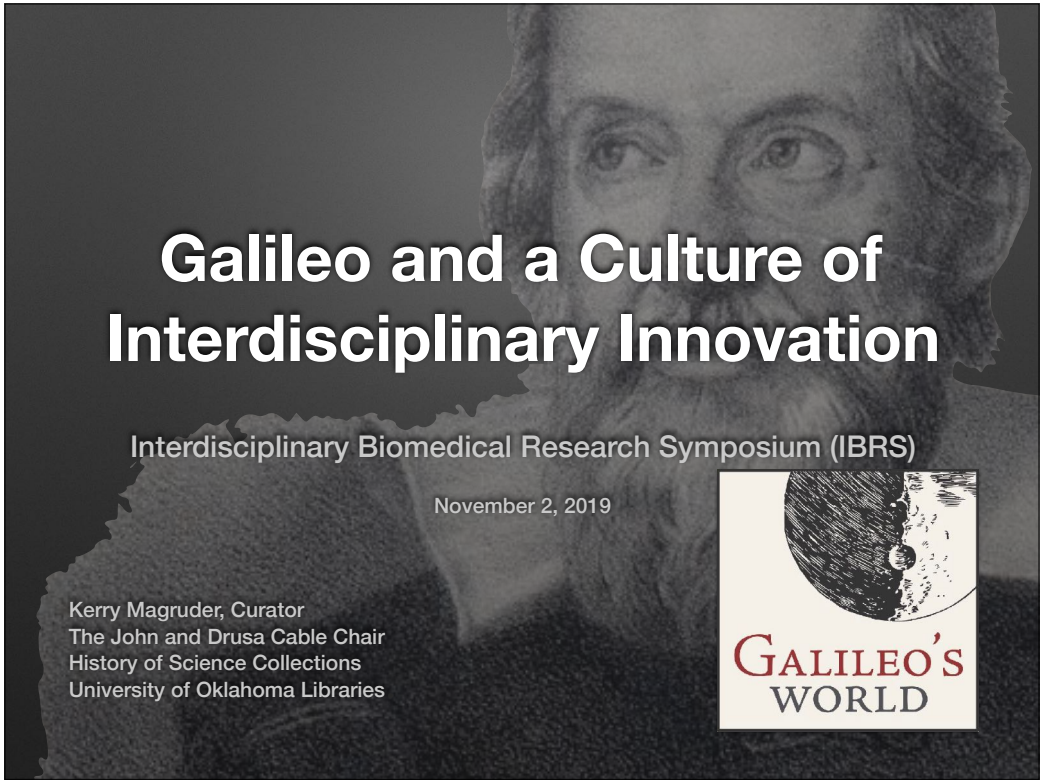


Dr. Degenhardt, thank you for inviting me to this Symposium. It is a joy and privilege to share with all of you this morning some stories about Galileo and a culture of interdisciplinary innovation.

———-

https://www.atsu.edu/research/events/IBRS.htm

I am very pleased to invite you to be the 2019 Interdisciplinary Biomedical Research Symposium Keynote Presenter on Nov. 2, 2019 sponsored by the AT Still Research Institute in Kirksville MO. The presentation is held at 11:00 am and is to last 50 minutes followed by a question and answer period.

As we discussed earlier, I suggest a presentation that follows some of the contours of the "Galileo's World" exhibit I curated at OU in 2015-2016. Galileo's World juxtaposed the entire circle of subject areas from the world of Galileo with the disciplines and academic programs of today. Its purpose was to explore questions like the following: How are diverse disciplines connected? What special ingredients from the culture of Galileo's world made creativity and innovation possible? How do connections

between disciplines stimulate or constrain innovation? Where do sparks of creativity come from? How might understanding the connections between disciplines in the world of Galileo lead us to reconsider our own assumptions about the ways the disciplines are connected in our world?

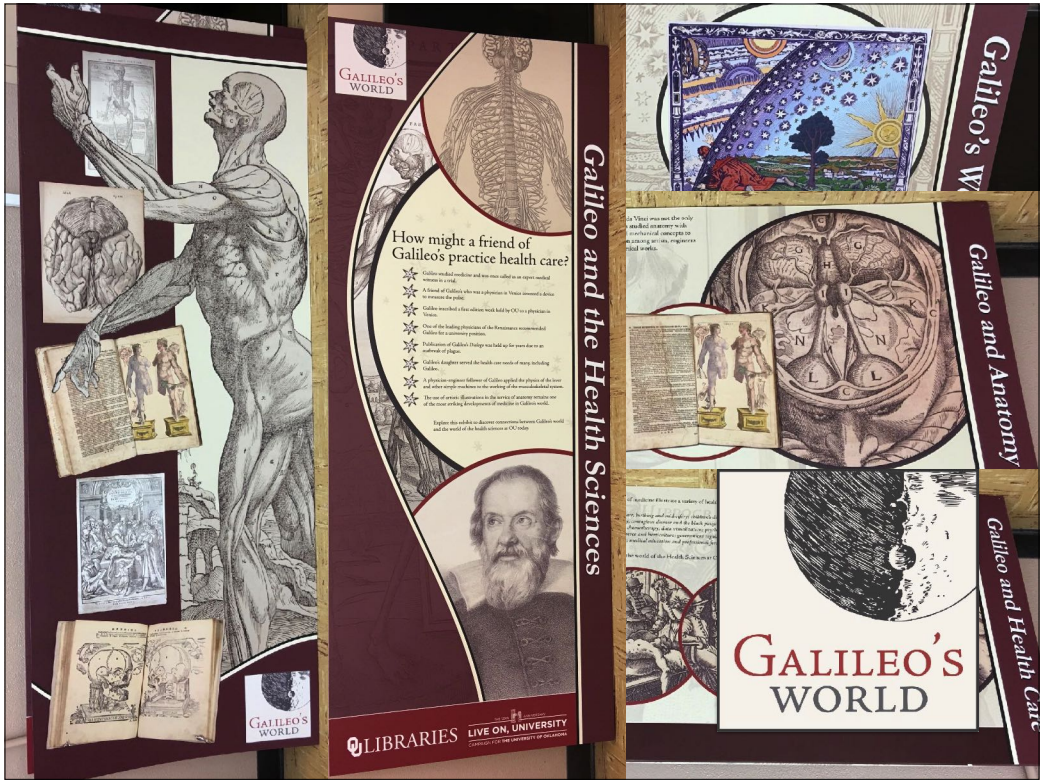
One of the most enjoyable galleries I created for the Galileo's World exhibit was hosted by the Health Sciences Campus of OU. This gallery explored the above questions as they specifically pertained to medicine and health care. Here is the page, from my website for educational outreach, listing the topics and books displayed there:
http://lynx-open-ed.org/health
Its introduction mentions a few of the examples of interdisciplinary connections we may explore in the keynote.

Graphic panels.
5 small (roughly 30x60 inches):
Boldly explore
Galileo and Anatomy (Leonardo mentioned on first line)
Galileo and Health Care ("Vignettes…")
Galileo quote ("I have been in my bed…")
Galileo and Experimentation (on the thermometer)

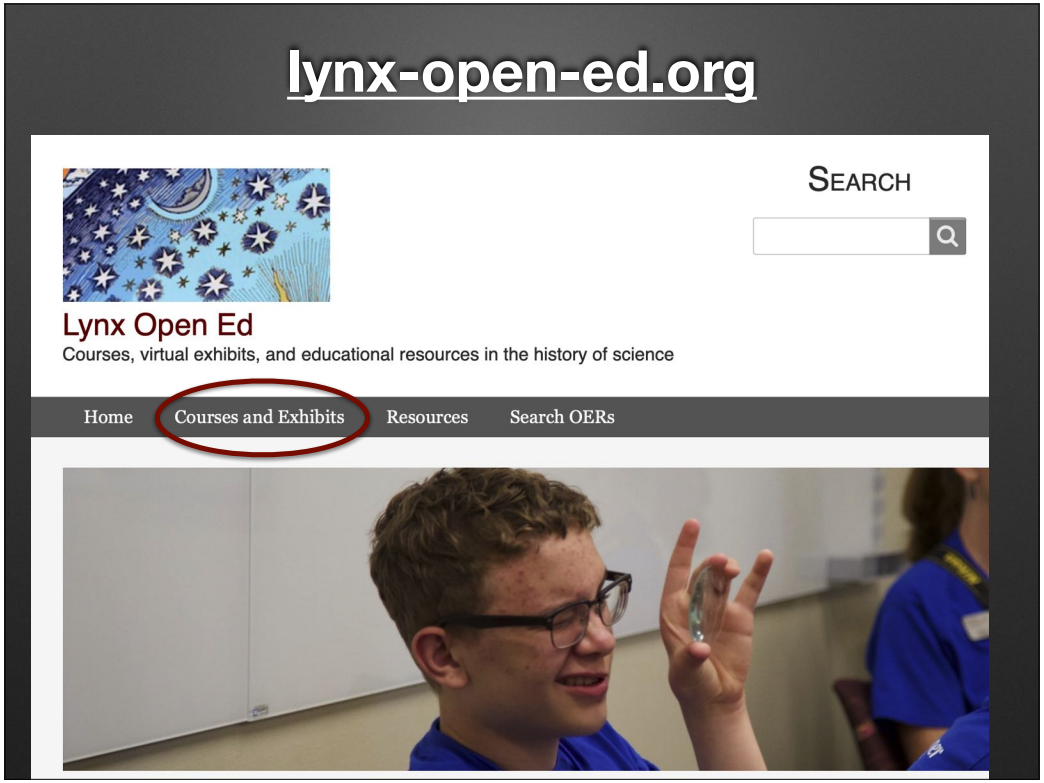
2 large (roughly 32x90 inches):
How might a friend of Galileo's practice health care?
Muscle man from Vesalius and other sources (no text)

Search Jessica Corrick

As an aside, at various points this morning, I'll refer to a major exhibit on Galileo we prepared at OU back in 2015-2016.



My thanks to Susan Swogger and Deb Loguda-Summers for putting some of the graphic panels from that exhibit on display in the AT Still Library for the occasion of this Symposium.



To dive deeper, go to the lynx-open-ed.org website, and pull down the Courses and Exhibits menu to select Galileo's World. You'll find an Exhibit Guide of more than 1,000 pages. Also, a PDF of the slides for this presentation is available on the home page.

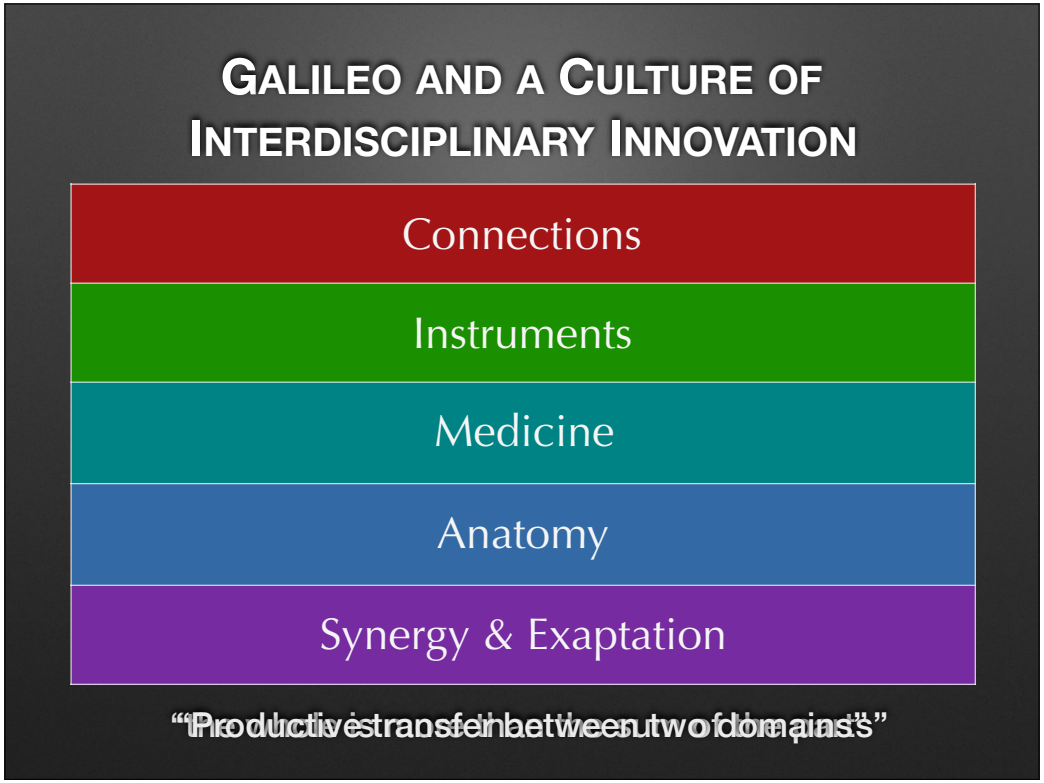
———————

[designed for educators, group leaders and individual study. It contains information about every book on display in each of the 20 galleries. An earlier version of the Exhibit Guide is available for iPads from the Apple Book Store.]

As another aside, research universities are often best known for their athletic programs. But among historians of science around the world,

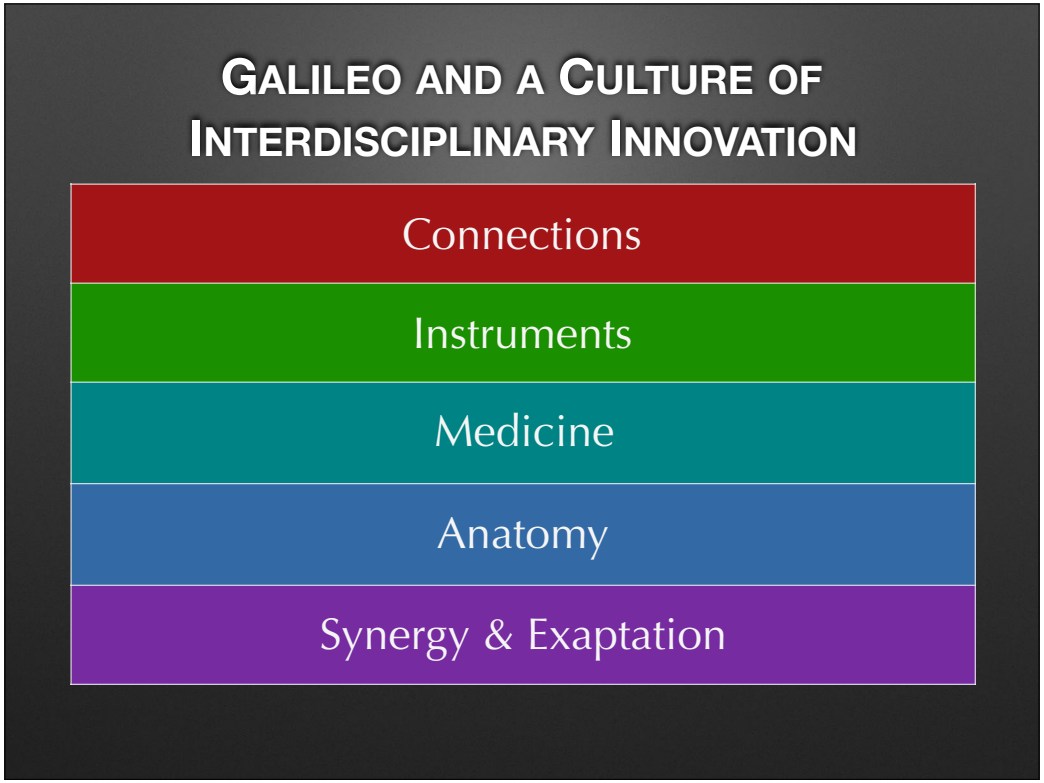
the University of Oklahoma is known for the History of Science. The History of Science Collections now hold about 100,000 volumes, preserved in two climate-controlled vaults. We have 11 faculty members in an academic Dept, and offer both graduate and undergraduate degrees in the history of science, technology and medicine. None of you need any extra degrees, but perhaps it's helpful to know that a program like this exists. And we offer travel fellowships for short-term research projects.

[All images of rare books used this morning are courtesy the History of Science Collections.]

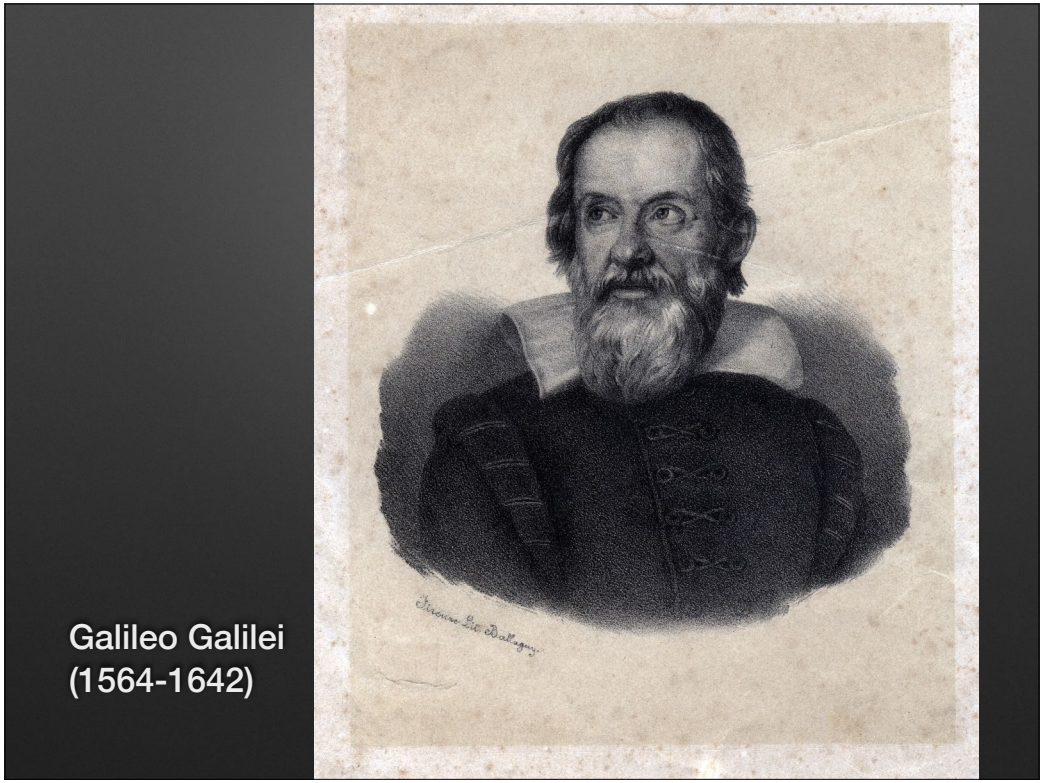


Now, to address our theme today, first, let's take a look at the theme of connections.

- Then we'll explore innovation in Galileo's world in three areas: Instruments, Medicine, and Anatomy.
- Finally, we'll conclude with some reflections on innovation in Galileo's World, in terms of "synergy" and of "exaptation."
- Synergy means the whole is more than the sum of the parts. Exaptation refers to the
- productive transfer of skills or knowledge between two domains.



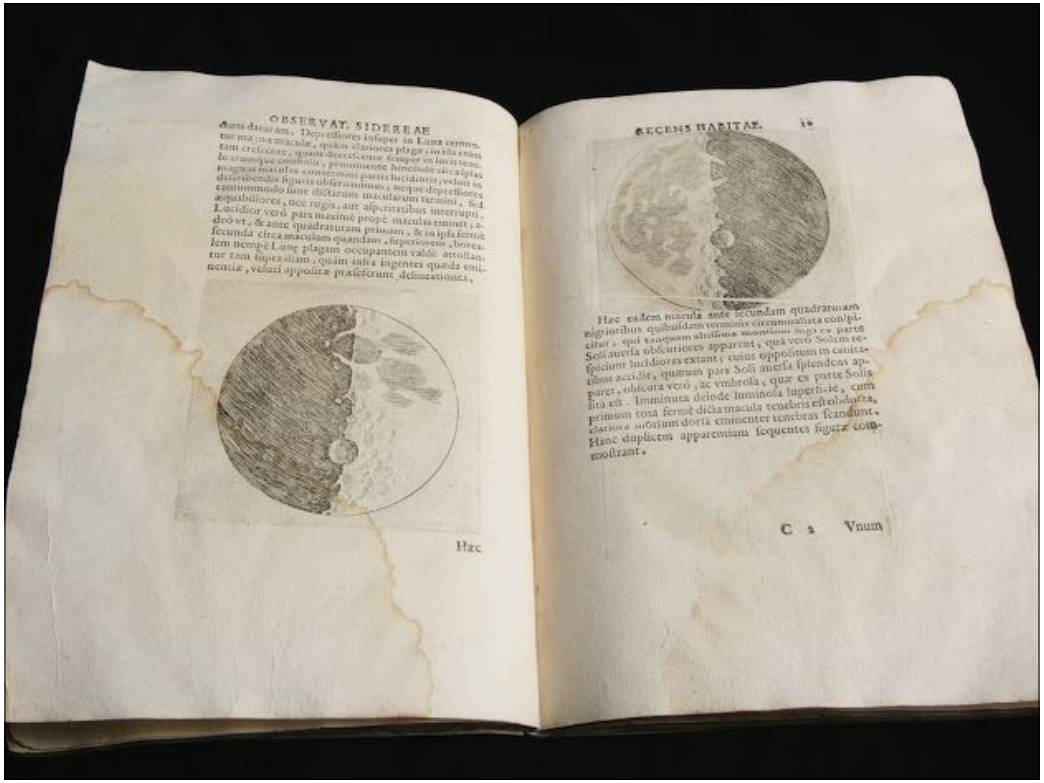
Let's begin with Galileo and connections.



