1 Continuity and discontinuity[1] (the established versus the revolutionary)
- 1.1 The question of how "revolutionary" the Scientific Revolution is: the actors own consciousness of doing something new[2]; the historiographical discussion about continuity and discontinuity[3]; appears to be more revolutionary in the theoretical aspect than the methodological aspect
- 1.2 The issue of boundary-drawing: general discussion[4]; examples such as those in natural magic, alchemy-medicine (Paracelsianism, Helmontianism, and derivative chemical philosophy[5]), and astrology;
- 1.3 The case of astronomy and astrology
- 1.4 The case of natural history (Aristotle and Pliny the Elder)[6]
- 1.5 The case of natural magic: general description[7]; its compatibility with scholasticism; Pomponazzi's stick to ecclesiastical authority and scholastic hylemorphism (such as occult quality)[8]; Kepler's rejection of Fludd should be understood as a reaffirmation of sound natural magic (see Kepler)
- 1.6 The case of medicine: Galenic and Hippocratic medicine continued well into the 18th century[9]
- 1.7 The case of alchemy and chymistry
- 1.8 The case of mechanical philosophy: Gassendi[10]
- 1.9 The fundamental and lasting influence of Aristotle (through the Middle Ages Scholasticism)
  - 1.9.1 Matter theory
  - 1.9.2 Inspiration and start point for development: causal questions (see natural magic, mechanical philosophy, and Newton); inspired Harvey's circulation idea[11]
  - 1.9.3 Criteria for natural philosophical knowledge (e.g. Bacon)[12]

2 Background changes and trends
- 2.1 Renaissance's influence: general discussion[13]; Aristotle was not the only philosopher[14]; example of rediscovery's influence on development in science (anatomy[15])
- 2.2 Reformation's influence: politicization of some disciplines (the case of Galileo's trial)
- 2.3 Enlightenment

3 Systems of natural knowledge (competing worldviews)
- 3.1 General trend: the new development of a connected world and its collapse
  - 3.1.1 The connected world[16]: Robert Fludd as an example[17]
  - 3.1.2 Collapse
- 3.2 Scholasticism (comprehensive, universities) [18]
  - 3.2.1 Matter and form
  - 3.2.2 Occult quality: as a starting point for development of various natural philosophies and the collapse of the scholastic tradition[19]
  - 3.2.3 Cosmology
  - 3.2.4 Aristotle's natural philosophy's change in history and the formation of Scholasticism[20]
  - 3.2.5 Disciplines
    - 3.2.5.1 University curricula: innovations always appeared first outside universities
  - 3.2.6 Collapse:
    - 3.2.6.1 Socio-economic factors: growing availability of patronage enabled some natural philosophers to work outside the universities (e.g. Tycho[21]); Reformation and the demise of Catholic-Aristotelian authority in Europe
    - 3.2.6.2 Mathematization: challenges from mathematical sciences
    - 3.2.6.3 The growing influence of experimentalism: see "natural philosophical instruments"
    - 3.2.6.4 From within: the Society of Jesuit
- 3.3 Natural magic (and "hermetic tradition")[22]
  - 3.3.1 The theoretical foundation and origin of natural magic: in Renaissance Europe, not Hermetic sermons[23]
  - 3.3.2 Definition of "natural magic": Ficino[24]; Agrippa[25]
  - 3.3.3 The purpose of natural magic[26] and its practical application (utility)[27]
  - 3.3.4 Why people believed in magic: general discussion[28]; Marsilio Ficino and the legitimacy of natural magic theories (why believe true)[29]; the bookish tradition of the 16th century and the proliferation of magical objects in words and image facilitated by the new technology of printing increased the credibility of such objects[30]
  - 3.3.5 Where to practice: in the courts of Europe[31]
  - 3.3.6 The problem of "Hermetic tradition":
    - 3.3.6.1 Before the Yates thesis: J.G. Frazer and others[32]
    - 3.3.6.2 Yates theses:
      - 3.3.6.2.1 Contents: main arguments[33]; change in the conception of man's relation to the cosmos; Renaissance magus as immediate ancestor of the 17th-century scientists [34]; mathematical magic as evidence that the Hermetic movement encouraged the development of mechanical and mathematical sciences in the 17th century (the examples of Florentine movement and mechanics, da Vinci, John Dee) [35]; the Rosicrucian type/phase in the history of the Hermetic tradition and the Rosicrucian manifesto (cooperation between magician-scientists)[36]; examples of Rosicrucian type (John Dee as a member, Renaissance utopia); Hermetic tradition's influence on Bacon who should be studied as a reformed Rosicrucian type [37]; explanation of Bacon' criticism on the sin of pride (the second Fall), his rejection of Copernican heliocentricity and William Gilbert's work on the magnet, and his avoidance of mathematics using the assumption of Bacon as a reformed and modest Rosicrucian type[38]; two attitudes historian of science should take (read backwards, and affiliation with Hermetic tradition does not debunk great figures, e.g. Bruno)[39]; two phases of emergence of modern science (e.g. Mersenne) and the Hermetic attitude as the chief

stimulus of shift attitude towards the world[40]

