have had a profound impact on science and technology. The humanities gave us grammar formalisms (linguistics) that were used in the development of high-level programming languages. The humanities provided tools for text reconstruction (stemmatic philology) that could be applied to DNA analysis. They also developed widely applicable source-critical methods (historiography) which are used in a variety of fields, from forensics to medicine. And the humanities most probably invented the empirical cycle of research, where empiricism gets the last word, no matter how beautiful the theory may be (early humanism). A thorough understanding of the development of systematic knowledge must therefore include both (the histories of) the humanities and the sciences. To do so, we must put aside our preconceptions on humanistic and scientific practices, and study the scholarly and scientific texts from an integrated point of view.

55 Raymond Williams, *Television: Technology and Cultural Form* (London: Collins, 1974).

56 Benedikt Löwe, Eric Pacuit and Sanchit Saraf, 'Identifying the Structure of a Narrative via an Agent-based Logic of Preferences and Beliefs: Formalizations of Episodes from *CSI: Crime Scene Investigation*™', in *MOCA'09, Fifth International Workshop on Modelling of Objects, Components, and Agents*, ed. Michael Duvigneau and Daniel Moldt (Hamburg: University of Hamburg, Department of Informatics, 2009).