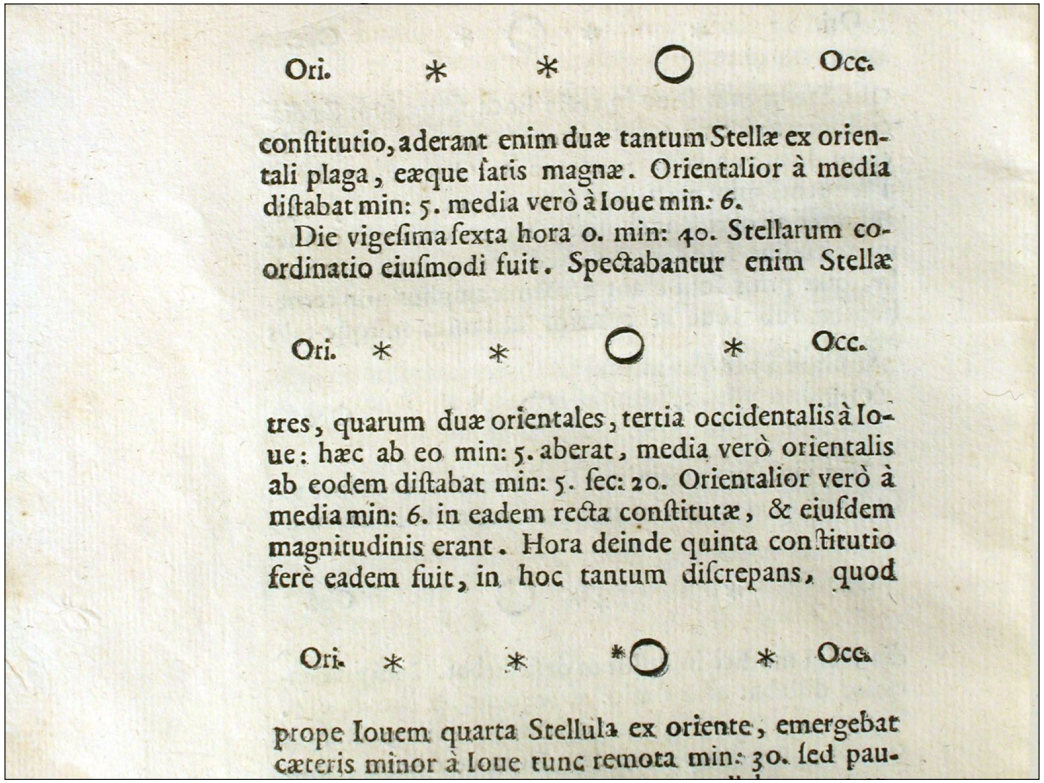
Galileo is regarded as a founder of modern science because of his contributions to astronomy, mathematical physics, and experimental methodology.

Galileo, *Sidereus nuncius* (1610)

This is the OU copy of Galileo's Starry Messenger. It was inscribed by Galileo in the lower right corner.



In the *Starry Messenger*, Galileo printed the first published observations made with a telescope. He reported mountains on the moon at a time when physicists argued that the lunar surface was smooth.



Ori. * * ○ Occ.

constitutio, aderant enim duæ tantum Stellæ ex orientali plaga, eæque satis magnæ. Orientalior à media distabat min: 5. media verò à Ioue min: 6.

Die vigesima sexta hora 0. min: 40. Stellarum coordinatio eiusmodi fuit. Spectabantur enim Stellæ

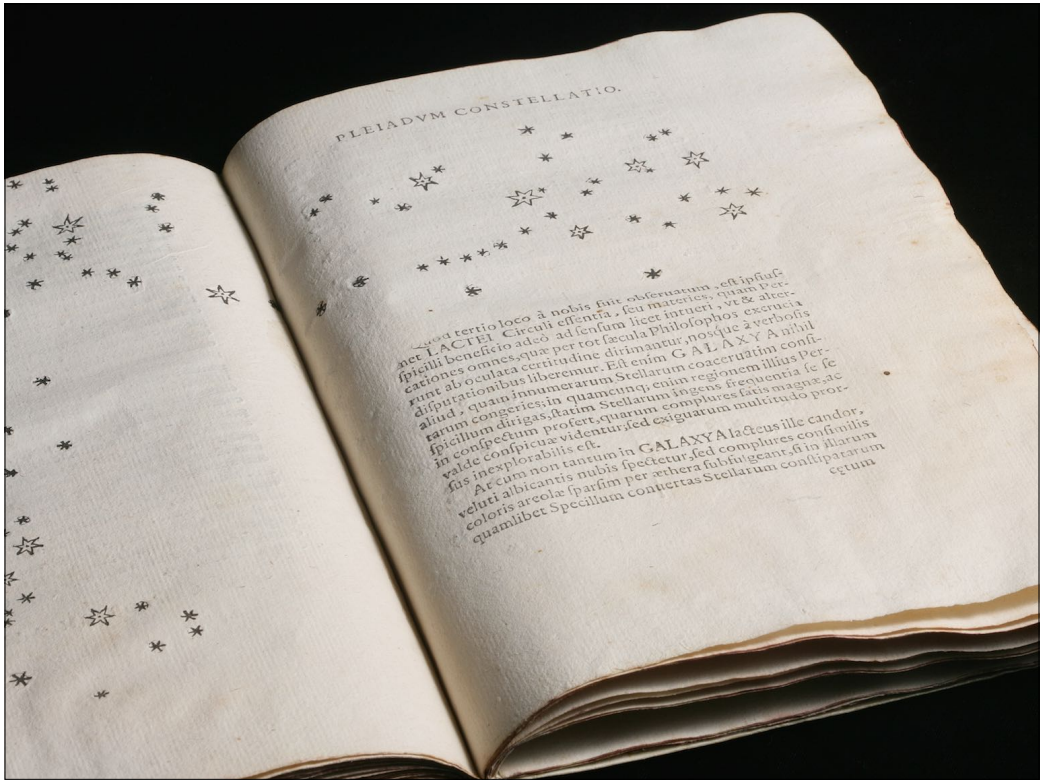
Ori. * * ○ * Occ.

tres, quarum duæ orientales, tertia occidentalis à Ioue: hæc ab eo min: 5. aberat, media verò orientalis ab eodem distabat min: 5. sec: 20. Orientalior verò à media min: 6. in eadem recta constitutæ, & eiusdem magnitudinis erant. Hora deinde quinta constitutio ferè eadem fuit, in hoc tantum discrepans, quod

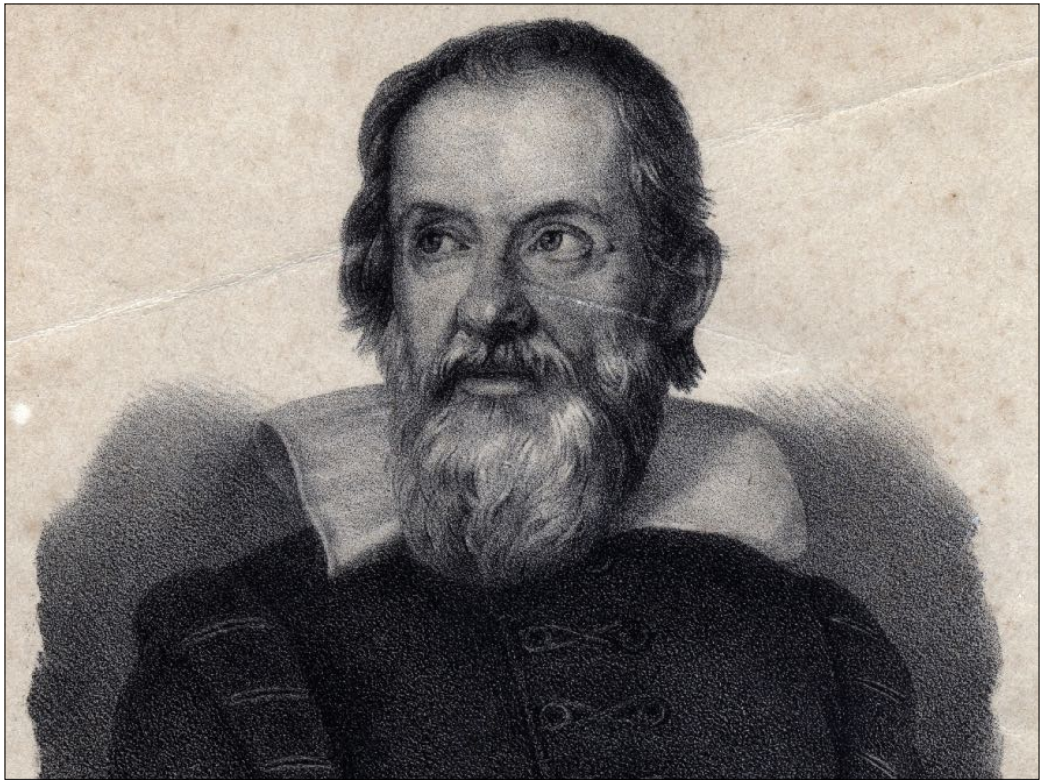
Ori. * * ○ * Occ.

prope Iouem quarta Stellula ex oriente, emergebat cæteris minor à Ioue tunc remota min: 30. sed pau-

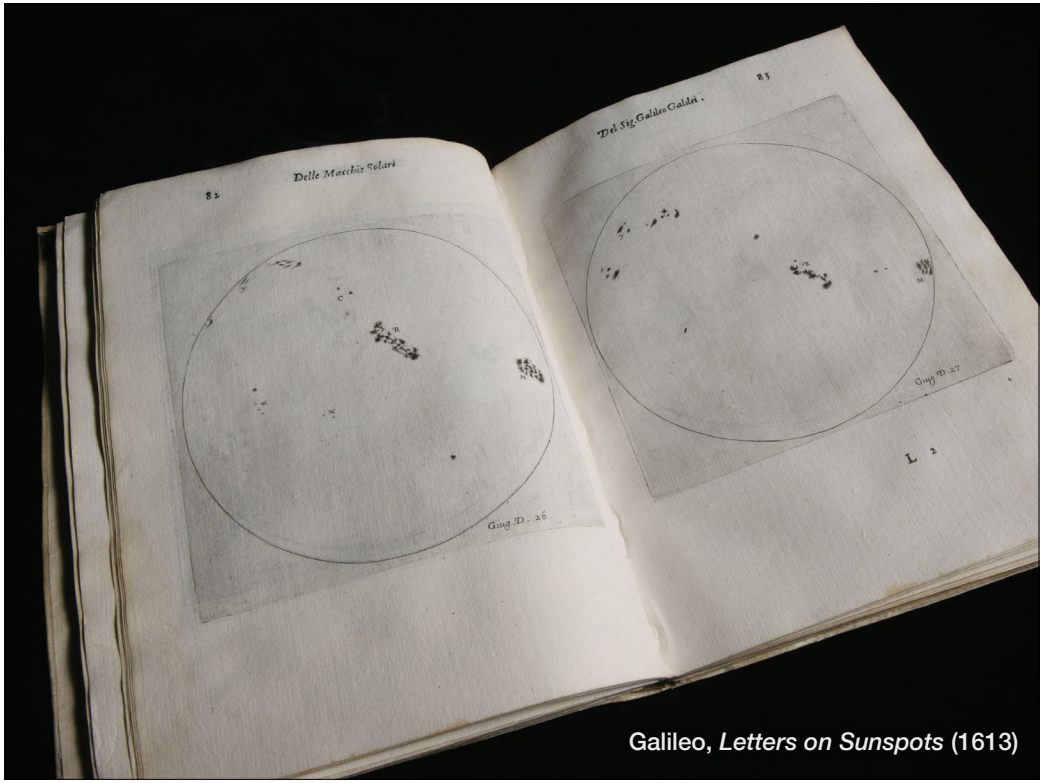
His discovery of the four largest satellites of Jupiter demonstrated that multiple centers of revolution exist in the solar system and proved that a moving planet need not outrun a moon.



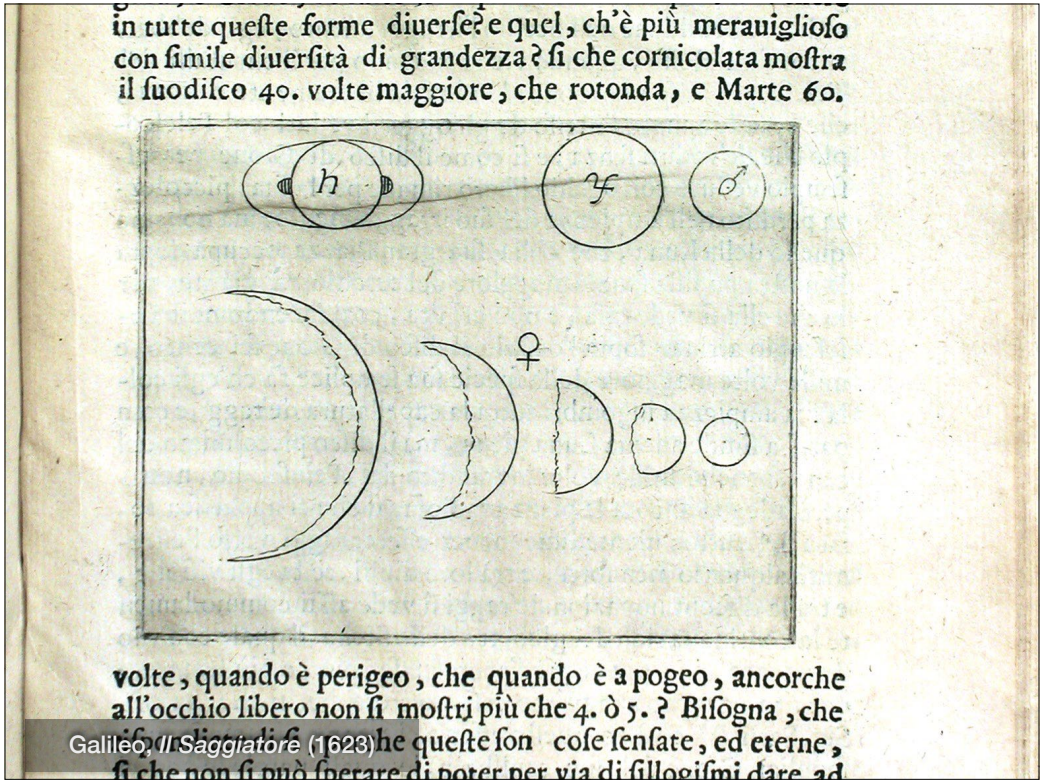
Unsuspected stars in the Pleiades, around Orion’s belt and sword, and in the lighter regions of the Milky Way, suggested the vastness of the universe. These discoveries made implausible the ancient notion of a celestial sphere carrying the fixed stars and rotating around the Earth every 24 hours.



The sensational discoveries revealed by the telescope catapulted Galileo onto the world stage, making him a celebrity almost overnight.

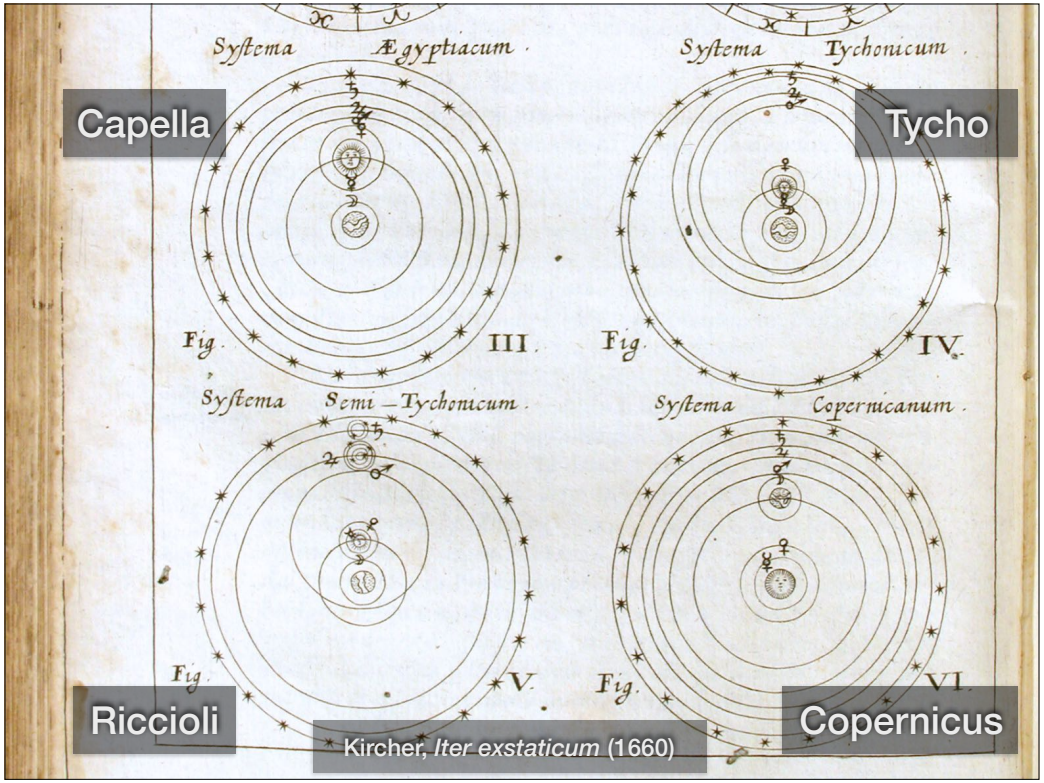


Galileo's *Letters on Sunspots* showed that the Sun is not changeless, which suggested that the heavens are corruptible, contrary to Aristotelian cosmology.



Galileo, *Il Saggiatore* (1623)

Galileo reported that, through the telescope, Venus shows a complete set of phases, which implies that it revolves around the Sun instead of around the Earth.

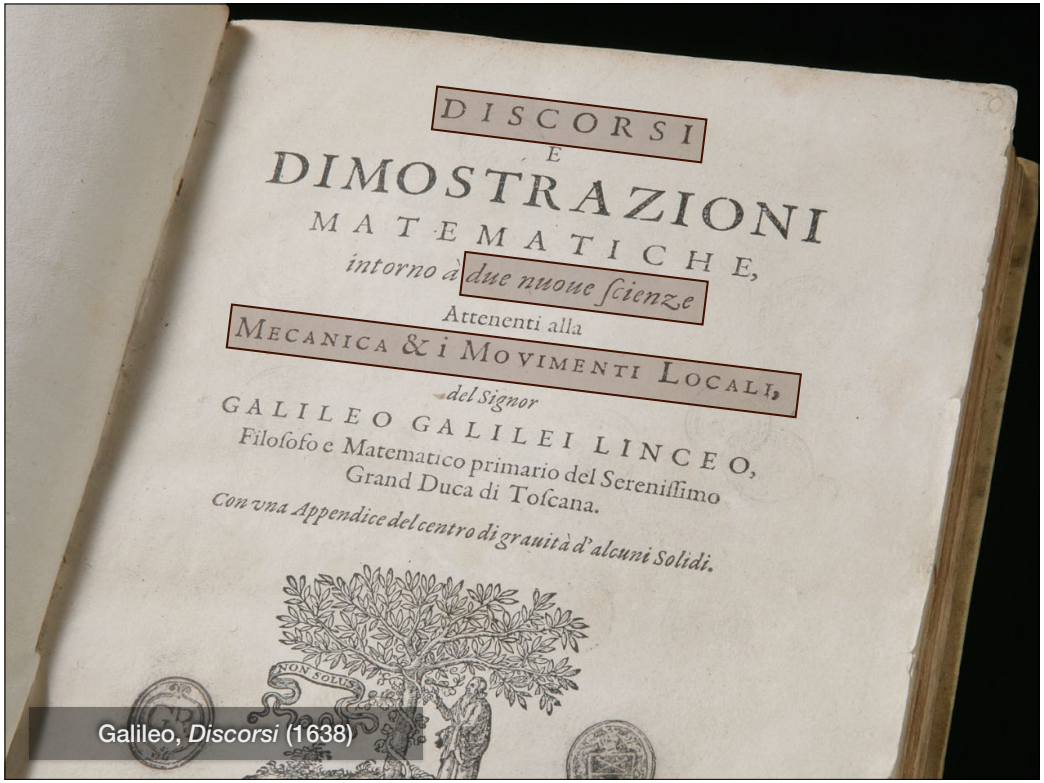


Although the phases of Venus were compatible with the Earth centered cosmologies of Martianus Capella, Tycho Brahe, and Riccioli, Galileo interpreted all of these discoveries as supporting the Sun-centered cosmology that Nicolaus Copernicus…

http://lynx-open-ed.org/node/306

Copernicus, *De revolutionibus* (1543)

… published the previous century in On the Revolutions of the Celestial Spheres (1543). This much is well-known.



Galileo, *Discorsi* (1638)

Still fairly well known is that Galileo published his masterwork in mathematical and experimental physics,

- the Discourse on Two New Sciences, in 1638.
- In this book, he laid a foundation for mechanics, a new science of motion.