3.3.6.2.2 Historians' definitions of "hermetic"[41]; Copenhaver's attitude towards Yates' theses[42]

3.3.6.3 Relation to natural magic: Copenhaver's opinion (related but not the same thing, does not imply each other, proposes occultist as substitute for hermetic)[43]

3.3.7 Natural magic, occultism, and Aristotelianism: examples

3.3.7.1 Pietro Pomponazzi:

3.3.7.1.1 General description: submission to ecclesiastical authority, committed to Aristotelian natural philosophy, while embracing natural magic; a natural philosopher of peripatetic natural magic

3.3.7.1.2 Why embracing natural magic: saving puzzling phenomena and experience (in many cases textual) by developing Peripatetic principles[44]; he had a distaste for simple explanations using demons because if demon could locate and exploit natural objects (applying "actives" to "passives", so can humans by following the same natural principles (used by demons), this stance led him to pursue a theory of natural magic that could explain magical phenomena[45]; his did not abandon "occult quality" as an explanation

3.3.7.1.3 Content of his theory of natural magic (strictly within the limit of natural actions): different from Ficino's; psychological (the faculties of the human soul and the power of imagination through the medium of physical vapors), astrophysical (God's power through celestial influence), metaphysical (the doctrine of occult qualities, e.g. his discussion of magnet), the latter two components were well established by scholastic authorities[46]

3.3.7.1.4 What magical phenomena qualified as subject of a Scientia (e.g. natural philosophy)[47]: those results from "applying actives to passives"; singular phenomena; effects of imagination; the latter two are singular and could not be used for supporting generalized reasoning

3.3.7.1.5 Different from Aristotle himself, but Aristotelian philosophy also changed over time[48]; peripatetic natural magic became the major enemy for opponents of traditional natural philosophy

3.3.7.2 Henry Cornelius Agrippa von Nettesheim: *On the Occult Philosophy* (1510)

3.3.7.2.1 General description: a comprehensive natural philosopher who had theorized a systematic occult philosophy with influence from both Aristotelianism and Neoplatonism

3.3.7.2.2 Occult philosophy:

3.3.7.2.2.1 Cosmology[49]: from the lowest to the highest: elementary world (quality in objects made of the lowest earthly matter, occult or hidden qualities as magician's effective instruments), celestial world (quantities made of celestial matter, figures or shapes are the best tools), intellectual world (immaterial angelic minds, free of all bodily quality and quantity); causality runs from above to below, from ideas of God's mind to the sublunary world[50]

3.3.7.2.2.2 Physics and matter theory [51] (Aristotelian in concepts, terminology and framework but also Neoplatonic): four elements that are themselves magical imbued with power; primary qualities give rise to secondary qualities, which makes tertiary qualities, these qualities come from matter while 'occult' qualities come from specific or substantial form, the imperceptible forms, which label 'occult' qualities, cause magical effects; these hidden qualities are hard to characterize but discoverable by experience and rational analysis); way to discover (celestial imprint, and similitude[52])

3.3.7.2.2.3 Three types of magic[53] (natural, mathematical, religious/ritual/ceremonial): corresponds to his cosmos; spirit as medium for exchanges of power (bi-directional flow of power) between bodiless and embodied things through sympathies and similitudes; the risk of attracting supernatural attention including angels and demons because Agrippa's world is a continuum[54]

3.3.7.2.2.4 Source: authorities and evidence (though not original)[55]; empirical details[56]

3.3.7.2.2.5 The practical purpose[57]

3.3.7.2.3 Influence of Agrippa's book[58]

3.3.7.3 Giordano Bruno and other renaissance magicians

3.3.7.3.1 Renaissance magicians[59]: Giambattista Della Porta and others' search for alternatives to Aristotle

3.3.7.3.2 Bruno's purpose: replace an older theory, based on hylemorphic physics and metaphysics, that no longer fits his infinite universe (too static, abstract, and rigid for Bruno)[60]

3.3.7.3.3 Bruno (radical dissident of Aristotelianism): sometimes atomist, sometimes monist and pantheist; passion for epistemic and moral unity; memory as both a part of rhetoric and a tool of magic and the power of imagination and pictures; shadow of words for exploring the infinite possibilities of the combination of things and meanings

3.3.7.3.4 Bruno's metaphysics: eternal, infinite potency is the core of Bruno's metaphysics; the equivalence of mind (active power) and matter (passive capacity) and the prevalence of a mindful world-soul as causes (replacing Aristotle's four causes)[61]; atomist theory of matter as part of Bruno's pantheist naturalism[62]

3.3.7.3.5 Theory for explaining magic: focus on the mutual (not hierarchical) and action-at-a-

distance spiritual "bonds" between everything[63]; "universal spirit, when localized, makes natural objects alive, sentient and ready for a magus to command"[64]

3.3.7.4 Relationship with Aristotelianism: some closer, some more deviated (Giordano Bruno and Tommaso Campanella (magical pansensism)[65]), many natural philosophers focused on the explanation of "occult" quality (e.g. Jean Fernel substituted occult faculties for occult quality[66]; Campanella[67])