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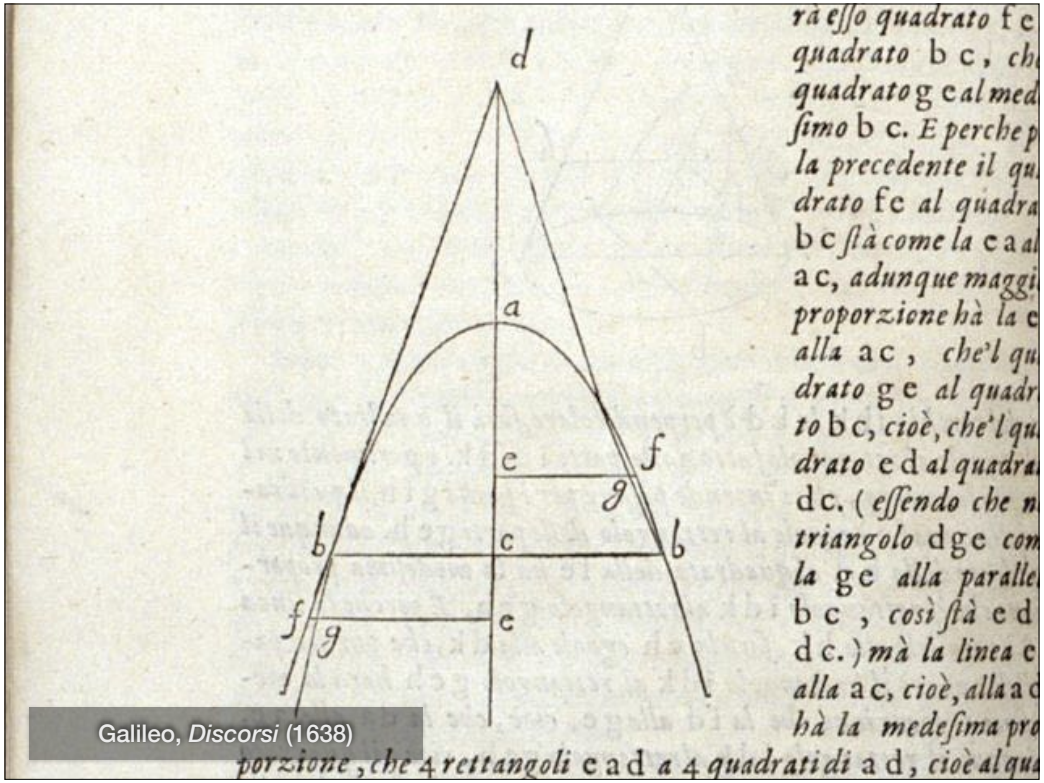
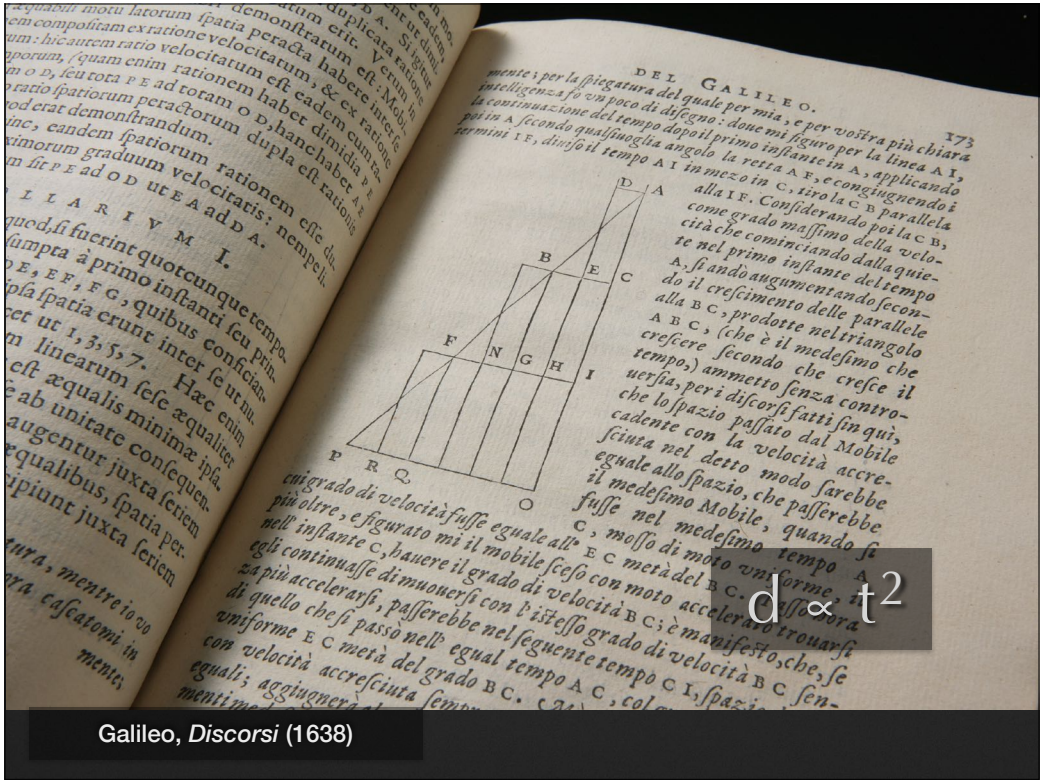
Galileo, Discorsi à Due Nuove Scienze (Leiden, 1638)
http://lynx-open-ed.org/node/560



Galileo, *Discorsi* (1638)

[Drawing on the impetus tradition of Jean Buridan,] Galileo proved that projectiles follow a parabolic trajectory.

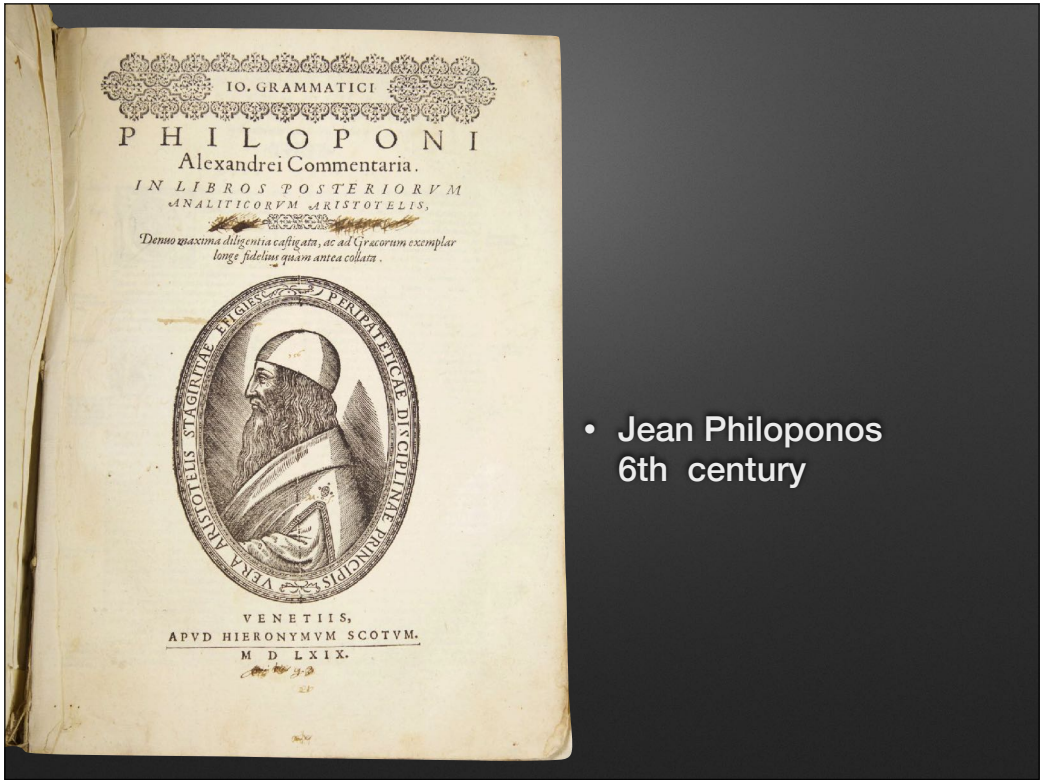
Apollonius, Conicorum (Oxford, 1710)
http://lynx-open-ed.org/node/461



Galileo, *Discorsi* (1638)

Galileo also demonstrated that falling bodies accelerate so that

• the distance they traverse is proportional to the squares of their times, regardless of weight.



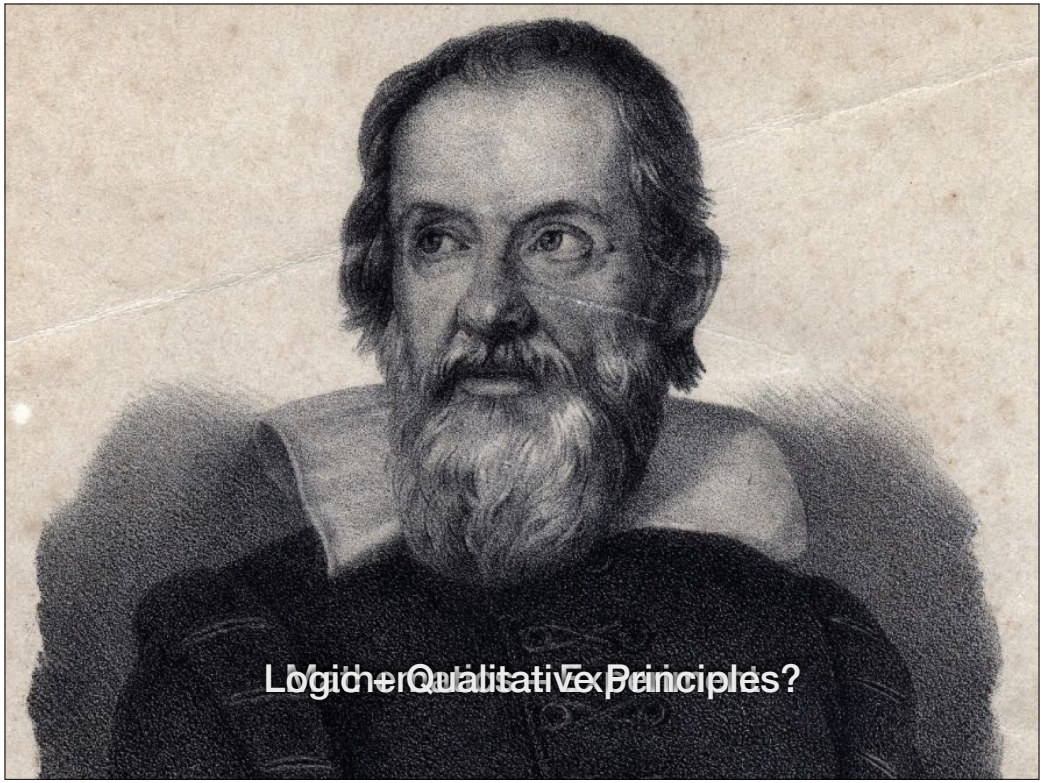
John Philoponos, working in Athens in the sixth century, dropped objects from a tall height to show that they do not fall at speeds proportional to their weight.

———

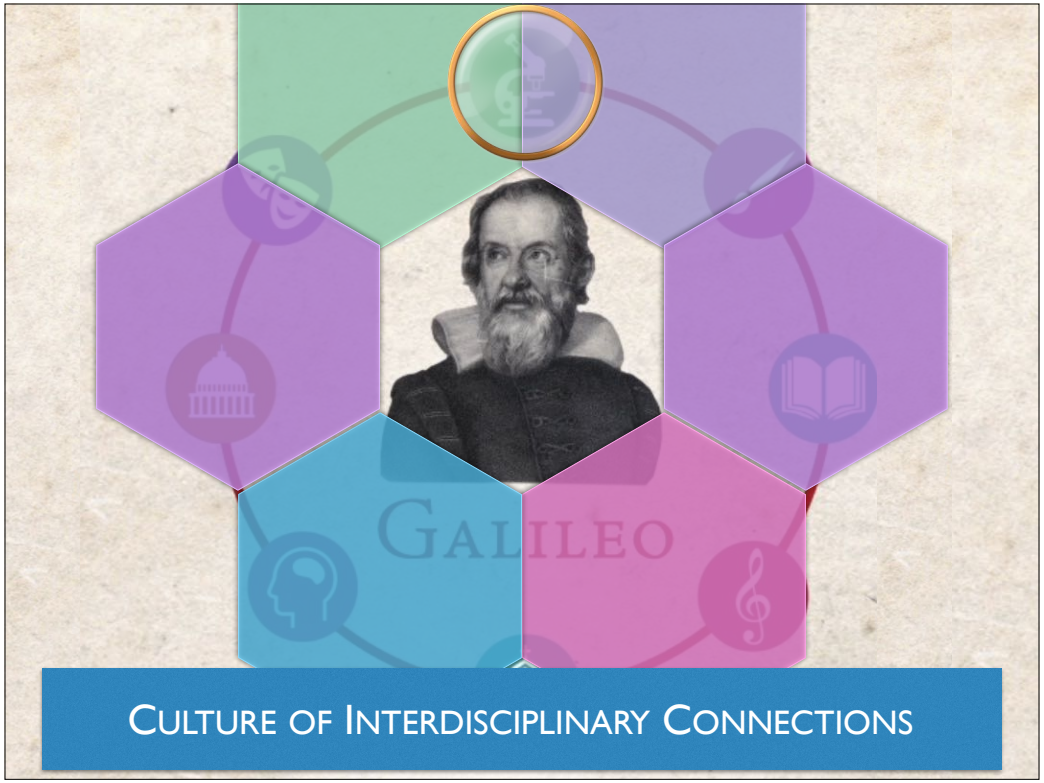
John Philoponos, In posteriora resolutoria Aristotelis Comentaria (Venice, 1504)
http://lynx-open-ed.org/node/463

Galileo never claimed to drop objects from the Leaning Tower of Pisa, nor did any eyewitnesses claim that he did so.

Rather, his insight was to use an inclined plane to slow the rate of freely falling bodies to a measurable speed. The inclined plane experiment, rather than the Tower of Pisa, best represents Galileo's new physics.



How did Galileo create a mathematical physics? In an era when physicists were not trained in mathematics but sought *logical* demonstrations based on *qualitative* principles, • Galileo pioneered an approach that combined mathematics and experimentation. This much is fairly well known.

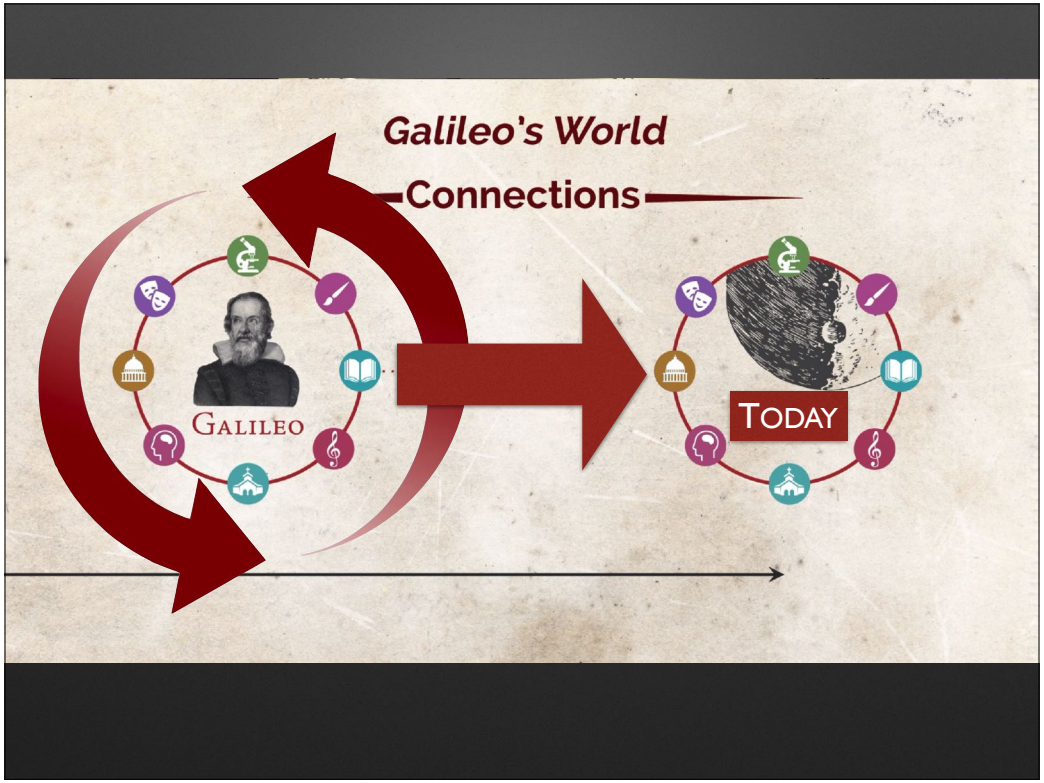


What is NOT very well known is how Galileo connected the entire circle of subject areas, some of which are shown here.

• Few people appreciate, for example, Galileo's involvement with medicine, our topic for today.

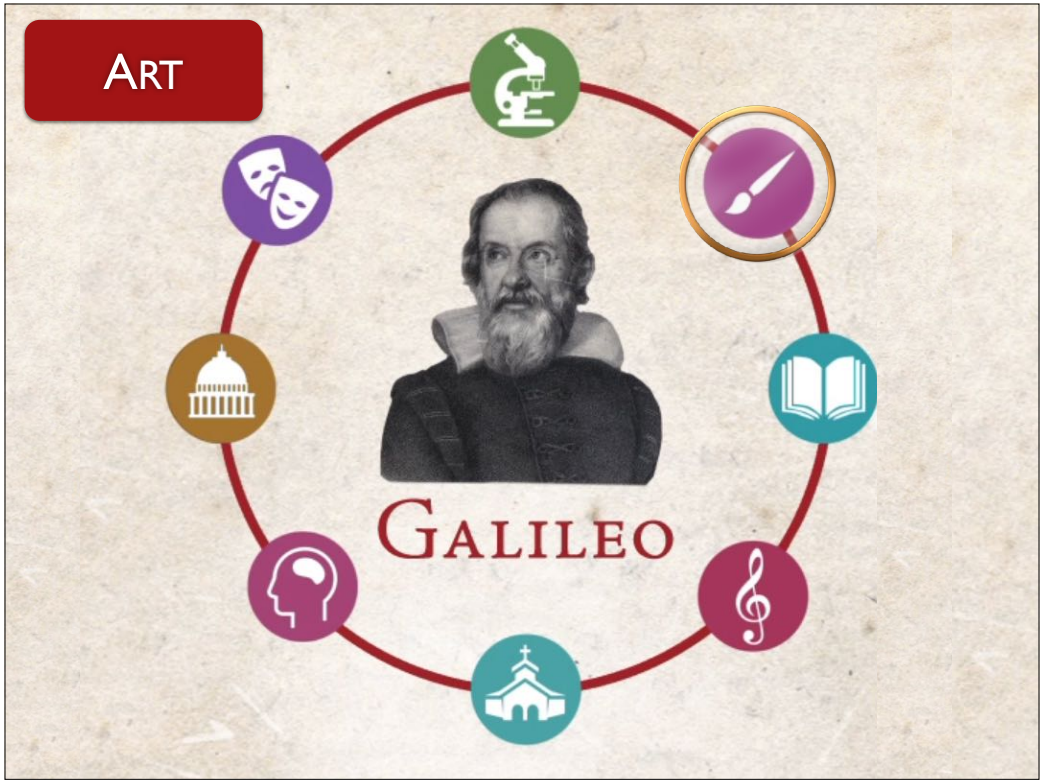
• Galileo's scientific innovations depended upon a culture of interdisciplinary connections. In typical Renaissance fashion, Galileo was a polymath. Instead of celebrating Galileo as a founder of modern science, I would like to shift our attention *from* Galileo himself to attend more carefully

• to the *culture* that surrounded and nurtured him. That interdisciplinary culture made Galileo's innovative work possible.

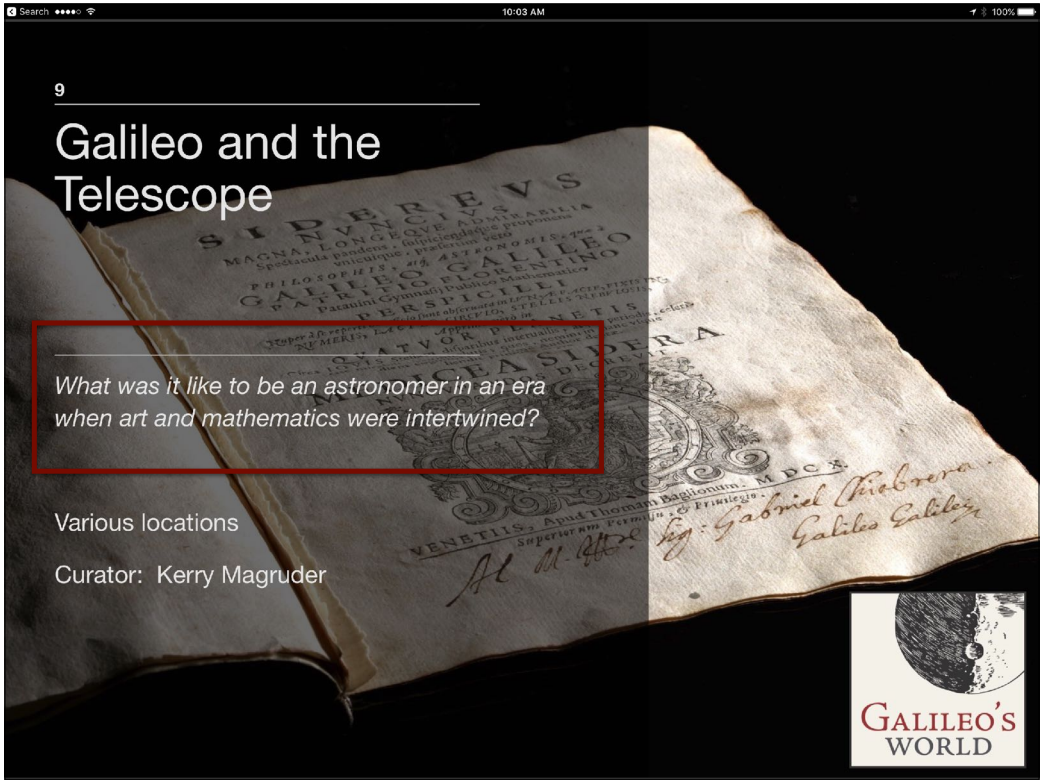


Connections occur in two dimensions:

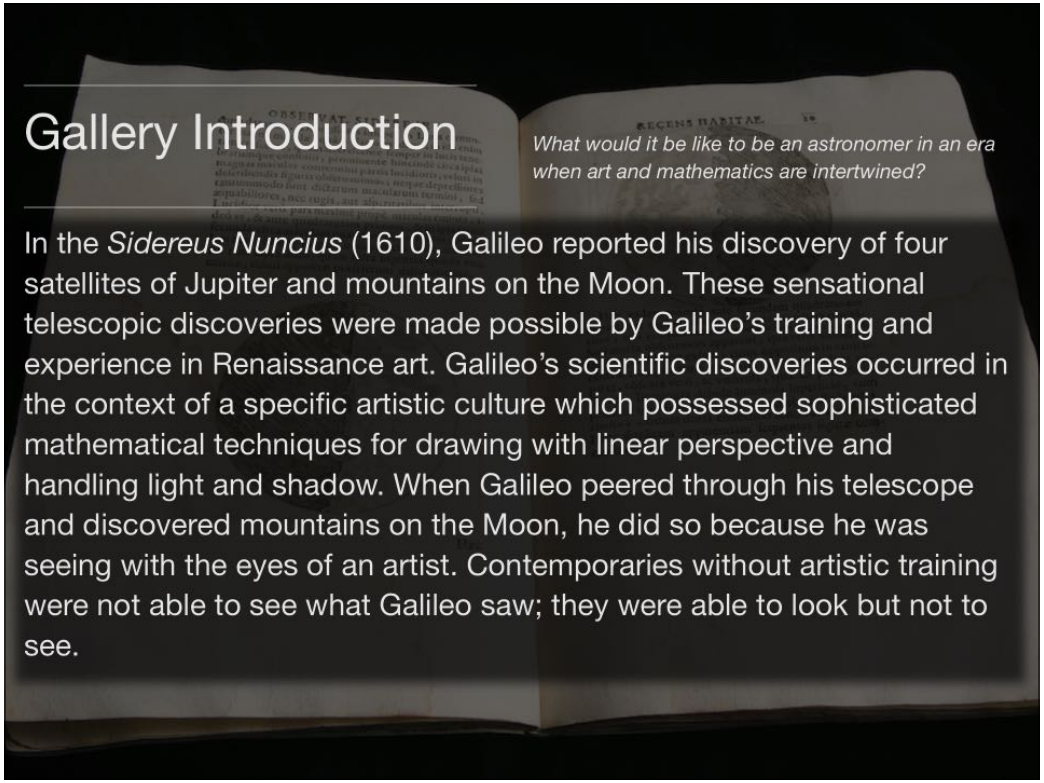
- First, connections between disciplines as shown in this circle of subject areas. How did the culture of connections between disciplines, back then, create conditions for creative innovation?
- Second, connections between Galileo's world 400 years ago, and our world today. How might we recreate a similar culture of interdisciplinary connections in our universities and research groups?



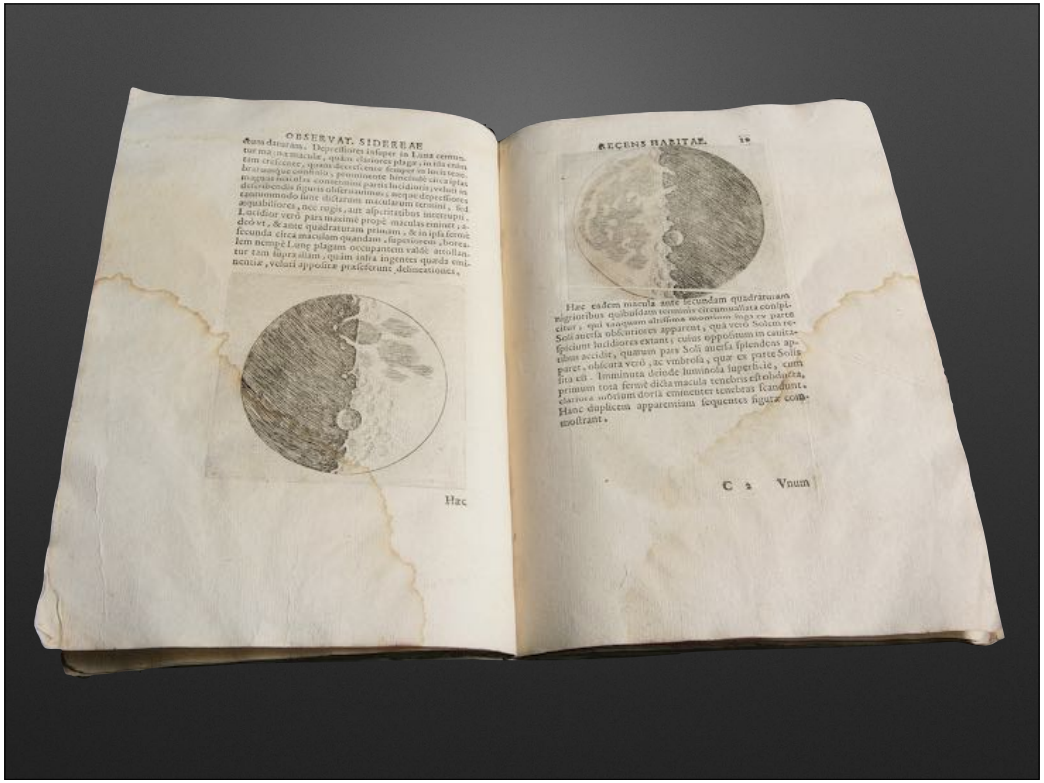
To get an idea of this culture of interdisciplinary connections, let's take a brief look at two examples involving the fine arts. First, some connections between art and science in Galileo's world.



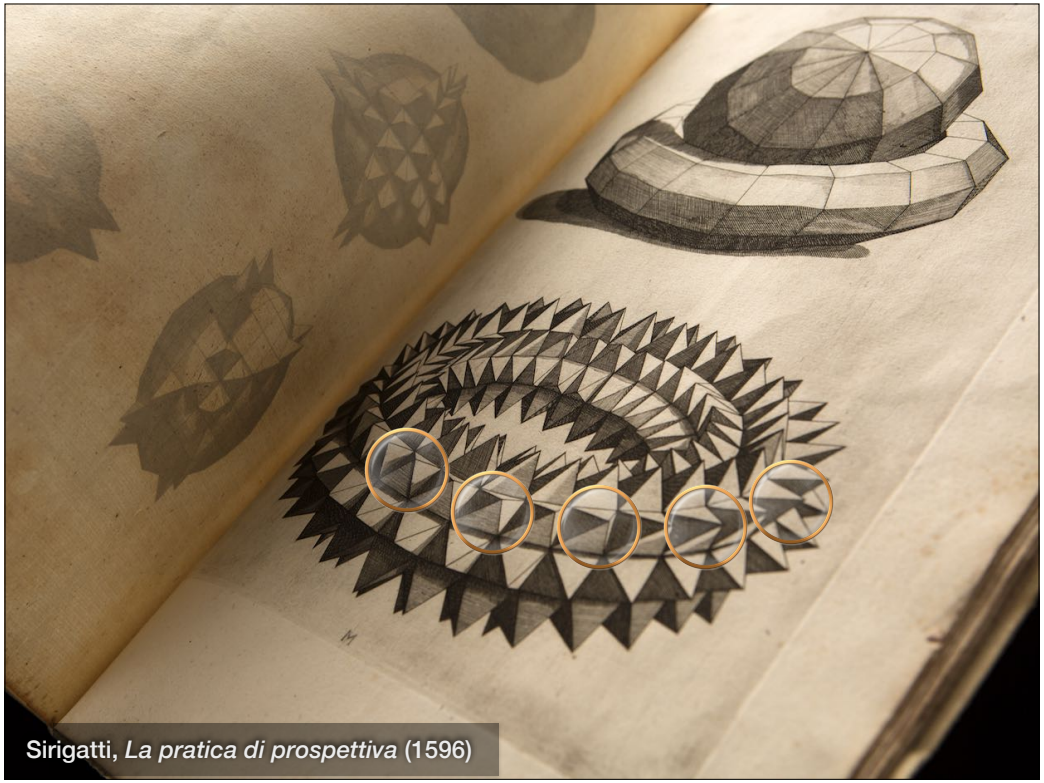
In the exhibit we inquired: "What was it like to be an astronomer in an era when art and mathematics were intertwined?"



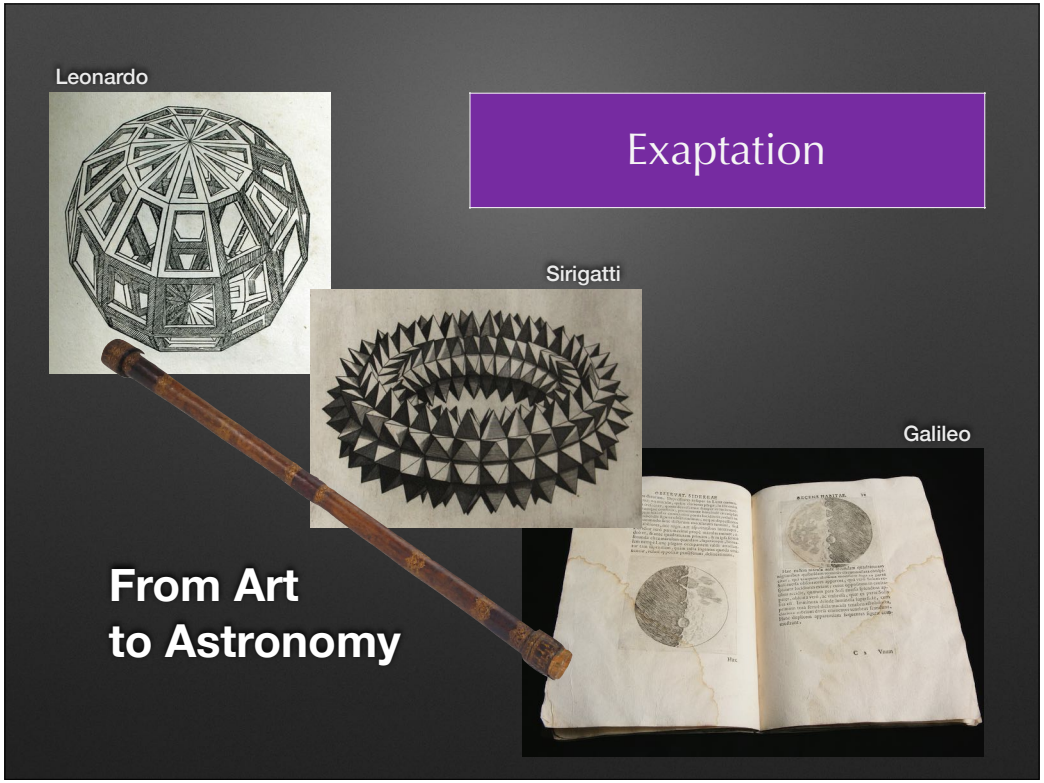
For this gallery, my introduction presented some bold theses: "In the Sidereus Nuncius (or Starry Messenger), Galileo reported his discovery of four satellites of Jupiter and mountains on the Moon. These sensational telescopic discoveries were made possible by Galileo's training and experience in Renaissance art. Galileo's scientific discoveries occurred in the context of a specific artistic culture which possessed sophisticated mathematical techniques for drawing with linear perspective and handling light and shadow. When Galileo peered through his telescope and discovered mountains on the Moon, he did so because he was seeing with the eyes of an artist. Contemporaries without artistic training were not able to see what Galileo saw; they were able to look but not to see."



Because telescopes at that time were of such poor quality, Galileo's discoveries were made not by optics but by the artistic training of his eyes.

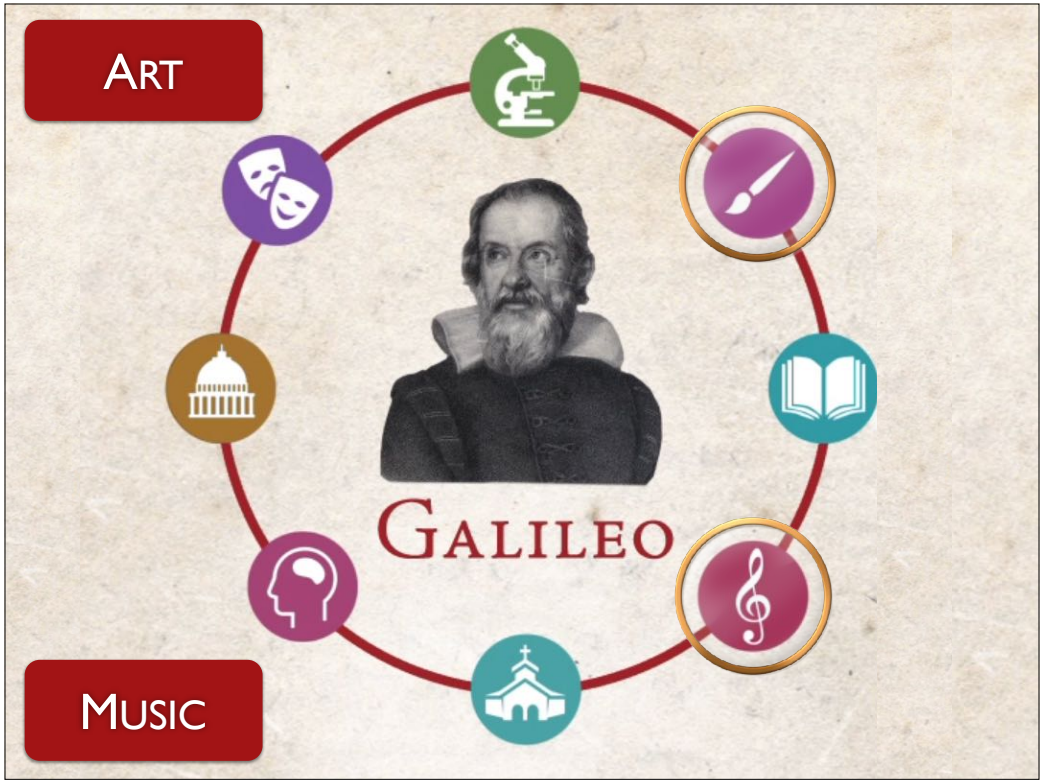


As a young man, Galileo was trained in perspective drawing. He worked his way through this manual by Sirigatti, recreating each of its drawings. • Imagine each spike is the same lunar mountain observed at different times under different angles of light. Careful study, and replication, of the spikes on this ring and the shadows they cast, prepared Galileo's eyes to interpret the shadows cast on the Moon by mountains and other topographical features.

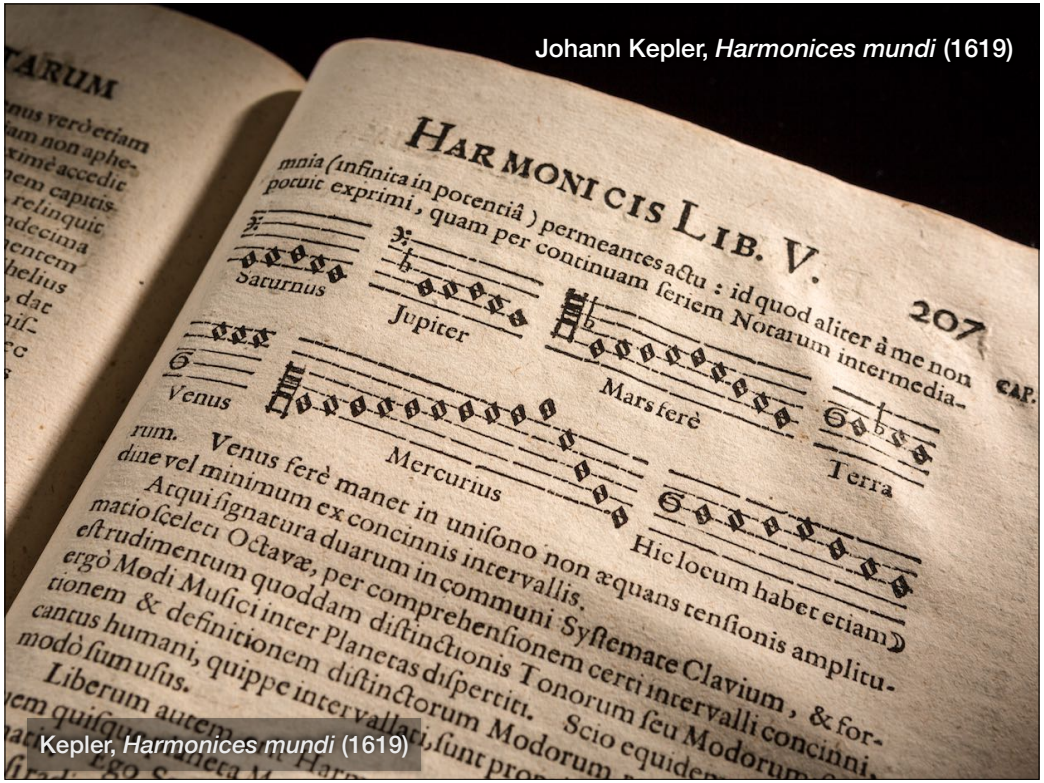


So the revolutionary astronomical discoveries of Galileo grew out of modes of inquiry and practice initially developed in art for perspective drawing.

• The appropriation of linear perspective drawing from art to astronomy is an example of innovation by exaptation, the transfer of knowledge or skill to a new domain. An artistic sequence of linear perspective drawing – from Leonardo, to Sirigatti, to Galileo – is the cultural context for the story that Galileo made his telescopic discoveries as much through art as through optics.



For a second example, again from the fine arts, let's look at connections between music and science in Galileo's world.

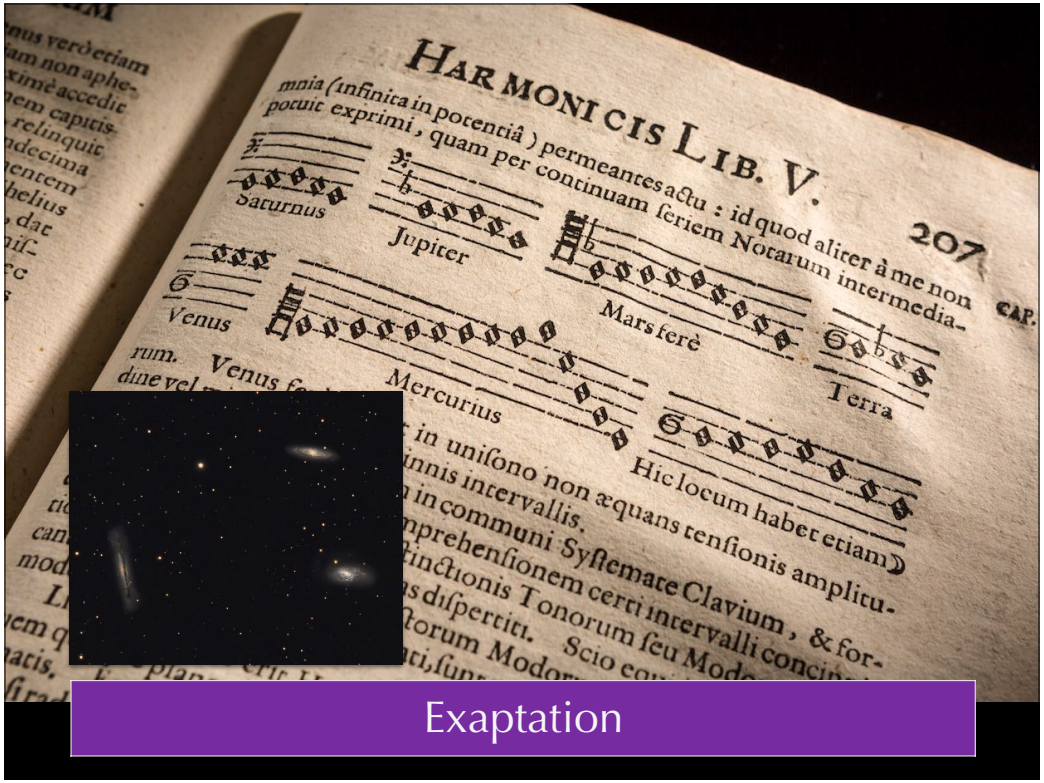


An astonishing example of music guiding astronomical inquiry is Kepler's Harmony of the Universe, which contains the laws of the motion of the heavens, including his harmonic law, written in musical notation. In this work Kepler was thinking musically. He regarded this work primarily as a contribution to music theory.

Kepler, *Harmonices mundi* (1619)

Kepler achieved a synthesis of his new astronomy with recent polyphonic musical theory. Kepler demonstrated that the motions of the planets consist of precisely the same harmonic ratios as the latest tuning of musical scales. The mathematical beauty of music provided the cultural context for what we call his “third law.”

Jonathan Annis, an OU graduate student in music composition, composed a suite for harp, flute and oboe entirely based upon musical themes from Kepler's book. Jonathan arranged the themes, but they're all from Kepler's musical description of the universe as a cosmic dance. Here's a 15-second clip: •[listen 15 secs]



So Kepler's musical mode of thinking led him to formulate his harmonic law that still governs the motions of planets, stars and galaxies.

• I regard Kepler's transfer from music theory to astronomy as a stunning example of innovation by exaptation.