3.3.8 The disenchantment and vulgarization of magic: general discussion[68]; the close relationship between magic and Aristotelianism and the attack on peripatetic natural magic by the latter's opponents[69]; empirical evidence and its demise[70]; thrived until the end of the 16th century and started a slow and erratic decline afterwards (trend) because of a reflexive deference to antiquity[71]; the philological debunk of the Hermetic scriptures and Trismegistus[72]; could not provide a better explanation for occult qualities than mechanical philosophy[73]

3.3.8.1 Examples of skepticism, attacks, and the complexity: Marin Mersenne[74]; Gassendi (and his occultism)[75]; Bacon (critics on magic, also influenced by it)[76]; Descartes[77]; Boyle[78]; Newton[79]

3.3.9 Influence of magical tradition: on William Gilbert, Kepler, Boyle, and Newton[80]

3.4 Natural history[81]

3.4.1 Emblematic worldview

3.4.1.1 Definition[82]

3.4.1.2 Gessner[83] and Aldrovandi (more intricate than Gessner and was a typical example of emblematic worldview *par excellence*)[84]; from medieval associative (situating plants in the environment) to the Renaissance emblematic worldview

3.4.1.3 Demise: New world and Joannes Jonston[85]; Thomas Brown's experiments of reexamining[86]; Francesco Redi's experiments and attack on alleged properties of natural products in East Indies and the New World[87]

3.4.2 New World natural histories:

3.4.2.1 Motivation and purpose: celebration of the Spanish empire and glorification of the King[88]; glorification of the God and conversion of the Indians to Christianity[89]; consummate/transcend the Plinian enterprise (Oviedo) and Aristotle's (Acosta)[90]; medical and other uses (Acosta[91] and Hernandez)

3.4.2.2 The acquirement of information:

3.4.2.2.1 other people's description (Martyr[92], Oviedo[93], López de Gómara who never went to the Indies[94]),

3.4.2.2.2 in-person experience and observation: Oviedo[95], Acosta's in-person observation and stress on the value of experience[96], Hernandez[97]

3.4.2.2.3 cooperation with indigenous experts (Hernandez[98]);

3.4.2.2.4 State sponsored survey of geography and resources through questionnaires (Antonio de Herrera and *relaciones de Indias*)[99]

3.4.2.3 The digest and interpretation of new discoveries:

3.4.2.3.1 the acknowledgement of originality of New World nature[100];

3.4.2.3.2 using existent frameworks and tensions: Peter Martyr's model of writing was Herodotus and used Pliny, Aristotle, and "the moderns" as authorities[101]; Francisco Fernández de Oviedo (1478–1557) followed Pliny[102]; José de Acosta (S.J.)'s philosophical project following Aristotle[103]; the Scripture as source of reasoning (Acosta used Noah's ark to argue for the common origin[104]);

3.4.2.3.3 categorization of animals (taxonomy): (Oviedo and Acosta)[105]; get information from local names (Acosta[106]) or incorporate indigenous naming system (Hernandez)[107]

3.4.2.4 Representation: language (Martyr: Latin; Oviedo: vernacular)[108]; illustrations (e.g. Hernandez); new genre of writings upon the foundation of the classics[109]

3.4.3 Natural history in Renaissance Europe (a trend of encyclopedic tradition in natural history[110] of collecting and knowing everything and its collapse, rethinking the concept of "emblematic worldview")

3.4.3.1.1 Trends:

3.4.3.1.1.1 1 from medieval associative (situating plants in the environment) to the Renaissance emblematic worldview

3.4.3.1.1.2 2 the increasing access to firsthand information and objects with the rising of Dutch and English commercial empire in the 17th century[111]→the increasing of skepticism and firsthand empirical examination and the disenchantment of exoticism and fascination; a shift from "philological" to "experimental" (be careful about the meaning of philology, see Gessner's[112])

3.4.3.1.1.3 3 "Renaissance and Baroque naturalists chose to extend the ancient paradigm of natural history rather than to dismantle it. Yet their decision to allow new influences to impinge upon this structure made it a precarious edifice indeed."[113]

3.4.3.2 Motivations, purposes, and goals: possibility of exploitation of nature (Girolamo Cardano (1501-76)[114], Aldrovandi[115]); compilation of encyclopedia containing everything (Conrad Gessner[116], Aldrovandi[117]); categorization (Jonston[118]); John Ray's goal of accurate description[119] and accommodation of new species of America[120] and the aim of recovering the links between words and things[121]; aesthetic motivation and pursuit of particulars[122]; collecting impulse and pleasure[123]; little interest in the economic aspects (Pierre Belon as an exception)[124]

3.4.3.3 The acquirement and validation of information:

3.4.3.3.1 Sources of information: from authors of New World natural history (Cardano[125]; Gessner[126]; Aldrovandi[127]; Jonston from Nieremberg and Markgraf[128]); from people travelling between the two Worlds (Belon[129]); from correspondents (Gessner[130]; Aldrovandi[131], Bauhin[132]); personal collection (Ulisse Aldrovandi's "Theater of nature"[133]); herbarium (Clusius[134], Caspar Bauhin and problems of using herbarium[135]); Gessner and Clusius[136]; the fauna of the North (through trade and travelers but penetrate south slowly)[137]; fossils[138]