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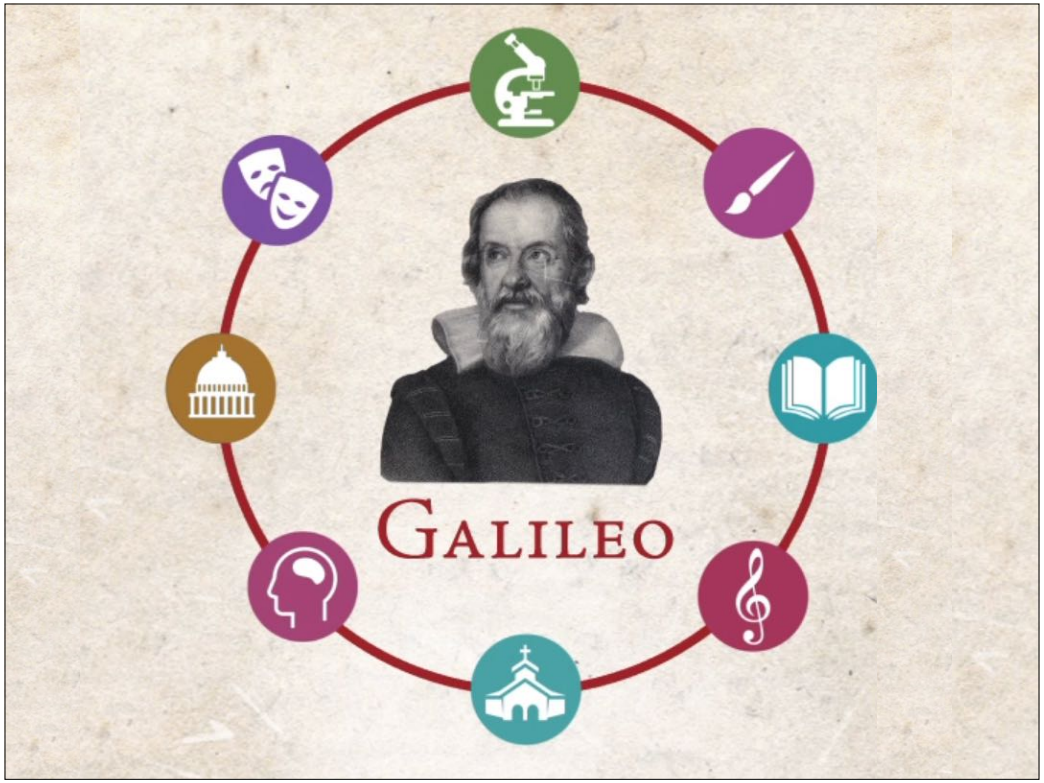
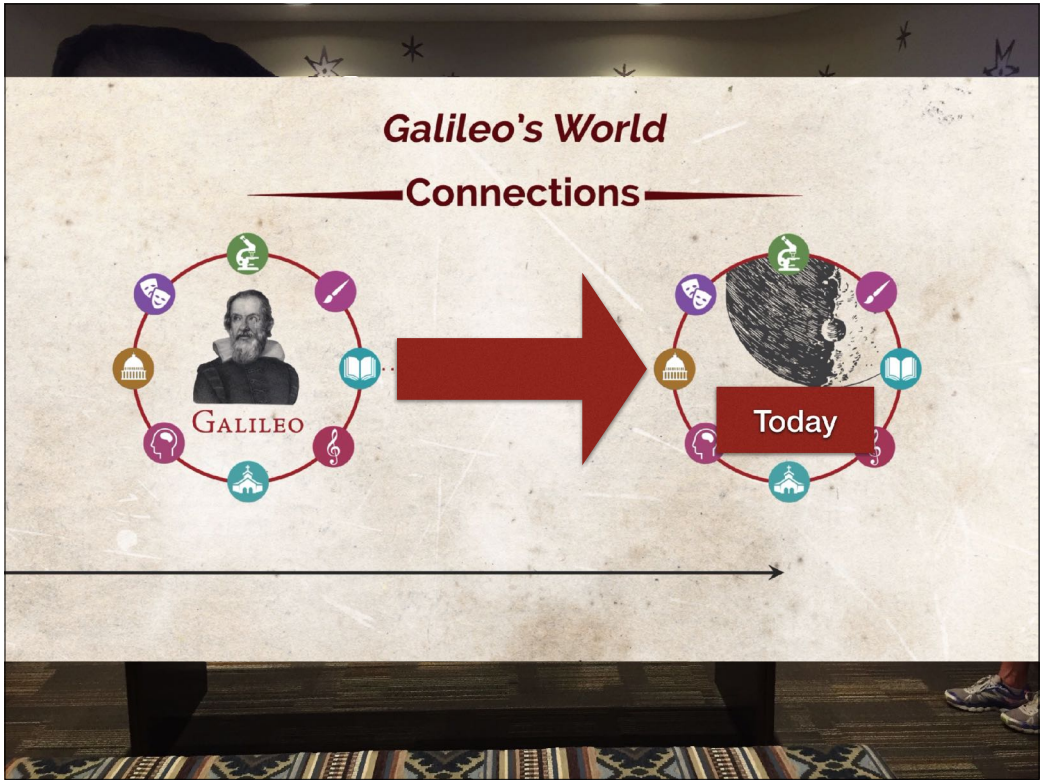
[This kind of interdisciplinarity, or connections between subject areas at a profound, creative, heuristic level, is what the history of science and the Galileo's World exhibition were all about.]



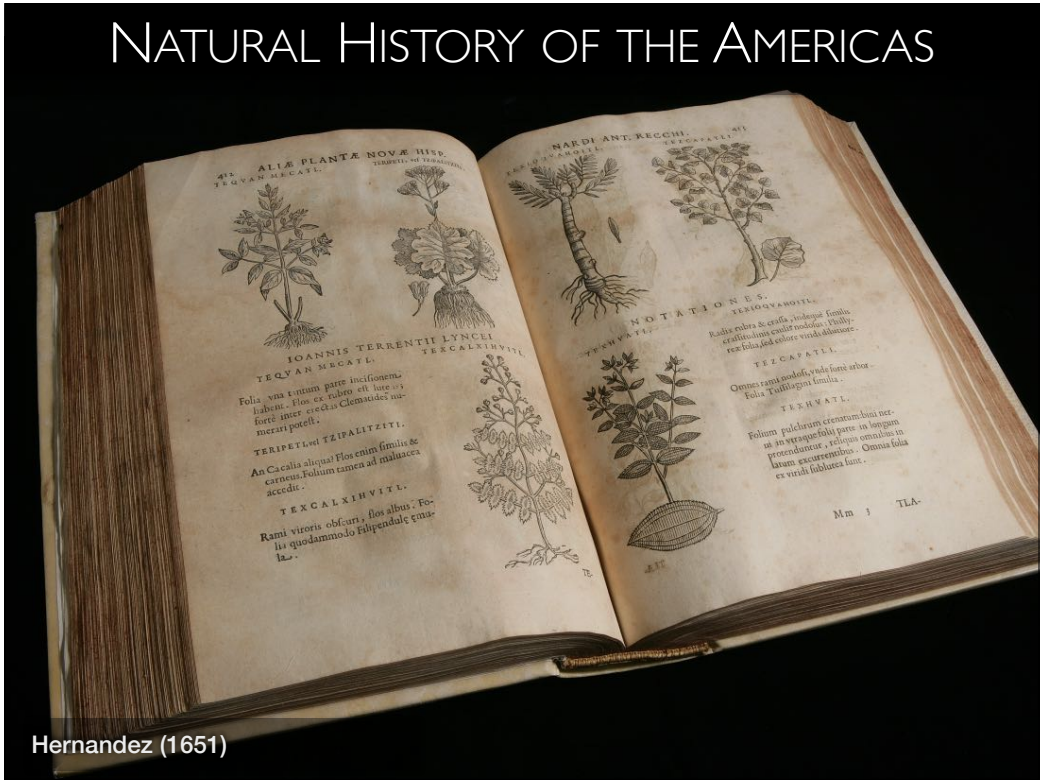
So a whole circle of different subject areas, some of which are symbolized here, reflect the interconnectedness of science and culture which characterized Galileo's world.



But how does Galileo's World connect to our own day? Let's glance at three more quick stories of connections that moved beyond Galileo's narrow world 400 years ago in Tuscany, to larger and wider worlds.

First, consider this book, bound and cased in a typical Asian style.

We've all heard of Shrek. But instead of this big green guy, *Johann* Schreck was a friend of Galileo's who assisted him during his telescopic discoveries. Soon afterward, Schreck went to China, where he wrote this work on engineering in Chinese. How many of our Asian students know Galileo had a friend in China?



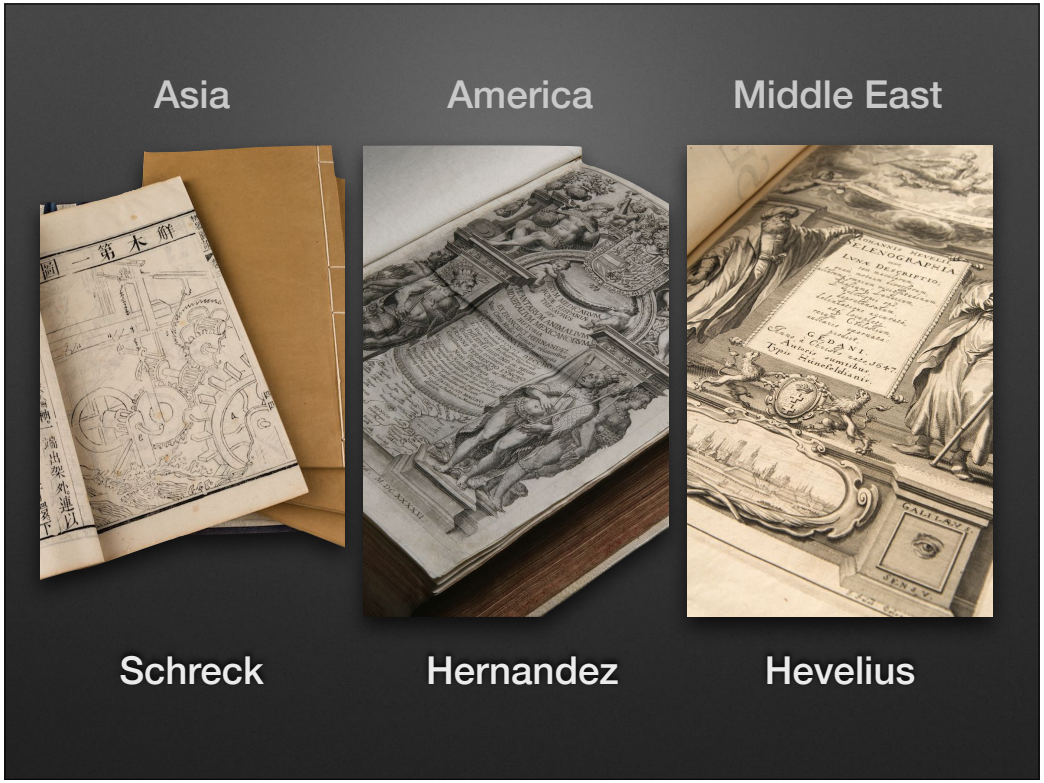
Here's a second example. This book, by Francisco Hernandez, is the most important early natural history of the Americas. Hernandez spent 7 years with the Aztecs in central Mexico. Galileo and his colleagues in the Academy of the Lynx worked to publish a definitive edition, which finally appeared in print nearly 80 years later.

The scientific and medical knowledge of Native Americans transformed European science in the age of Galileo. (Pause) The story of Hernandez brings together the Americas and the world of Galileo. How many of our Native American and Hispanic students appreciate that the science and medicine of indigenous Americans was so important to Galileo and his generation?

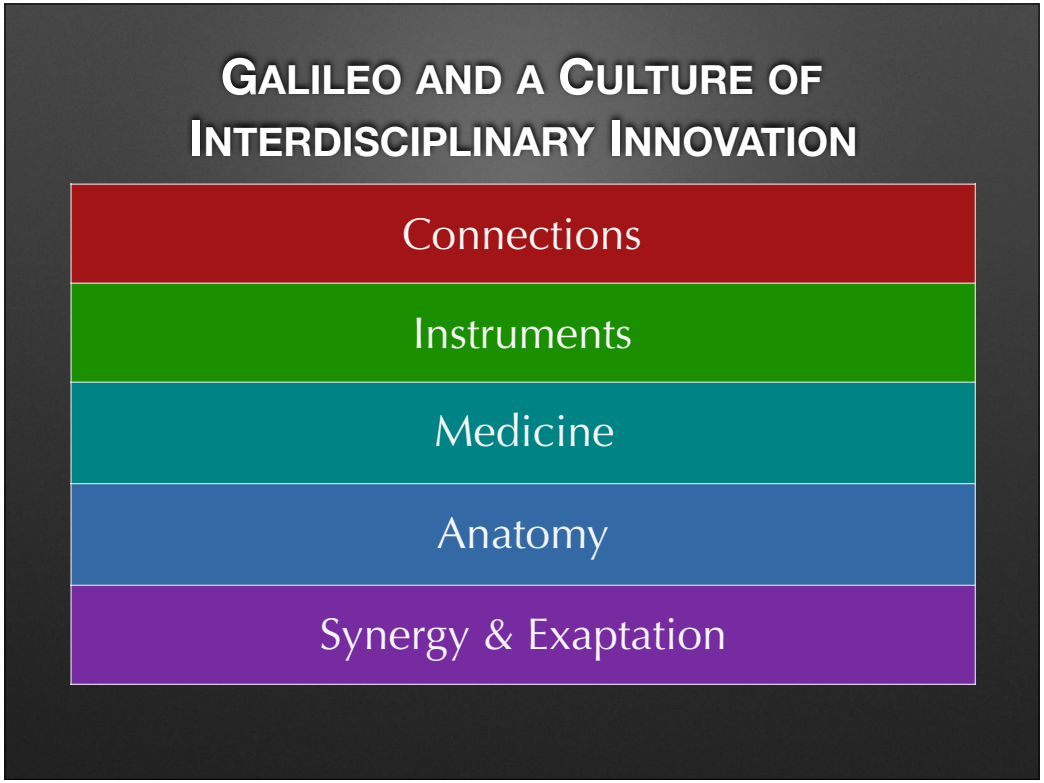
Consider a third story: Johann Hevelius was the leading European telescopic observer in the mid-17th century. This massive book was the first comprehensive lunar atlas. It accurately mapped the Moon within 40 years of Galileo's telescopic discoveries.

On the frontispiece, Hevelius portrays Ibn al-Haytham, a leading medieval Islamic astronomer and optical theorist.

On the right, holding a telescope, is Galileo. Who would have guessed that one of the most impressive works of the "Scientific Revolution" would portray Galileo in Middle Eastern dress as a tribute to Islamic science?

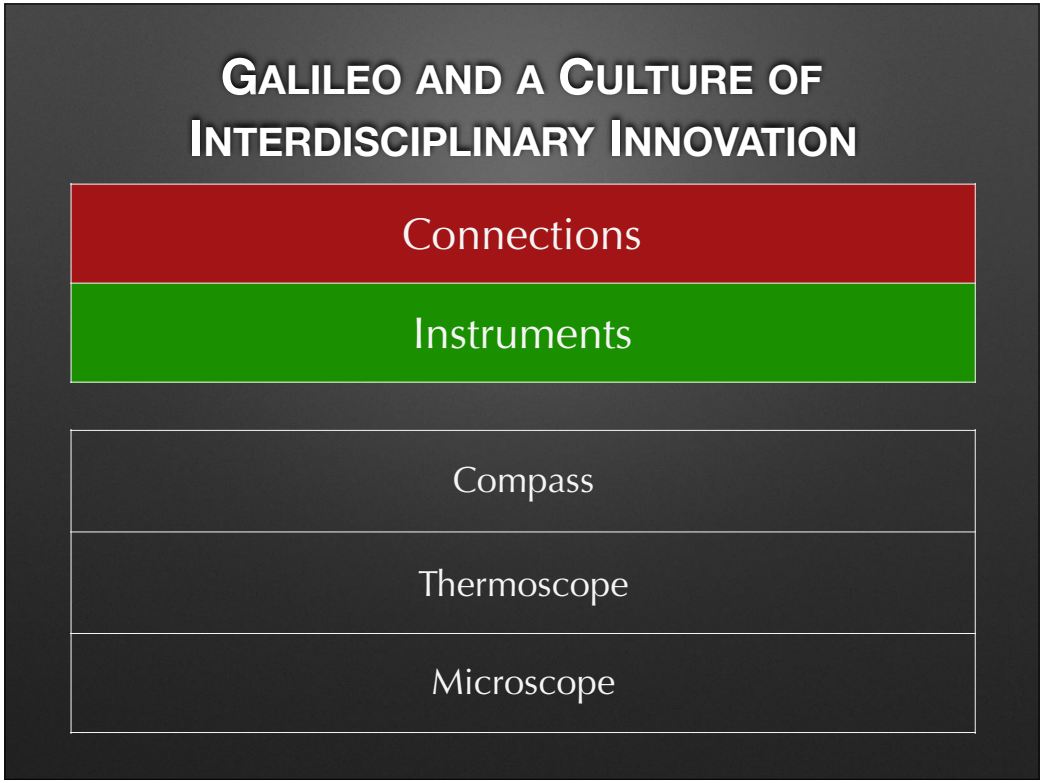


We'll have more to say about the Hernandez story in a few minutes. But for now, we've seen that Galileo's world connected Asia, America and the Middle East. If Galileo's world brought worlds together in the past, are there lessons we may learn from connections like these that apply to ATSU and to research in medicine?



So that's an introduction to the culture of interdisciplinary connections in the world of Galileo.

• Let's turn to Galileian innovations in Instruments.



In this section, we'll look at the stories of three of Galileo's instruments: • the compass, thermoscope and microscope. Galileo was an engineer in the Republic of Venice. Venetian engineering was the cultural context for his innovative work with instruments. We'll begin this section by looking at a few examples of what it meant to be an engineer.

Manzini, *L'Occhiale* (1660)

Galileo began grinding his own lenses as early as 1609. He continued to prepare lenses for telescopes and microscopes until late in life, both in Venice and in Florence. Galileo designed this lens grinding machine when he was 75 years old.

— — — —

Manzini's book describes methods for making mirrors and lenses, using a spherical stone to grind and polish a glass surface into a parabolic shape. Mirrors were made of glass backed with a reflecting surface made of tin and mercury.

This is an author's presentation copy, with hand-written corrections.

Carlo Antonio Manzini, L'Occhiale all'Occhio, Dioptrica Practica (Bologna, 1660)
http://lynx-open-ed.org/node/348

The book on the left displays a machine designed by Ramelli, a generation before Galileo, which employs the Archimedean screw mechanism for transporting water. Schreck took a copy of Ramelli with him to China. On the right is the same machine from a book Schreck wrote in Chinese, after his arrival in Beijing.

Lorini, *Delle fortificationi* (1597)

Here is a book on fortifications by Lorini. Drawing upon Archimedes, Lorini asserted that all machines could be reduced to the balance and thus to the lever. From his home in Padua, Galileo taught a private course on fortifications. Both Lorini and Galileo were shaped by a common Florentine tradition in engineering.

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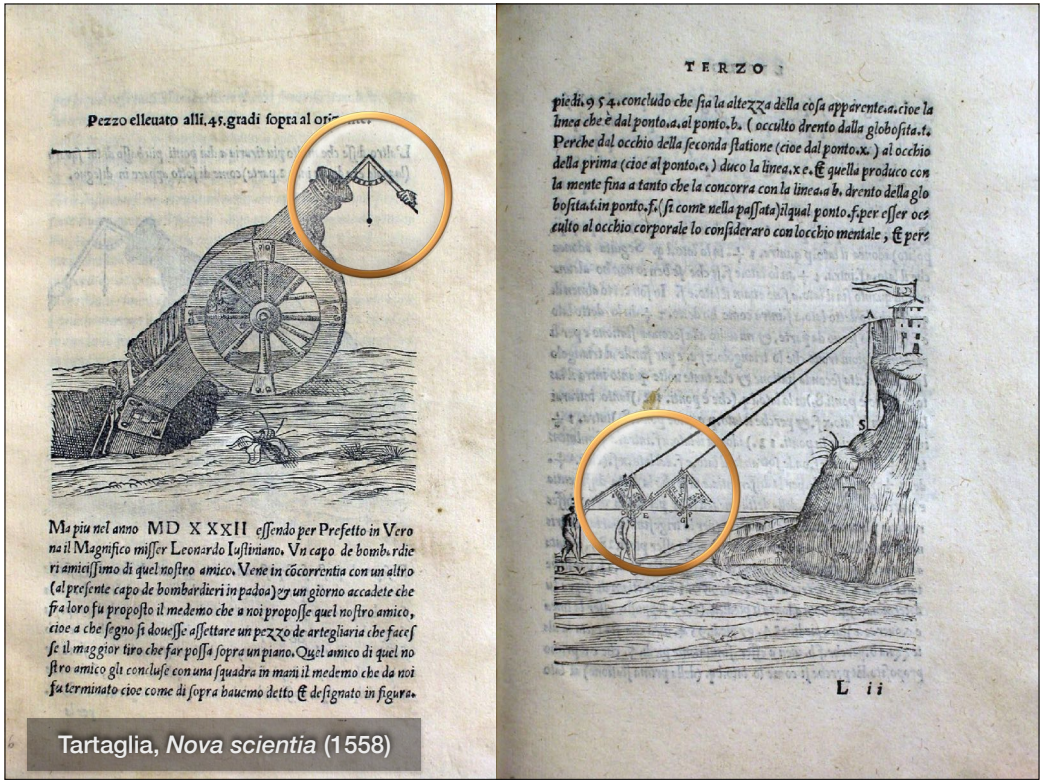
Buonaiuto Lorini, Delle Fortificationi (Venice, 1597), "On Fortifications"
http://lynx-open-ed.org/node/344



Tartaglia, *Nova scientia* (1558)

Tartaglia's compass (also known as a "sector") incorporated the functions of a quadrant and a caliper measuring device.

• His "new science" investigated the ballistics of cannonballs, laying a foundation for Galileo's studies of projectile motion and free fall. Tartaglia taught a teacher (Ostilio Ricci) of Galileo.

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Niccolo Tartaglia, Nova scientia (Venice, 1558), "New Science"
http://lynx-open-ed.org/node/346

The Museo Galileo in Florence holds Galileo's original sector compass. From a distance, it looks like Tartaglia's, but it contains innovative scales of Galileo's own design.

Galileo, *Del compasso* (1606)

(1635)

Galileo's first printed book {Compasso, 1606) was a manual for his sector compass.

• The scales were depicted in a later edition. Galileo provided the instrument and the book to students who boarded with him for engineering tutorials.