3.4.3.3.2 The issue of trust[139]: the preference of observation[140] and the limit of observation[141]; Gessner's way of validating truth (consensus of authorities as the most important guarantor of secondhand truths)[142]; Aldrovandi's way of validating truth[143]; Clusius's way of validating truth and selecting trustful witnesses (the example of his encounter with Cristobal Acosta, the pitfall of the bird of paradise's leg, the banyan tree)[144]; trained witness as a solution for Clusius and his colleagues at Leiden and its weakness[145]; John Ray's accounts of northern animals[146]

3.4.3.4 The understanding and interpretation of new information:

3.4.3.4.1 General understandings: a natural philosophical enterprise (Cardano)[147]; creatures of the New World as an expression of the rationality and balance of nature (Cardano)[148]; climate as explanatory factor for creature differences (Cardano)[149]; animals of the New World as "species" or "varietis" of those of the Old World (Gessner, Hernandez, Clusius)[150] (Jonston[151]); Kircher's comprehensive worldview (see below)

3.4.3.4.2 Using existent frameworks and tensions: Belon's enthusiasm of classics and his disappointments (disruptive effect of New World species)[152]; the tension (and pictures' role of circulating new information free from the baggage of words) and Jonston (whose work was viewed as a turning point)'s attempt of reconciling predecessors' methods and conceptual framework with new concrete reality from America[153]

3.4.3.4.3 Athanasius Kircher as a culmination of the encyclopedic tradition

3.4.3.4.4 The tensions and breaking away from the encyclopedic tradition (disenchantment): Francesco Redi's attack on Kircher based on experiments (not in modern sense)[154]; Bacon's ideas and practices of natural history[155]; Thomas Browne's notions of proper methods and skepticism of authorities[156]; John Ray and Francis Willughby (associated with RS)[157]'s break from the emblematic tradition of natural history; Royal Society natural philosophers and physicians' pursuit of new methods and new goals (Nehemiah Grew,[158] Edward Tyson and his systematic Baconian agenda[159])

3.4.3.4.5 Categorization and organization of information:

3.4.3.4.5.1 A trend: classification was not a significant problem for Renaissance naturalists but only became serious in the later 17th century[160]

3.4.3.4.5.2 Fauna: Cardano (natural things, artificial things, supernatural things)[161]; Gessner's large categories and alphabetical order within them and his philological/humanist approach to texts[162]; Jonston's dichotomic and hierarchical organization method[163]; John Ray's taxonomic category (some built mainly on the basis of new world species, and the items reduced to names and sober descriptions; principle on the external and morphological descriptions) and his interest in building a universal language (c.f. Kircher)[164]; the classification based on dissection and comparative anatomy (Edward Tyson, Charles Perrault and the Parisian Academie's collective investigation into animal anatomy and its epistemology)[165];

3.4.3.4.5.3 Flora: Clusius's vicarious element[166]; Bauhin's dry, clinical description based on his herbarium and difference with Linnaeus's[167]; the concept of "species" in 16th century[168]; folk taxonomy (anthropocentric, has influence on Bauhin and his predecessors and late Renaissance natural history's break from it, decontextualization of nature)[169]; Andrea Cesalpino's reflection on the problem of taxonomy and classification (his classification method rooted in 16th-century Aristotelianism, his concentration on morphology and the possibilities beyond folk taxonomy)[170]; Adam Zaluziansky's critics on existing classification and theorized classification based on pedagogical and disciplinary grounds without philosophical justification[171]

3.4.3.5 Representation (also as a method of knowing): association of texts and pictures through pressing[172] (Gessner's using of pictures for quick update of information (and possibly contributed to the dismantle of meaningful network around animals)[173]); specialized writing about animals (Rondelet and Belon)[174]; Aldrovandi's use of pictures[175]; John Jonston's use of copper engravings[176]; pictures' role in facilitating the circulation of new information and the collapse of meaningful network[177]

3.4.4 Transmission and collection of information and materials in Europe

3.4.4.1 Books on New World natural history: limited sources[178] indiscriminate citation of them by contemporaries[179]; the flow of information between Spain and Italy in the 16th century[180]; the expansion of the Dutch and English commercial empires and the increased first-hand access to the world beyond Europe in the 17th century[181]

3.4.4.2 Material flows: samples brought to Europe by sailors (bird trade and Belon[182]); sent by correspondence[183]; the sources of RS's collection[184]; the anatomical practice of Parisian Academy based on imported animals[185]; the Northern land's naturalia and trade[186]

3.4.4.3 Botanical garden, Cabinet of Curiosity, and early museums (as places of decontextualization

and re-contextualization)
3.4.4.3.1 Aldrovandi's "Theater of nature"[187] and Francesco I de'Medici's cabinet (*studiolo*)[188]
3.4.4.3.2 Kircher's museum
3.4.4.3.3 Museum of the Royal Society and new classification[189]
3.5 Alchemy and chymistry[190]
3.5.1 Theories of matter and change
3.5.2 The criteria for authenticity: building and collapse of credibility of texts
3.5.3 Boundary-drawing between chemistry and alchemy
3.5.4 utility
3.6 Human body and medicine (Galen, Paracelsus, Helmont, Vesalius, Harvey)[191]: Helmontianism[192]
3.7 Astronomy and astrology (see week_6_precis_v2)
3.7.1 General trend:
3.7.1.1 Theories and methodology: The history of astronomy during late medieval and early modern periods is marked by the co-existence and gradual substitution of different astronomical systems. The Aristotelian-Ptolemaic system was the authority in the late medieval period. In this system, the earth is the center of the universe and celestial bodies are carried by thick orbits and evolved around the earth in uniform circular motion in the unchangeable superlunar world. Starting from the 15th century, its authority was challenged by new systems proposed by Copernicus, Tycho Brahe, and Johannes Kepler. These new systems either moved the earth out of the universal center, denied the existence of thick orbits, or abandoned the idea of uniform circular motion. Besides the theoretical changes, there were also significant shifts in methodology. While mathematics was considered merely as a tool for calculation in the Aristotelian-Ptolemaic system, it was believed to have reflected the physical reality in the new systems. The increasing accuracy of observation played an increasingly important role in producing these new systems. The rest of this essay discusses these major theoretical and methodological changes in the history of astronomy that parallels the Scientific Revolution.
3.7.1.2 Cosmology: the eroding of distinction between the sublunary and superlunary worlds; Newton
3.7.2 Copernicus
3.7.3 Tycho
3.7.4 Kepler
3.7.4.1 Kepler and the magical tradition (he believed that numbers and numerical ratios were real feature of the physical world)[193]
3.7.5 Galileo's various discoveries[194]
3.7.6 Newton
3.7.7 Astrology[195]
3.8 Mechanical philosophy (Gassendi, Descartes, motion)[196]
3.8.1 Relationship with alchemy[197]
3.8.2 Challenge and problems[198]
3.9 Key figures and institutions and their way of doing "experiments"
3.9.1 Galileo: general discussion[199]; his experiments about motion[200]
3.9.2 Lincei
3.9.3 Cimento[201]: self-censorship; purely empirical presentation of experiments in publication Sagi; the underlying natural philosophical concern and tension among its members; dispute between "vacuists" and "plenists" centered on experiment (explanation of barometer)
3.9.4 Gilbert
3.9.5 Bacon[202]: not purely empirical (has the process of theorizing and criticized one of the idols of being too empirical) and utilitarian[203]
3.9.6 Gassendi[204]
3.9.7 Descartes
3.9.8 Boyle[205]
3.9.9 Hooke, RS
3.9.10 Parisian Academie
3.9.11 Newtonian system (force, universality)
3.9.11.1 Theological concerns: the idea of "two books"
3.9.11.2 Natural philosophy: synthesis
3.9.11.3 Newton's natural philosophical and theological enterprises are compatible or even equivalent[206]
4 Methodology for knowing (generation of knowledge systems, meta-system, epistemology)
4.1 Projects and steps of knowing (overall projects for acquiring natural knowledge)
4.1.1 Scholasticism: Aristotle's method[207]; sensory origin of knowledge; the step for knowledge about a being to achieve certainty is knowing not only the form but also explanation based on four causes; first principle, causal questions, deductive syllogism[208]; the acknowledge of unknown natural philosophical phenomena by using the concept of occult quality, which became a starting point for further knowledge inquiry.
4.1.2 Bacon: ladder of knowledge and inductive method[209];
4.1.3 Descartes: a priori approach, formation of first principle based on cases through sense and experience and applying these principles for explaining myriad of phenomena
4.1.4 Newton[210]: complicated set of experiments, hypothesis comes together with experiments (hate hypothesis untested by experiments)
4.2 Experiments and experience
4.2.1 Pre-history: experience, sense, and thought experiments in late Middle Ages: Aristotelianism's

emphasis on the sensory origin of all knowledge and the universality of experience and its lasting influence[211]; Pomponazzi's classification of magic phenomena[212]

4.2.2 Trend 1 (criteria for knowing): because of natural philosophy's strict definition of experiential data valid for its knowledge, the specific set-piece experiments about particulars and singularity and the idea of seeing historical reports/events as a valid way of representing experimental results (which finally suggest universal statements) first became part of the knowledge-making process in mathematical science because they had different criteria for qualifying knowledge of the disciplines. Reason: In mathematical sciences, the major concern was quantitative and measurable properties of things. Of course, the use and presentation of experience and experiments in mathematical sciences were also shaped by scholastic natural philosophy's criteria for knowledge foundation.[213] E.g. the Jesuits (pedagogy and others) [214] →mathematical sciences are "mixed" so their disciplinary knowledge was inevitably related to natural philosophy/physics→The mathematization of sciences with Newton's synthesis symbolling a culmination eventually established the eighteenth-century criteria for set-piece experiments to become a valid way of knowing the natural world, a gradual process from the 17th-century (e.g. RS, Boyle, the publication of Leeuwenhoek's experiments on the *Philosophical Transaction*)[215]

4.2.2.1 A related trend: experiment (experience)'s changing role in constructing new knowledge systems

4.2.2.1.1 New thought experiments: Galileo and Descartes's extrapolation of real-world experiments in ideal/extreme cases

4.2.2.1.2 From validation of theories and Aristotelian questions to production of new questions and experiments [216]; this mechanism of continuously producing questions and knowledge in experiments helps historians to understand scientific revolution as part of the beginning of Anthropocene which is characterized by sustainable growth in production/economy and the exponential accumulation of knowledge and capitals. (e.g. Bacon's ladder, Newton's prim experiment and the following exploration of physical optics, the emergence and solving of the problem of how celestial bodies travel on orbits in astronomy (sphere, orbit, motion[217], force, gravitation); the barometer and the issue of vacuum, see "instrument" below) It should be pointed out that the Aristotelian system is not as close and unchangeable as Bacon and other opponents criticized.