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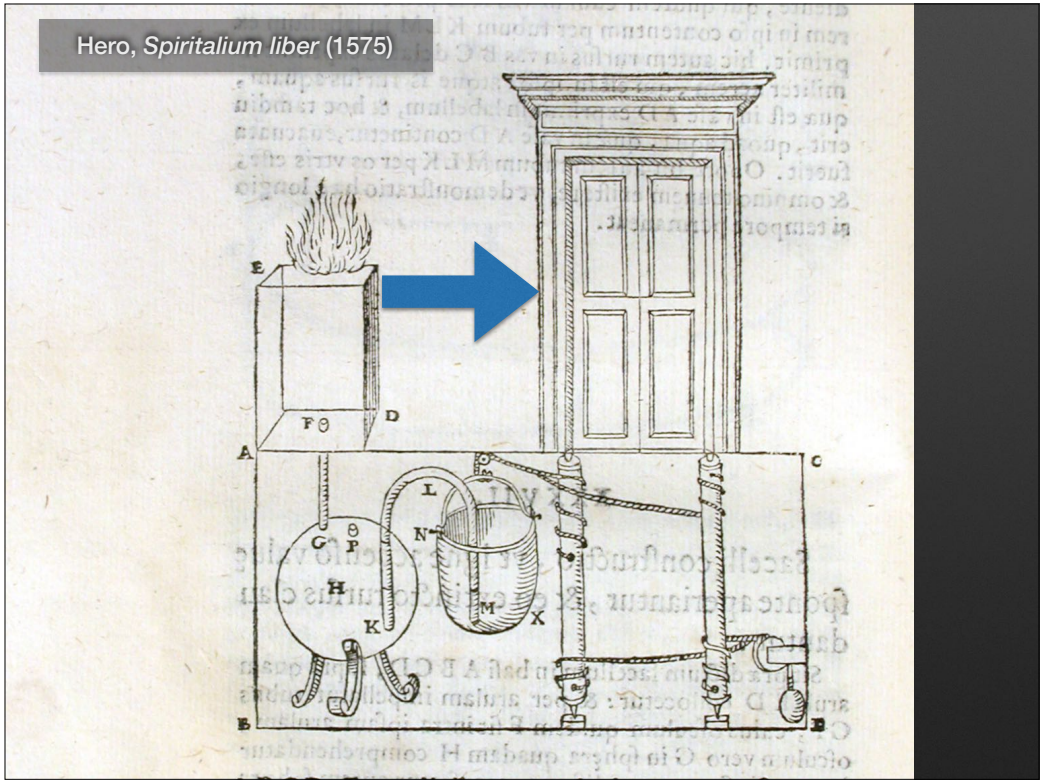
Galileo, Tractatus de proportionum instrumento (Strassburg, 1635), 2d ed.

http://lynx-open-ed.org/node/363



The second instrument is Galileo's thermoscope. For the tradition of pneumatic engineering, let's go back to the first century C.E., when Hero of Alexandria fashioned all sorts of marvelous automata using steam, air pressure, hydraulics and falling weights.

• Once the altar portrayed in this image is lighted, the temple doors will open automatically. Hero's inventions were an important source for Renaissance engineers like Galileo.

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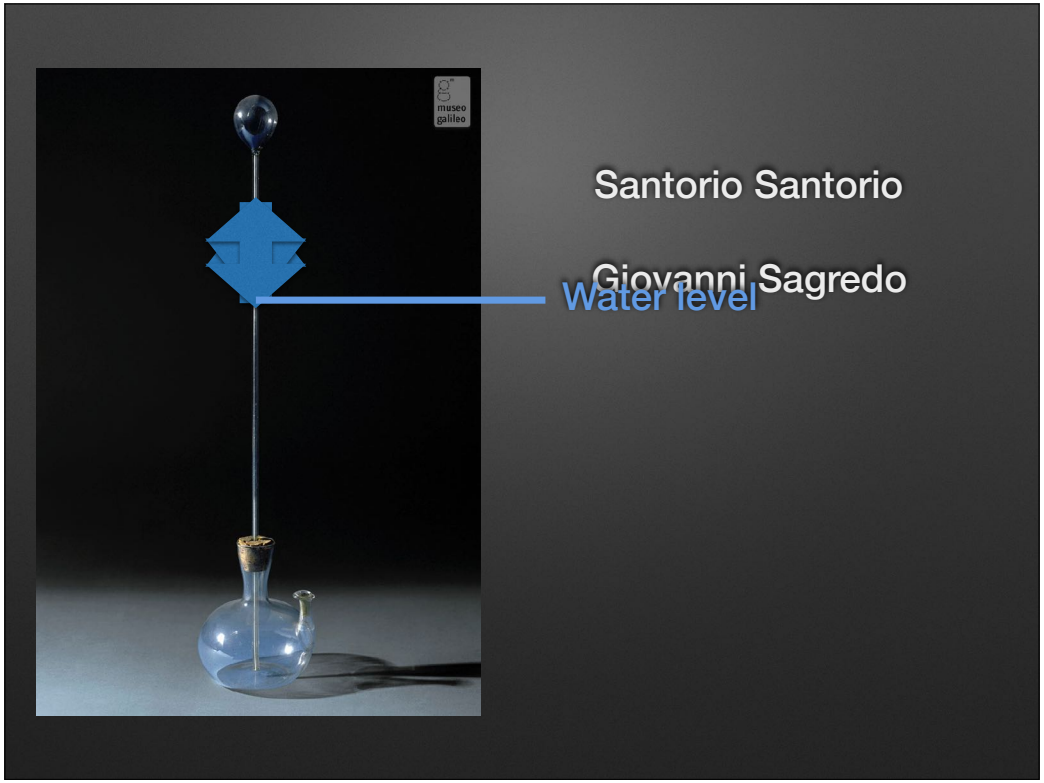
Hero of Alexandria, Spiritalium liber (Urbini, 1575), trans. Federico Commandino
http://lynx-open-ed.org/node/413



Galileo's thermoscope, developed in the tradition of Hero, was an ancestor to the thermometer.

• If a glass tube is filled with water, then inverted and its lower end placed in a small decanter, the water level will

- rise when heat is applied, say, by holding the decanter in one's hand,
- or fall when the room grows colder.
- The thermoscope relies upon the principle that the volume of water changes when the temperature changes, expanding at higher temperatures and contracting when it is cooler.
- Galileo pioneered scientific investigations with the thermoscope along with his two Venetian friends, Santorio Santorio and Giovanni Sagredo. Together they quickly improved the thermoscope in two ways: first, by adding measuring units and, second, by sealing the tube at both ends. Until the glass tubes were sealed at both ends, early thermoscopes measured the mixed effect of air temperature and atmospheric pressure, so the development of the thermometer and barometer occurred together.

———-

Galileo Thermoscope replica (Museo Galileo)
http://lynx-open-ed.org/node/364

Galileo’s thermoscope made it possible to refute a then-widespread belief that well water grows warmer in the winter than in the summer.

Santorio affixed measuring units to the glass tube — which marks the transition from the thermoscope to the thermometer. Sagredo attempted to standardize the scale to correspond to the temperatures

• of snow, of salt water on a cold day, and of the hottest day of summer. Thereby they were able to test the common belief that well water is warmer in the winter than the summer. Well water does *seem* warmer in the winter, once our senses grow accustomed to colder temperatures, but the thermometer demonstrated that well water is actually colder in the winter, contrary to common sensory perception.

Accademia del Cimento, *Saggi* (1666)

In the wake of Galileo, Grand Duke Ferdinand II, in Florence, established the Academy of Experiment,

• which carried further the research program of Galileo. The Academy of Experiment pioneered meteorological investigation using the thermometer, barometer and air pump.

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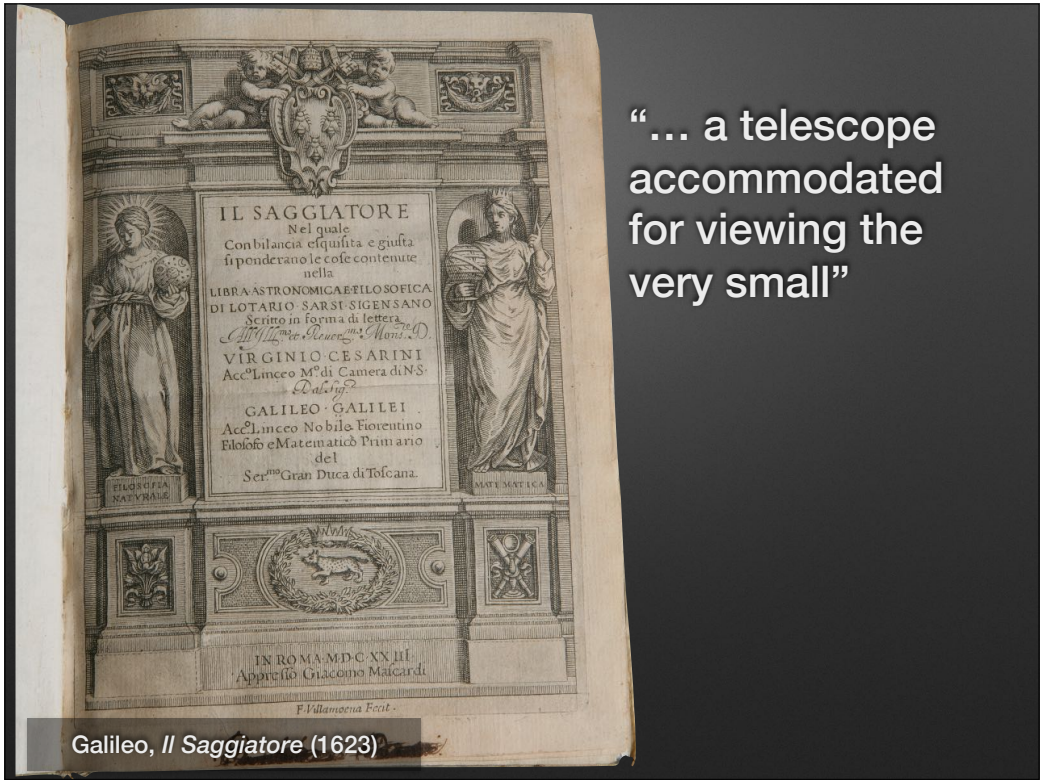
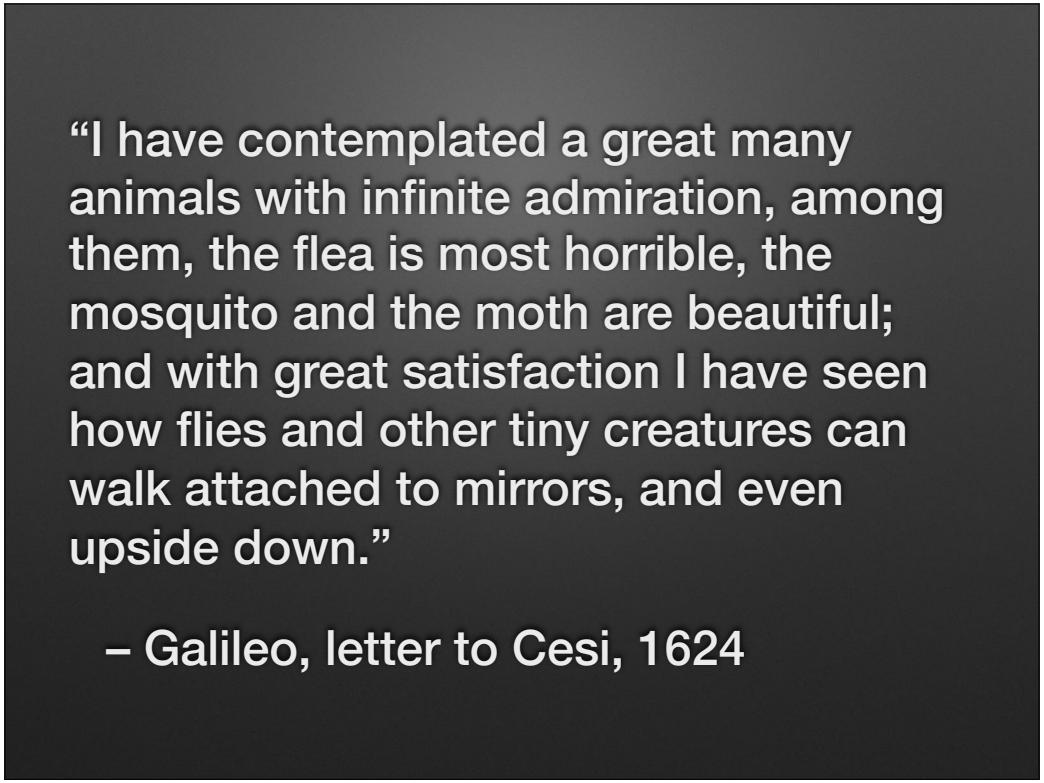
Accademia del Cimento, Saggi di Naturali Esperienze (Florence, 1666)
http://lynx-open-ed.org/node/418



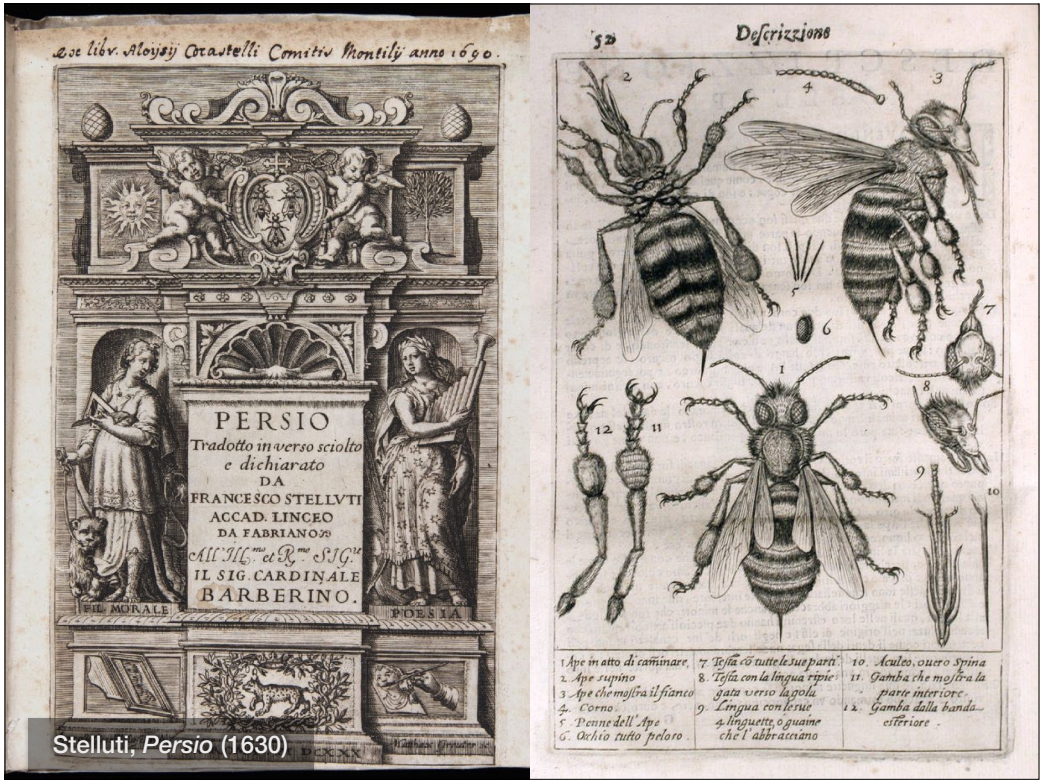
The third instrument we'll single out is Galileo's microscope. Galileo devised a tube containing three lenses, which he described in this book

- as "a telescope accommodated for viewing the very small." A friend, Johann Faber, named it a "microscope."



Galileo wrote his friend and patron, Prince Federigo Cesi, “I have contemplated a great many animals with infinite admiration, among them, the flea is most horrible, the mosquito and the moth are beautiful; and with great satisfaction I have seen how flies and other tiny creatures can walk attached to mirrors, and even upside down.”

Cesi and Francesco Stelluti used Galileo's microscope to study the bee. They published the Apiarium, the first published report of observations made with a microscope. • If you haven't heard of it before, that may be because the OU copy is one of only 4 extant printed copies.



Stelluti, *Persio* (1630)

Another work written at the same time is Stelluti's critical edition of the poems of Persius, an obscure Roman poet. Stelluti added scholarly annotations on various topics,

• including a discussion of bees. In this plate Stelluti depicted structures of the bee as they appeared under Galileo's microscope, as described in the Apiarium.

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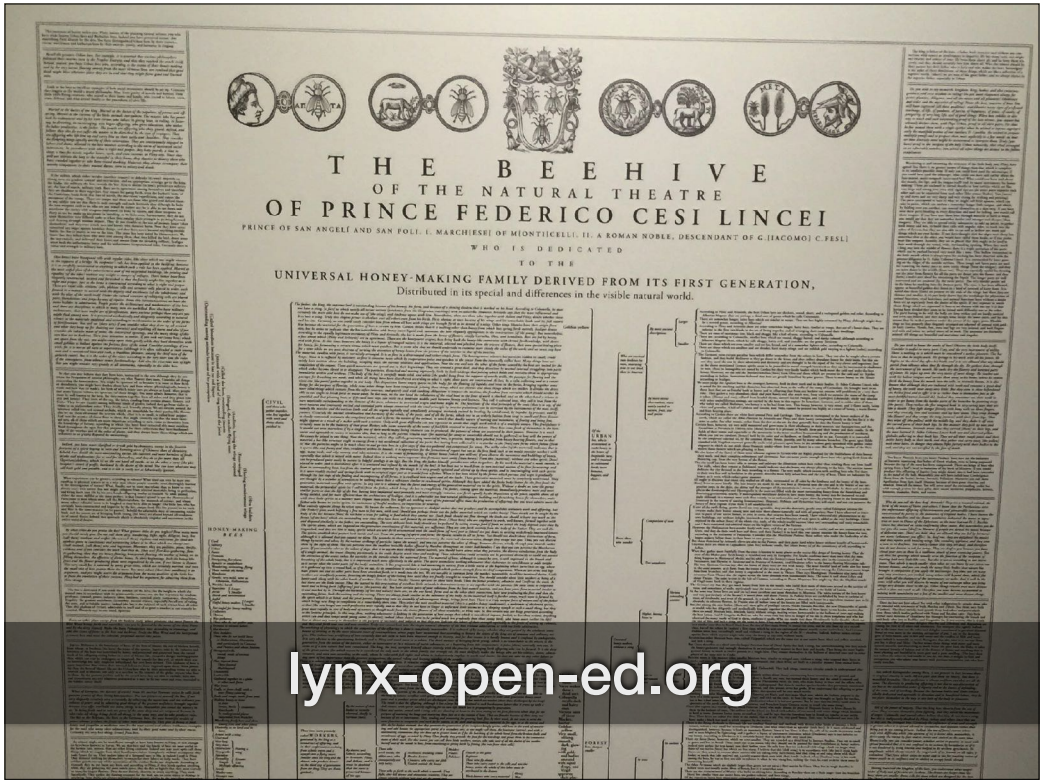
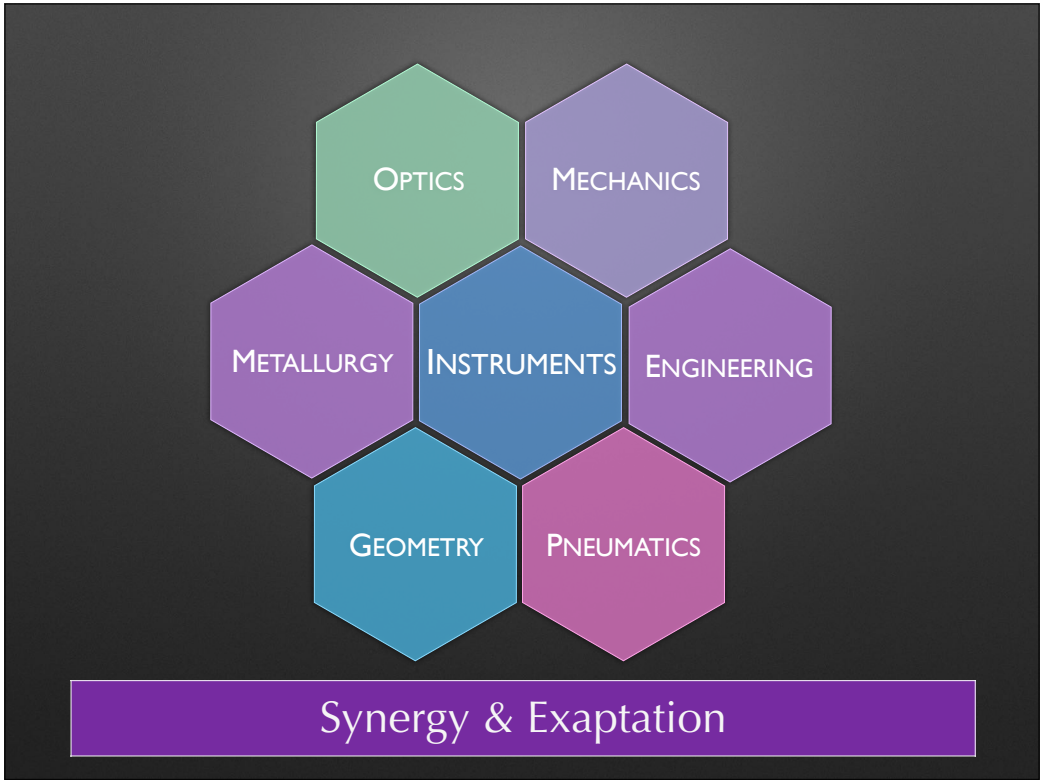
Francesco Stelluti, Persio (Rome, 1630)
http://lynx-open-ed.org/node/546

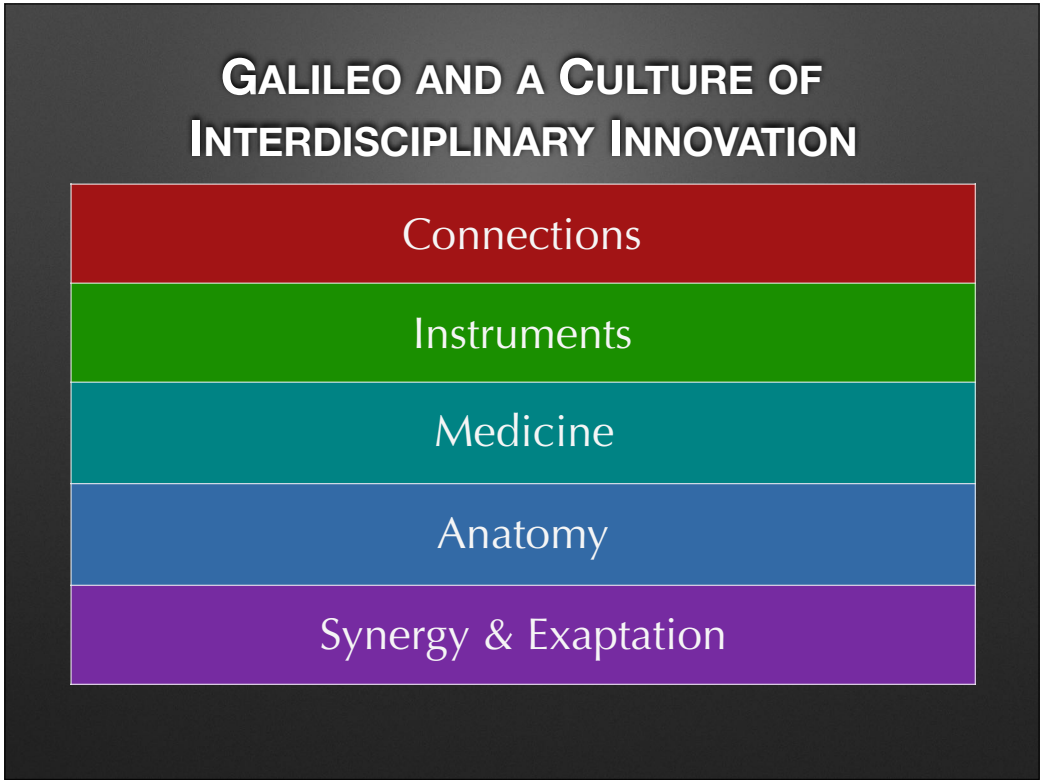


You can learn more about the Apiarium, and download this English translation, from our educational website, Lynx Open Ed.