4.2.3 Trend 2 (from the perspective of the material foundation of doing experiments, the emergence of natural philosophical instruments and new experiments)[218]

4.2.3.1 Mathematical instruments for practical use (by less-educated users): navigation, military (artillery projectile and Galileo)

4.2.3.2 The elevation of mathematicians' social status and artisanal knowledge: the increasing importance (utility) of mathematical techniques such as navigation, surveying and cartography in the expansion of empires and warfare; the increasing chance of getting patronage in royal courts in a Europe of increasingly absolutist states[219]; the case of Galileo[220]

4.2.3.3 Instruments closely related to important issues in natural philosophy

4.2.3.3.1 Gilbert's study of loadstones and the movement of earth[221]: "The core of Gilbert's elegant, groundbreaking experimental method is his use of laboratory models and argument by analogy from them to the earth. The analogy was the central principle of magnetic philosophy."[222]

4.2.3.3.2 Galileo, telescope, and the Galilean tradition of "experimental" philosophy in Italy[223]; Aristotle's cosmology challenged

4.2.3.3.3 microscope[224] and mechanical philosophy, microscope's relationship with the debate over the nature of animal and plant generation (Performationism vs. epigenesis)[225]; the matter theory of Aristotle challenged

4.2.3.3.4 barometer and air-pump; Aristotle's idea about the existence of vacuum challenged

4.2.3.4 Constructed and particular experimental scenes using artificially designed instruments as a legitimate epistemological tool for natural philosophy (construction of previously-unknown/less-known/extreme scenes)

4.2.3.4.1 (what is "evident"): Aristotle's criteria and its influence on the Jesuits[226]

4.2.3.4.2 Astronomical observation as extreme and anti-experience experimental scenes

4.2.3.4.3 Baconian attitude towards natural world

4.2.3.5 Collective experiments, large and expensive instruments, and patronage from persons and states[227]: Uraniburg, RS, Parisian Academy (professionalization and utility to the state)

4.2.4 Trend 3: Mathematics, certainty, and experiments (see Mathematization below)

4.2.5 Historical meaning of "experiments"[228] and different understandings of experiments (experiments during the SR should not be understood in its modern sense):

4.2.5.1 The lasting influence of Aristotle's emphasis on universality of phenomena: Harvey (see trend 1's citation)

4.2.5.2 Purpose of experiment: for matters of fact in English natural philosophy (the example of Boyle's air-pump and Boyle and Hooke' explanation of the springiness of air); continental experimentalism's emphasis on theoretical preconceptions and experimental validation of theories; reasons[229]

4.2.5.3 Way of presenting: as historical event in English natural philosophy

4.2.6 Empiricism and experiments in various disciplines (multiple sources of experimentalism and experiments in a broader sense)

4.2.6.1 General trend: a shift from scholastic natural philosophy to more empirical and practically useful natural philosophy[230]; the strategy of setting aside causal question became a valid way

of doing natural philosophy (e.g. Bacon's inductive approach; Newton's distaste for hypothesis and his response to the critics that he was using "occult quality" for explanation; the English natural philosophy's understanding of experiments; the Parisian Academie's distaste for Cartesianists)

4.2.6.2 Natural magic's empirical evident

4.2.6.2.1 General description: magical phenomena were triggers of magicians' passion, and empirical evidence had always been an indispensable source for them to develop natural magic theories

4.2.6.2.2 Examples: Ficino's sources and induction[231]; Pomponazzi's naturalism (wonders and miracles as effects of natural causes)[232] and his choice of saving puzzling phenomena and experience (in many cases textual) by developing Peripatetic principles[233]; Agrippa's empirical details for confirming his magical theory[234]; Leonardo da Vinci's picture such as those "credible" images for incredible animals were magic apparatus for seeing and knowing, therefore although he emphasized naturalism but was in the middle of a movement from allegory representation to scientific observation[235]; mathematical magic and technology[236]; magical tradition's important role in the shift to empirical natural philosophy[237]

4.2.6.3 Alchemy and chymistry[238]: alchemy had a long tradition of doing experiments and also integrate experiments with theories; the tradition of recipes; in the Scientific revolution, the alchemical experimentalism started to make it felt among natural philosophers; chymists were always at the same time medical practitioners

4.2.6.3.1 Examples: Paracelsianism (formation of matter theory from practice and chemical experiments); van Helmont (see class notes)

4.2.6.4 Medicine, anatomy and physiology[239]: reexamination of Galenic medicine and human anatomy by Vesalius; Harvey (see trend 1's citation); particularized treatment for each patient[240]

4.2.6.5 Natural history (as new experiments about the unknown realms)

4.2.6.5.1 Trend: a shift from "philological" to "experimental", a process of disenchantment; from meaningful to realistic and naturalistic[241]

4.2.6.5.2 Emphasis on observation and experience: fact and experience in Acosta's natural history[242]; preference for personal observation (visual inspection) of Clusius and other Renaissance naturalists[243]; Francesco Redi's "esperienza" on natural products (see above)

4.2.6.5.3 Shift in classification system: the transcendence of common sense and the demise of folk taxonomy in natural history[244]

4.2.6.5.4 Kircher's museum and the Jesuits' collecting activity as a process of creating contrived extremity; Kircher's version of experiments and its utility[245]

4.2.6.5.5 Francesco Redi's "esperienza" on natural products

4.2.6.5.6 Baconian "natural history": Bacon's ideas and practices of natural history[246]

4.2.6.6 The arts and technology (doing and knowing)[247]: mathematical magic and technology[248]

4.3 Mathematization:

4.3.1 Description: from an instrumental attitude towards mathematics to a more realist outlook[249]

4.3.2 General trend:

4.3.2.1 the role of artisanal technologies and mathematical instruments: the utility of mathematics and related instruments resulted in the elevation of mathematics and mathematical sciences' status in society and in the hierarchy of disciplines, the increasing importance of mathematical techniques such as navigation, surveying and cartography in the expansion of empires and warfare; the increasing chance of getting patronage in royal courts in a Europe of increasingly absolutist states[250]; the case of Galileo[251]; the case of the Jesuits[252]

4.3.2.2 the growing discrepancy between new knowledge in mathematical sciences and those of Scholastic natural philosophy increased the skepticism towards the latter and facilitated the idea that mathematics reflects physical reality.

4.3.2.3 The Renaissance humanists' recovery of ancient texts and authorities of mathematics→facilitated practical use

4.3.3 mathematics' disciplinary issue:

4.3.3.1 location in discipline: Scholasticism; the Jesuits;

4.3.3.2 reality or instrumental: the case of astronomy from Copernicus to Isaac Newton

4.3.4 Cases of mathematization

4.3.4.1 Astronomy[253]

4.3.4.2 Study of motion and mechanics[254]: increasing mathematical abstraction in study of motion (e.g. Galileo's experiments)[255]; Isaac Beeckman[256]; Huygens

4.3.4.3 Optics[257]: Descartes, Huygens

4.3.4.4 How these cases facilitated experimentalism: quantitative measurement and detailed questions requires the design of more contrived experiments to determine the mathematical relations

4.3.5 Key figures: Galileo

4.4 Representation

4.4.1 Changes in writing and publishing formats[258]

4.4.2 Role of pictures: Leonardo da Vinci's picture such as those "credible" images for incredible animals[259]; use in mechanical philosophy[260]; Kircher's images for guidance

4.4.3 Role of mathematics

4.4.4 Role of displaying and witness,
4.4.5 Printing technology

5 Technology and the utility of natural knowledge[261]
5.1 General description: an increasing focus on natural knowledge's utility
5.1.1 Reason: natural philosophy's inclusion of knowledge from other disciplines and traditions[262]: artisans and craftsmen's growing contribution to natural philosophy[263]; growing influence of alchemy (which had a focus on utility since the ancient time) among natural philosophers in the 16th century[264]; the demand of state and patrons (Baconianism)
5.2 The reason for the integration of artisanal technology and natural philosophy
5.2.1 Renaissance humanists' emphasis on the importance of living for the public good[265]
5.2.2 Mathematization of natural philosophy (see above)

6 Grand infrastructure (Information and materials/media)
6.1 State and its socio-economic environment:
6.1.1 emergence of nation states
6.1.2 absolutism: institutions, professionalization, and construction of instruments
6.1.3 military development and warfare,
6.1.4 economic development,
6.1.5 empire building and expansion: natural history; navigation (e.g. House of Trade in Spain)
6.2 Institutions and public sphere[266]: universities (curricula, establishment of Scholasticism and challenges to it), correspondence network, academies; use of vernacular languages
6.3 Pressing: accumulation of knowledge, acknowledgement of priority, reliable exchange of ideas

7 Network and complexity (formation and growth/transformation, dynamics)
7.1 Centralization and decentralization (topology of network)