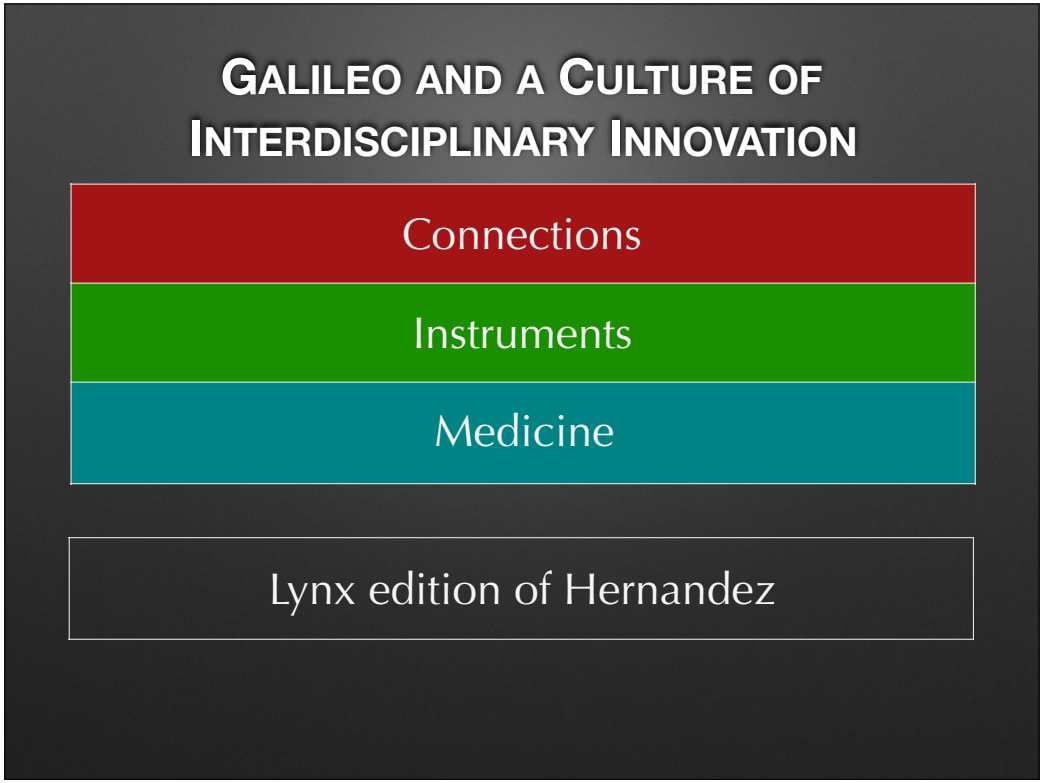
In this section we have seen a circle of subject areas inter-connecting in the

- creative fashioning of innovative instruments by Galileo and his friends.
- The interaction, and transfer of skills and knowledge, between these domains reflect a culture that promoted interdisciplinary synergy and exaptation.



So that's Instruments – that is, Galileo's compass, thermoscope and microscope.

• Now let's turn to Galileian innovations in Medicine.



Let's return to the story of the Lynx edition of Hernandez, the most important early natural history of the Americas.

The biological investigations in which Galileo participated were carried out by the Academy of the Lynx. The Lynx joined together many of the leading naturalists of the day. In antiquity, the lynx was renowned for possessing sharp eyesight at night. The founder of the Academy of the Lynx, Federigo Cesi, believed that the eyes of the Lynx would peer more deeply into the secrets of nature than ever before. The keen eyes of the Academy of the Lynx stretched the boundaries of European thought in the life sciences, with the microscope and the Hernandez, as well as in the physical sciences, with the telescope.

Galileo, *Letters on Sunspots* (1613)

Galileo proudly included the emblem of the Lynx on the title pages and frontispieces of his subsequent books,

• and added the title “Linceo” (member of the Lynx) after his name.

Stelluti's edition of Persius displays the emblem of the Academy of the Lynx.

• Just as Stelluti added scholarly annotations on bees, so he added a digression on the lynx.

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Francesco Stelluti, Persio (Rome, 1630)
http://lynx-open-ed.org/node/546

This early book by Colonna, a member of the Lynx and an editor of Hernandez, is the earliest book to contain copperplate engravings of plants.

• The 26 engravings show much more detail than was possible with woodcuts, as is evident by comparing Colonna's wood block borders with the engravings of the plants themselves.

• The plant phu (this page), was believed to be a cure for epilepsy, which motivated Colonna's botanical work.

———————-

Fabio Colonna, Phytobasanos (Naples, 1592)
http://lynx-open-ed.org/node/553


Crescenzi, *Ruralium* (1471)

Let’s consider a few examples in the western tradition that would have been familiar to naturalists. This is the earliest published work on agriculture, a manual for managing a feudal estate. It is an ancestor to the early printed herbals. It explains what plants one must cultivate to be able to make the common herbal remedies.

———————————

Pietro de’ Crescenzi, Ruralium commodorum (Augsburg, 1471)
http://lynx-open-ed.org/node/554

Fuchs, *De historia stirpium* (1542)

Leonart Fuchs, a professor of medicine at Basel, Switzerland, extracted the best knowledge available from ancient sources,

- This work contains descriptions of 500 plants, 400 of which were native to Germany.
- Fuchs gave each plant a German name as well as the traditional Latin. Medicinal uses of Aloe were described by Dioscorides in the first century C.E. Fuchs described nearly 100 northern European plants unknown to the ancients.

———————

Leonhart Fuchs, De historia stirpium (Basel, 1542)
http://lynx-open-ed.org/node/556

This is the most important English herbal prior to the Lynx edition of Hernandez.

• Gerard directed the gardens of William Cecil (Lord Burghley), Queen Elizabeth's chief executive.

———-

John Gerard, The Herball (London, 1597)

http://lynx-open-ed.org/node/558

Gerard, *Herball* (1597)

In this capacity, Gerard maintained contacts with naturalists around the world who sent him both exotic plants and the soil to grow them in.

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John Gerard, The Herball (London, 1597)
http://lynx-open-ed.org/node/558

Turkie corn was cultivated by the Mayans as a staple crop. Although maize originated in Mexico, it became known as Turkey Corn because it was shipped to Europe through Turkey and the Ottoman empire. Hernandez included long and detailed descriptions of corn, and the varieties of drinks and meals prepared with it.

Of Potatoes of Virginia. Chap. 335.

Batata Virginiana ſiue Virginianorum, & Pappus.
Potatoes of Virginia.

The deſcription.

VIrginia Potatoes hath many hollowe flexible branches, trailing vppon the grounde, three ſquare, vneuen, knotted or kneed in ſundry places at certaine diſtances; from the which knots commeth foorth one great leafe made of diuers leaues, ſome ſmaller, & others greater, ſet togither vpon a fat middle rib by couples; of a ſwart greene colour tending to rednes. The whole leafe reſembling thoſe of the Parſnep, in taſte at the firſt like graſſe, but afterward ſharp & nipping the toong: from the boſome of which leaues come foorth long rounde ſlender footſtalks, whereon do grow very faire and pleaſant flowers, made of one entire whole leafe, which is folded or plaited in ſuch ſtrange ſort, that it ſeemeth to be a flower made of ſixe ſundrie ſmall leaues, which cannot eaſily be perceiued, except the ſame be pulled open. The colour whereof it is hard to expreſſe. The whole flower is of a light purple color, ſtripped down the middle of euery folde or welt, with a light ſhew of yellownes, as though purple and yellow were mixed togither: in the middle of the flower thruſteth foorth a thicke fat pointell, yellow as golde, with a ſmall ſharpe greene

Gerard includes the earliest printed illustration of the “Virginia potato.” The history of the world would have been quite different if the potato had never been brought to Europe from the Americas.


is ſomewhat rounder; ſometimes greater, and manie times leſſer: and oftentimes of a green colour with an harder barke; nowe and then ſofter and whiter. The meate within is like the former: the ſeedes haue alſo the ſame forme, but they be ſomewhat leſſer.

1 *Pepo maximus oblongus.*
The great long Pompion.

2 *Pepo maximus rotundus.*
The great round Pompion.

* *The deſcription.*

3 Of this kinde there is alſo another Pompion like vnto the former in rough ſtalks, and in gaſhed and nicked leaues: the flower is alſo great and yellowe, like thoſe of the others: the fruite is of a

Gerard grew and described many American plants, including pumpkins,

Gourds and squash. Reading Gerard is like enjoying a Thanksgiving meal while reading Shakespeare.

[chili peppers]

speede, and so assuredly as the Romane Nettle.

Of Hempe. Chap. 227.

Cannabis.
Hempe.

✲ *The description.*

HEmpe bringeth forth round stalks, straight, hollow, fiue or sixe foote high, full of branches, and that when it groweth of it selfe wilde: but when it is sowen in fields, it hath very few or no branches at all. The leaues thereof be hard, rough, somewhat blacke, and if they be bruised they be of a ranke smell, made vp of diuers little leaues ioined togither, euerie particular leafe whereof is narrow, long, sharpe pointed, and nicked in the edges: the seede commeth foorth from the bottoms of the wings and leaues, being round, somewhat hard, full of white substance. The rootes haue many strings.

There is another being the female Hempe, yet barren and without seede, contrarie to the nature of that sexe, which is very like vnto the other being the male, & one must be gathered before the other be ripe, else it will wither away, and come to no good purpose.

✲ *The place.*

Hempe, as *Columella* writeth, delighteth to grow in a fat dunged and waterie soile, or plaine and moist, and deepely digged.

✲ *The time.*

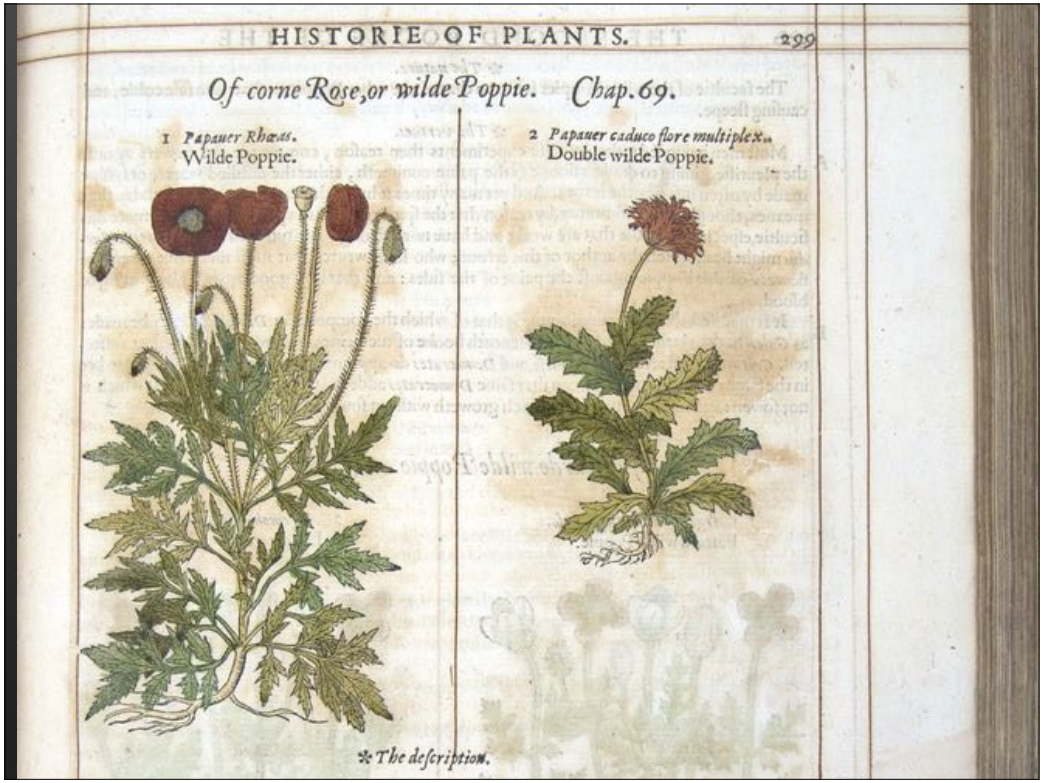
Hempe is sowen in March and Aprill. The first is ripe in the end of August, the other in July.

✲ *The names.*

This is named of the Grecians κάνναβις, also of the Latines *Cannabis*: the Apothecaries keepe that name: in high Dutch Zamer hanff: of the Italians *Canape*: of the Spaniards *Canamo*: in French *Chanure*: of the Brabanders Kemp: in English Hempe. The male is called Charle Hempe, and Winter Hempe. The female Barren Hempe, and Sommer Hempe.

✲ *The*

And there are medicinal plants such as hemp…



and the wild poppie.

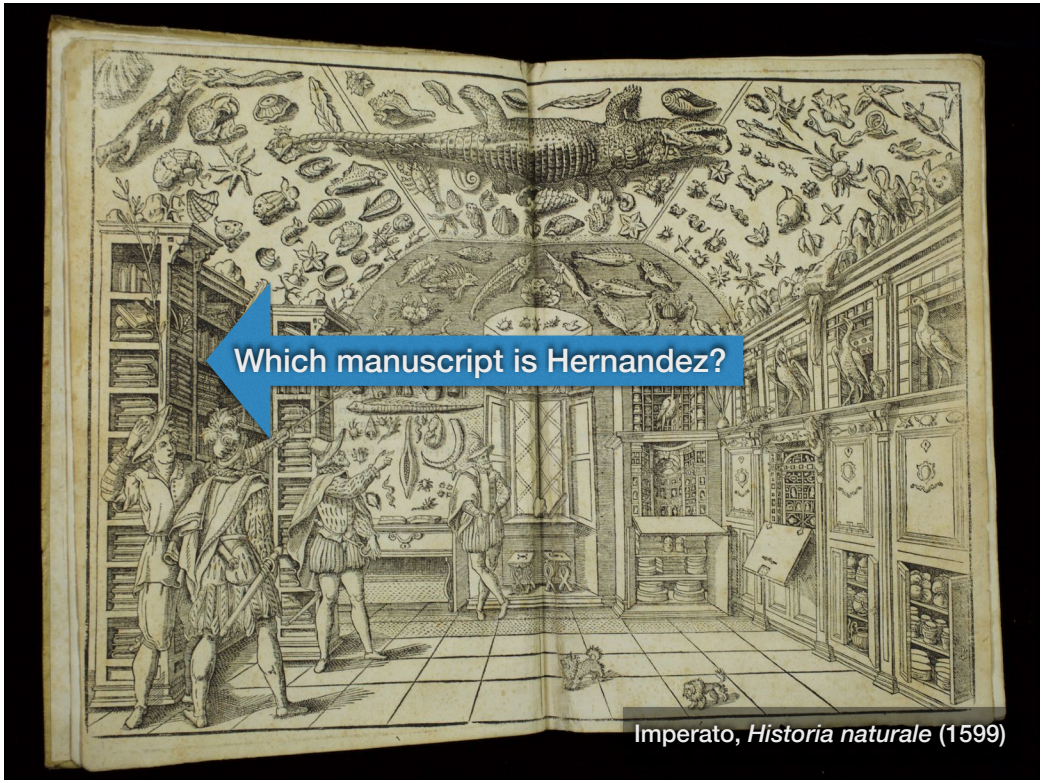
Now we come to Hernandez. Philip II, the king of Spain, commissioned his physician, Francisco Hernandez, to compile Native American natural history and medical knowledge. During the 1570's, in central Mexico, Hernandez worked closely with indigenous physicians, and artists. With their help, he described 3,000 Mexican plants. During three years of travel, followed by three more years working in a Mexican hospital, he studied local medicinal practices.

http://lynx-open-ed.org/americas

Hernandez eventually returned to King Phillip, bringing a manuscript along with paintings, seeds and specimens. After numerous delays, the king passed the manuscript on to his physician and science librarian

- Nardo Antonio Recchi. Recchi compiled an abbreviated edited copy,
- before the original was destroyed [in 1671] in a calamitous fire that destroyed much of the king's science library.

http://lynx-open-ed.org/americas



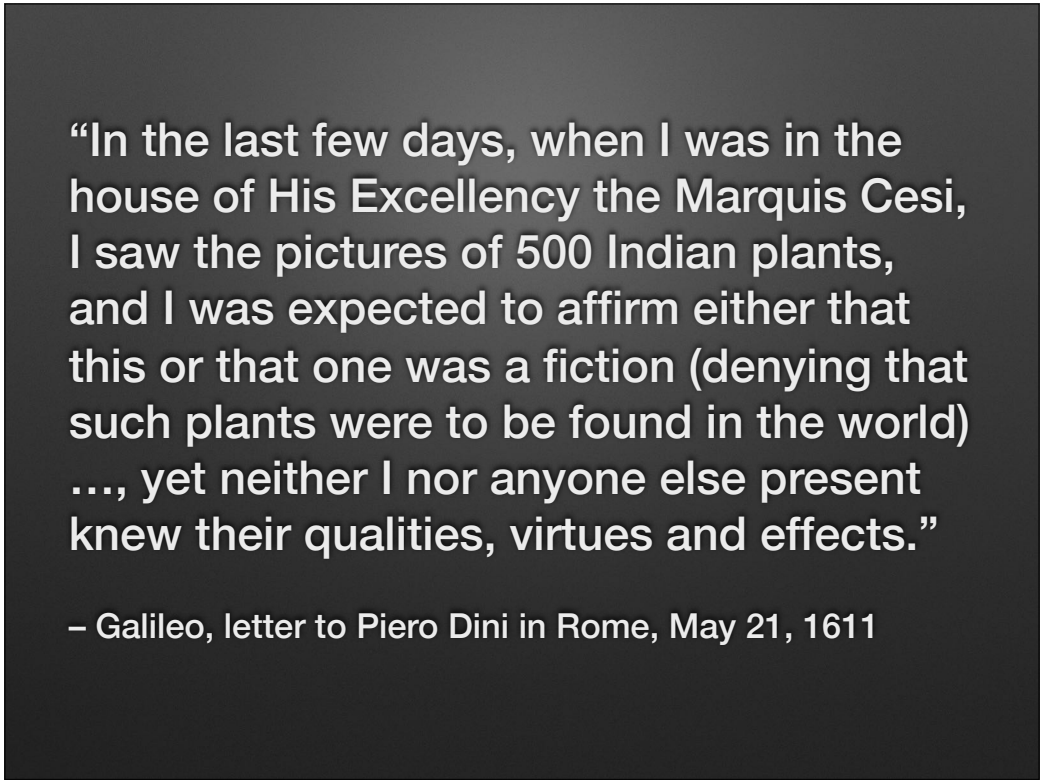
Recchi's manuscript made its way to Naples, to the collection of Ferrante Imperato. While in Naples in 1603, Cesi met with Imperato and viewed his remarkable cabinet of curiosities.

- During this visit Cesi examined Recchi's manuscript of Hernandez.
- Rumors about Hernandez' work had spread widely, being published in fragments here and there. A full edition was now eagerly anticipated as a guide to the "fountain of youth."

———-

Ferrante Imperato, Dell' Historia Naturale (Naples, 1599)
http://lynx-open-ed.org/node/569

Cabinets of curiosities were museums in miniature, combining books, fossils, antiquarian and natural history objects. In this engraving, Ferrante Imperato observes his son Francesco pointing out the marvels of the cabinet to visitors. Fabio Colonna, a member of the Lynx who worked on the Hernandez manuscript, studied with Imperato in Naples.



Cesi acquired the manuscript, and showed it to Galileo. Galileo expressed amazement at the wealth of plant knowledge relayed by Hernandez, entirely unknown to Aristotle and Pliny: (read)

Hernandez (1651)

Publishing a definitive edition, with commentary and illustrations, comprised the central, albeit elusive, goal of Cesi and the Academy of the Lynx. Stelluti eventually published the Lynx edition in 1651, eighty years after Hernandez arrived in central Mexico.

The title translates, “Thesaurus or Treasury

- of the Medicinal goods of New Spain.”
- Or “a description of
- the plants, animals and minerals of Mexico.”

Multiple title pages reflect the chaotic history of revision and editing: “History, or Description, of the New Plants, Animals and Minerals of Mexico.”

- The OU copy is unique, containing throughout many pages from an earlier draft the Lynx hastily printed in 1628.

The definitive Lynx edition incorporated approximately 800 woodcuts. Locating specimens and creating the illustrations proved very challenging and caused many delays.