8 Anthropocene and fluidity of network (materials and capitals, information, efficiency of energy exploitation)

9 Science, technology and culture (including religion, arts)

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[1] Henry, 1-2
[2] Henry, 2
[3] Henry, 3-5
[4] Henry, 5
[5] Henry, 61
[6] Asúa and French, 209; Ogilvie, 261, 263, 264 (bottom)
[7] Henry, 57 (middle), 60
[8] Copenhaver, 274-6, 281, 283
[9] SR notes, 5.1.1.3
[10] Osler's article, 437-9
[11] SR notes, 5.2.2.4.3
[12] Applebaum, 341-3
[13] Principe, SF, chap. 1; Henry, 12-7; Copenhaver, 17-8, 284
[14] Henry, 14
[15] Osler, 33-36
[16] Principe, SF, chap. 2
[17] Copenhaver, 377
[18] Osler, 5-13; Applebaum, 58-65
[19] Henry, 66
[20] Osler, 11-12
[21] Henry, 23
[22] SR notes, 2.2
[23] Copenhaver, 24
[24] Reappraisals, 280-1
[25] Copenhaver, 285 (bottom)
[26] Henry, 57 (bottom)
[27] SR notes, 2.3
[28] Copenhaver, 276 (bottom)
[29] Reappraisals, 270-5; Copenhaver, 23
[30] Copenhaver, 292-3
[31] Henry, 59 (bottom)
[32] Copenhaver, 19-21
[33] Reappraisals, 263; a shorter version see Copenhaver, 19.
[34] Yates, 257-8
[35] Yates, 259-62
[36] Yates, 263-4
[37] Yates, 265-6
[38] Yates, 267-70
[39] Yates, 270
[40] Yates, 271-272
[41] Reappraisals, 282
[42] Reappraisals, 262, 290; Copenhaver, 22-3
[43] Reappraisals, 289
[44] Copenhaver, 277
[45] Copenhaver, 278
[46] Copenhaver, 278-81
[47] Copenhaver, 282
[48] Copenhaver, 283
[49] Copenhaver, 286
[50] Agrippa, 111
[51] Copenhaver, 288-9; Agrippa, 8-10
[52] Agrippa, 46-9
[53] Yates, 259
[54] Copenhaver, 290
[55] Copenhaver, 287; Agrippa, 6
[56] Copenhaver, 288
[57] Copenhaver, 289
[58] Copenhaver, 287
[59] Copenhaver, 314-5
[60] Copenhaver, 324-5
[61] Copenhaver, 323
[62] Copenhaver, 325-6
[63] Copenhaver, 324; for the types of "bonds" see 327-8
[64] Copenhaver, 325
[65] Copenhaver, 315, 374
[66] Copenhaver, 306
[67] Copenhaver, 374

[68] Copenhaver, 299
[69] Copenhaver, 284, 366
[70] Reappraisals, 275-79 (empirical evidence) 279-80 (disenchantment and complexity in the demise process)
[71] Copenhaver, 287
[72] Copenhaver, 316 (7th line from bottom)
[73] Copenhaver, 307-8
[74] Copenhaver, 378-81
[75] Copenhaver, 381-6
[76] Henry, 60-1
[77] Copenhaver, 386-94
[78] Copenhaver, 406-9
[79] Copenhaver, 414-21
[80] Henry, 62-5
[81] SR notes, 5.5
[82] Reappraisals, 312
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[88] Asúa and French, 64, 66
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[90] Asúa and French, 62, 68, 80 (Acosta)
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[93] Asúa and French, 72
[94] Asúa and French, 75
[95] Asúa and French, 69, 72
[96] Asúa and French, 80, 83, 84 (bottom)
[97] The Mexican Treasury, 60.
[98] The Mexican Treasury, 60.
[99] Asúa and French, 85
[100] Asúa and French, 82-3
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[102] Asúa and French, 65, 70-1
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[107] Bustamante, 35-36.
[108] Asúa and French, 69
[109] Asúa and French, 88
[110] For the tradition, see SR notes, 5.5.1
[111] Ogilvie, 210, 257
[112] Ogilvie, 259
[113] Findlen, 52
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[132] Ogilvie, 211
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[137] Ogilvie, 231-2, 235-6 (slowness and limits of the Renaissance science)
[138] Osler, 137-9
[139] Ogilvie, 230
[140] Ogilvie, 257, 263 (bottom)
[141] Ogilvie, 268
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[145] Ogilvie, 254-6
[146] Ogilvie, 263
[147] Asúa and French, 188-9
[148] Asúa and French, 186
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[151] Asúa and French, 204-6
[152] Asúa and French, 190
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[164] Asúa and French, 218
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[166] Ogilvie, 213-4
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[171] Ogilvie, 226-228
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[187] Asúa and French, 197
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[189] Asúa and French, 209
[190] SR notes, 4.5
[191] SR notes, 5; Osler, 33-36, 140-4
[192] SR notes, 5.4
[193] Henry, 59
[194] Henry, 28
[195] SR notes, 3.5
[196] SR notes, 4.6; Osler, chap. 4; Osler's article
[197] SR notes, 4.5.9, 4.6.3
[198] Henry, 82-84; Applebaum, 92-94; SR notes, 4.6.4
[199] Osler, 59-74
[200] Henry, 27-29; Osler, 95-99; SR notes, 4.3.1
[201] Boschiero; Baretta
[202] Applebaum, 102-11; SR notes, 6.2.9
[203] SR notes, 6.2.9.2
[204] Osler's paper; Osler, 78-82, 85-87, 90 (bottom);
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[221] Gilbert; http://www.lancaster.ac.uk/fass/projects/gilbert/works/demagnete.htm
[222] Applebaum, 416
[223] Asúa and French, 210-1; Henry, 30 (bottom)
[224] SR notes, 5.3; Henry, 46-7
[225] SR notes, 5.3.1
[226] Henry, 52-53
[227] Henry, 38-9
[228] Henry, 51-5
[229] Henry, 54-5, 67
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[231] Reappraisals, 275, 277
[232] Copenhaver, 273-4
[233] Copenhaver, 277
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[237] Henry, 60, 66 (middle)
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[250] Henry, 25-6
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