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Francisco Hernandez, Nova plantarum, animalium et mineralium Mexicanorum historia (Rome, 1651)
http://lynx-open-ed.org/node/568

Note the Nahuatl names. The new plants resisted classification according to traditional European categories and qualities. Let's look a few examples…

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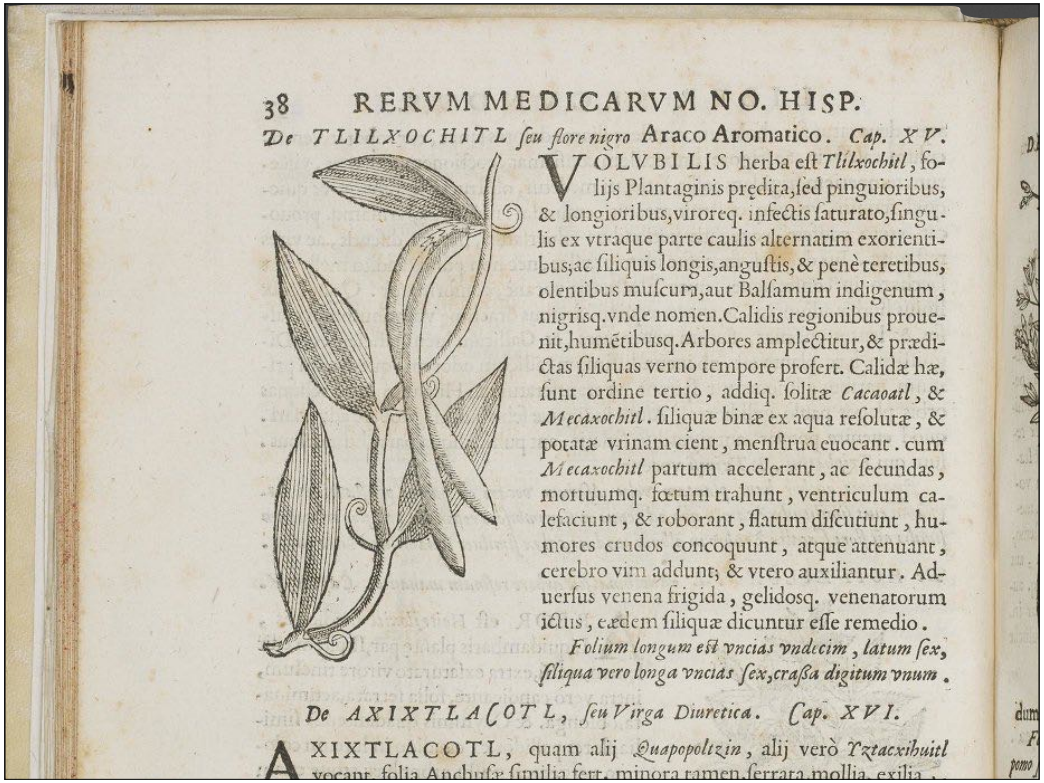
Francisco Hernandez, Nova plantarum, animalium et mineralium Mexicanorum historia (Rome, 1651)
http://lynx-open-ed.org/node/568



38 RERVM MEDICARVM NO. HISP.

De TLILXOCHITL *seu flore nigro* Araco Aromatico. *Cap. XV.*

VOLVBILIS herba est *Tlilxochitl*, foliis Plantaginis prędita, sed pinguioribus, & longioribus, viroreq. infectis saturato, singulis ex vtraque parte caulis alternatim exorientibus; ac siliquis longis, angustis, & penè teretibus, olentibus muscum, aut Balsamum indigenum, nigrisq. vnde nomen. Calidis regionibus prouenit, humẽtibusq. Arbores amplectitur, & prædictas siliquas verno tempore profert. Calidæ hæ, sunt ordine tertio, addiq. solitæ *Cacaoatl*, & *Mecaxochitl*. siliquæ binæ ex aqua resolutæ, & potatæ vrinam cient, menstrua euocant. cum *Mecaxochitl* partum accelerant, ac secundas, mortuumq. fœtum trahunt, ventriculum calefaciunt, & roborant, flatum discutiunt, humores crudos concoquunt, atque attenuant, cerebro vim addunt; & vtero auxiliantur. Aduersus venena frigida, gelidosq. venenatorum ictus, eædem siliquæ dicuntur esse remedio.

Folium longum est vncias vndecim, latum sex, siliqua vero longa vncias sex, crassa digitum vnum.

De AXIXTLACOTL, *seu Virga Diuretica. Cap. XVI.*

AXIXTLACOTL, quam alij *Quapopoltzin*, alij verò *Yztacxihuitl* vocant, folia Anchusæ similia fert, minora tamen, serrata, mollia, exilia,

Hernandez provided the first written account of vanilla (Tlilxochitl). Mmmmm, there's nothing like Mexican vanilla.

DE CASSIA, LIGNEA, CINNAMOMO, seu Cannella. Cap. XI.

MEDIOCRIS arbor est Cassia lignea. Folijs Lauri Citriuè formam referentibus, frequentibusq. ac ternis nerueis discursibus secundum longitudinem procedentibus. Fructu nigro, & albenti flore. folia, corticis ipsius saporem referunt, sed minus acrem, & celerius elangueſcentem. ternis quibusque mensibus arborem delibrant, corrasa prius cuticula, quæ amara est. Cortex ipse recens adeo lubricus sentitur, atque glutinosus, vt mansus dentibus adhæreat, additusq. ferculis eadem in saliuosam quandam conuertat naturam; postea verò qua cernitur substantia constat. de qua in tanta luce nihil addendum putaui, præterquam experimento esse iam notum Cassiã, Cinnamomum, & Cannellam ex eadem perpetuò arbore, non ex diuersis, (quicquid antiquiores herbarij tradiderint) esse propagata, & varijs nominibus nuncupari. Ob ingens namque precium, maioremq. hominum lucri cupiditatẽ adulterabantur aromata, & ob hoc (tametsi plerumque eiusdem essent generis) diuersa illis indebantur nomina. In Mindanai, insula Philippica, vnde ramum magnum accepi, & aliis Indiæ orientalis partibus copiosè prouenit.

Cinnamon makes an appearance

De NVCIS INDICAE, ET COCCI vocati arbore. Cap. XL.

NVX Indica, quam vulgus Indorum *Maron*, Strabo verò (vt quidã volũt) Palmam vocat, à Mexicenſibus *Coyolli*, à Luſitanis ob oculos quoſdam Cercopitheci ſimiles Coccum, à vulgo verò Perſarum, & Arabum nuncupatur *Harel*. Arbor eſt vaſta, Palmæ magnitudine, & figura, in cuius genus citra dubium eſt referenda. materie denſa, fungoſa, leui, & ferulacea. fructu orbiculari, aut paulò oblongiore, capitis humani amplitudine, duplici contecto cortice, externo villoſo, interno nitido. præduro, & nigri coloris vt inferius latius dicetur, racematim dependente, ac menſtruo, ſed intra trium menſium ſpatio maturescente, interdumq. ſeptem, octouè, racemis centum ſexaginta libris pendentibus arborem ſuam onerante: Cuius duo ſunt præcipua genera, alterum fructui ferendo, alterum verò liquori euocando, idoneum. Fructifera. Liquoris.

Naſcitur paſsim apud orientales & iam

and pineapple

243
nucis indicae et cocci

LIBER TERTIVS. 63

HOAXACAN, LIGNVM SANCTVM est abundè amarus. quò fit vt calidus ordine secundo, cum folijs quoque ipsis haberi posit, cum manifesta siccitate. etsi medullam non sensérim amaram, referre verò quos effectus præstet in curanda Gallica lue, alijsq. diuturnis affectibus capitis, thoracis, ventriculi, epatis, lienis, renum, artuumq. doloribus, aut quis sit administrandi modus in tanta luce superuacaneum duxi. Nascitur in calidis *Ytzocanis*, & Misticæ inferioris. & apud Haitinos quoque prouenit.

GVAYACAN.

GVAYACAN est arbor Iuglandis, vel Ilicis magnitudine cuius cortex colore, extrinsecus cineritio permixtis tamen multis maculis viridibus intrinsecus verosubruber, non admodum densus, sed immodicè durus crassitudinis nempe semidigitalis, is ligno recenter cæso, adeo firmiter hæret: vt vix ferro separari queat, progressu vero temporis facile seiungitur.

Lignum in extremis colore qui in Buxo interne nigrescente conspicitur, & medullium eius est maximum, totumq. adeo lignum splendida quadam donatum duritie.

Pinguitudo eius resinaceum quid spirat, vriturq. odore non insuaui, & ab accenso gummi profluit, quod prædurum est vbi refrixerit.

Pondus eius quale nulli præterea ligno, nulla eius quantumuis minima pars, in

The heartwood of the Guaiacum tree, or lignum sanctum, was used to cure syphilis.

121, 130, 191, 244
https://historymash.com/2018/05/01/what-is-guaiacum-and-was-it-connected-to-syphilis/

NARDI ANT. RECCHI LIB. V. 135

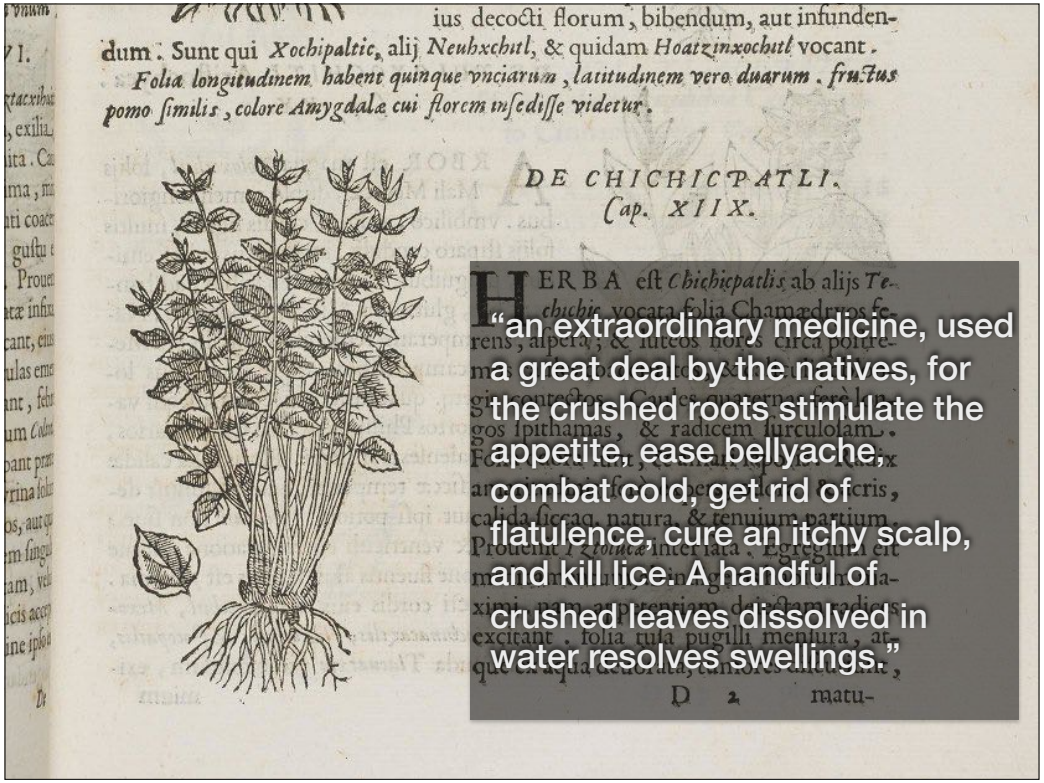
CHILLI, *Piper ſiliquoſum Mexicanum.*

dant, qui totus pene vetuſtate euaneſcit. vnde fit, vt ſæpe excitato flatu, Venerem ſtimulent, ac interim aluum non ſine quodam teneſmo, ac ſenſu doloris, ijs præcipue qui huiuſmodi condimento ante non aſſueuerant, leniter emolliant. Quanquam eius rei acumen nõ immeritò cauſſam eſſe affirmare poſſumus. Vrinam, & mẽſes euocant. corroborant ventriculum ob frigus imbecillem. coctionem eadem occaſione labefactatam iuuant. appetentiam contemperato ex eis cũ uocatis *Tomamæ* intinctu mire excitant. & pituitoſos humores vndecumque, potiſſimũ coxæ adhæreſcentes articulis, diſcutiunt, & euacuant. Aiunt, hecticorum peropportunum eſſe remedium, ventrem lumboſq; aculeis *Chilli* madentibus perpungere. nutrimentum item calens, ac ſiccum præſtant, &, vt Indi paſſim experiri teſtantur, haud modicum. renes tamen excalefaciunt, & inflammato ſanguine, atque iecinore ad nephriticos, phrẽneticos, pleuriticos affectus, peripneumonias, alioſq; tumores internos. & alia ſimilia ſymptomata, ſeu nutrimenti, vt ſæpiſſime Indi ſolent, ſeu condimenti vice, immodice, aut frequenter vtan-

Incõmoda.

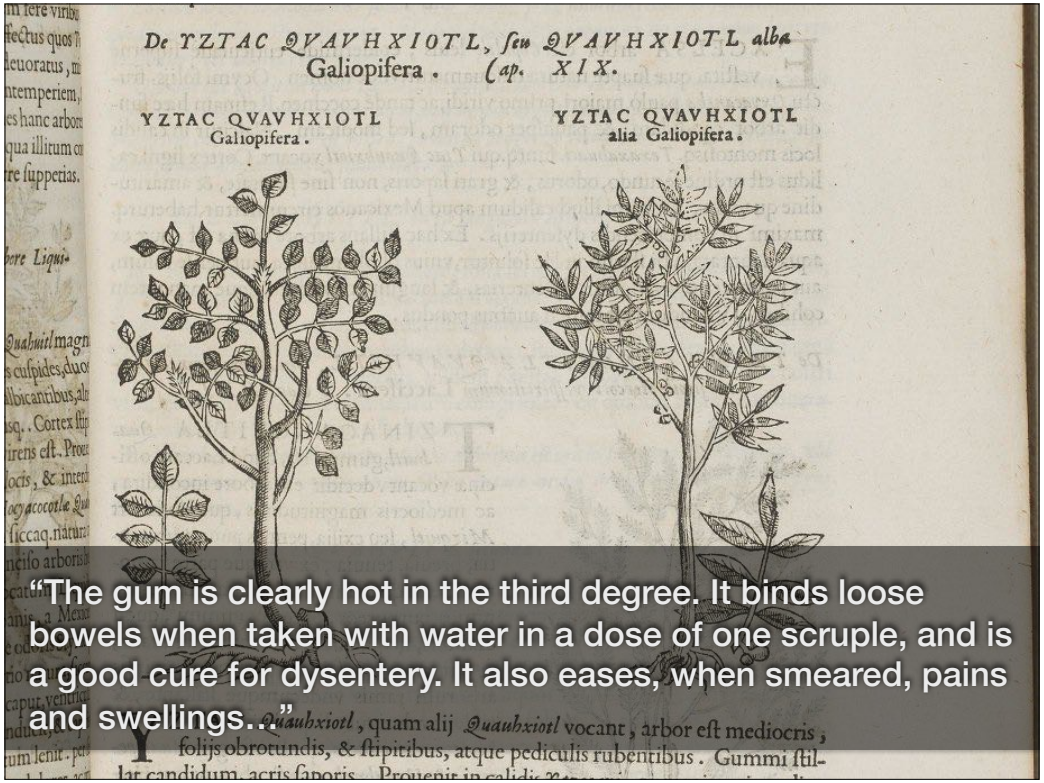
Hernandez described many varieties of chili peppers as a purgative for phlegmatic humors.

19, 70, 84, 109, 112, 113, 116, 149, 171, 188



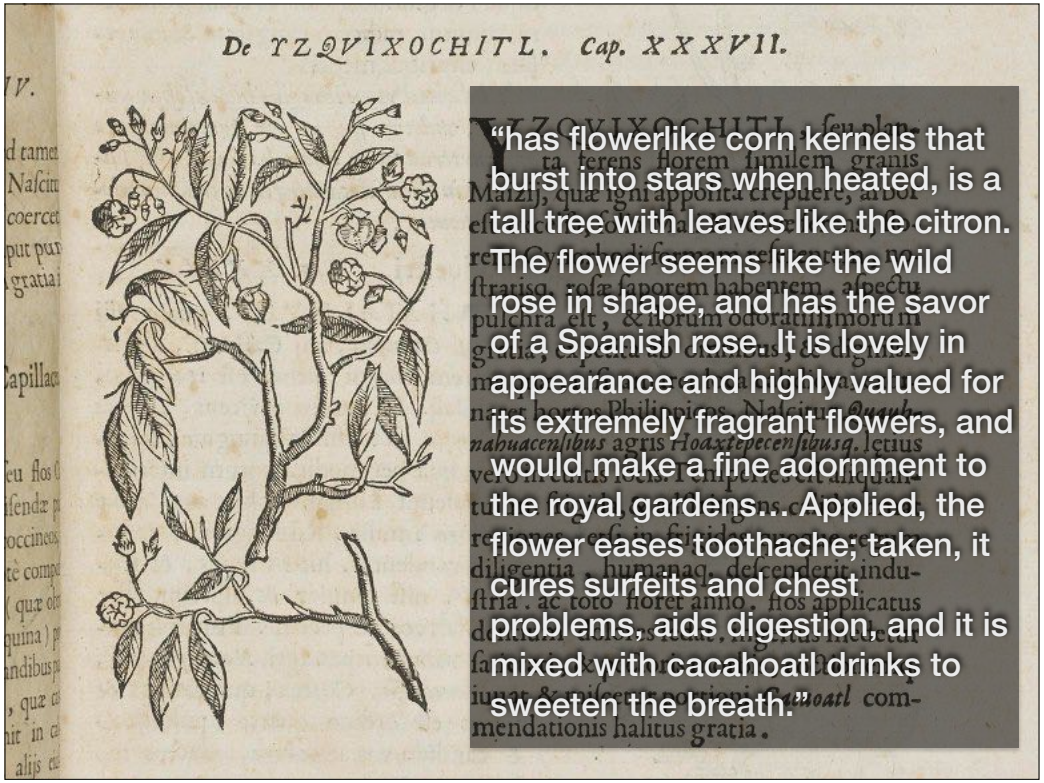
This plant (Chichipatli) is described as “an extraordinary medicine, used a great deal by the natives, for the crushed roots stimulate the appetite, ease bellyache, combat cold, get rid of flatulence, cure an itchy scalp, and kill lice. A handful of crushed leaves dissolved in water resolves swellings.”

196:



Of this plant (Iztac quauhxiotl), Hernandez wrote: “The gum is clearly hot in the third degree. It binds loose bowels when taken with water in a dose of one scruple, and is a good cure for dysentery. It also eases, when smeared, pains and swellings…”

196: Iztac quauhxiotl



This plant (Izquixochitl): “has flowerlike corn kernels that burst into stars when heated, is a tall tree with leaves like the citron. The flower seems like the wild rose in shape, and has the savor of a Spanish rose. It is lovely in appearance and highly valued for its extremely fragrant flowers, and would make a fine adornment to the royal gardens… Applied, the flower eases toothache; taken, it cures surfeits and chest problems, aids digestion, and it is mixed with cacahoatl drinks to sweeten the breath.”

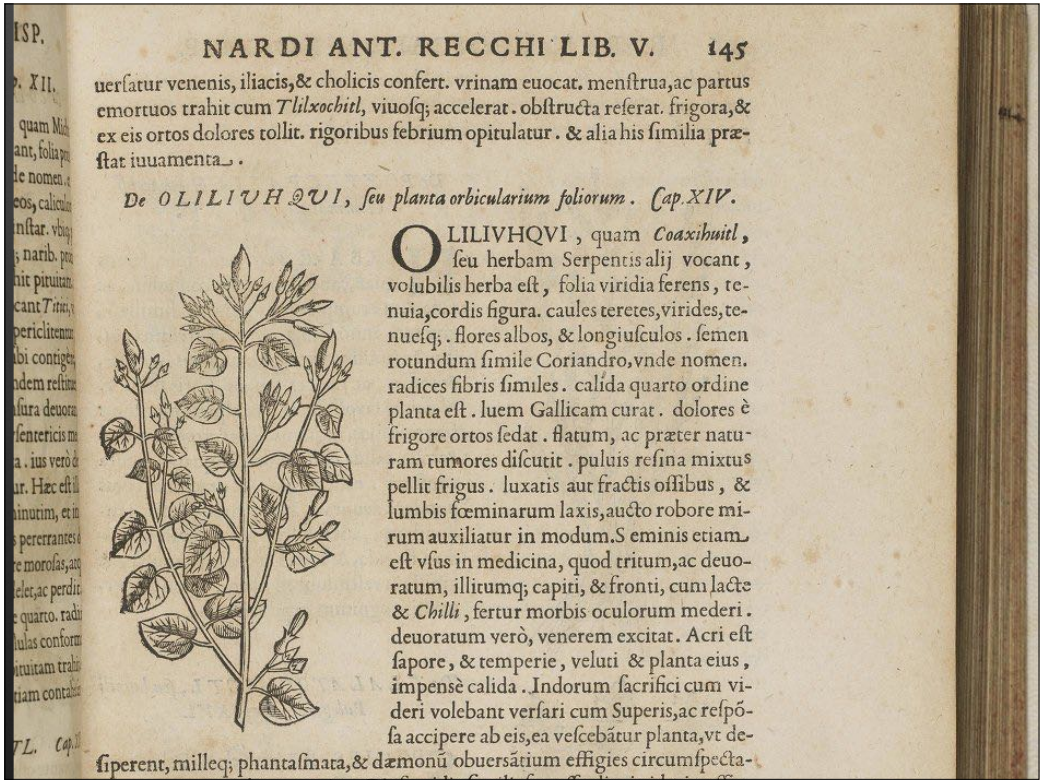
———-

197

cocoa, and the drinks made from it

four varieties of cacao, 10, 19, 107, 119, 167, 197

214



NARDI ANT. RECCHI LIB. V. 145

uerſatur venenis, iliacis,& cholicis confert. vrinam euocat. menſtrua,ac partus emortuos trahit cum *Tlilxochitl*, viuoſq; accelerat. obſtructa reſerat. frigora,& ex eis ortos dolores tollit. rigoribus febrium opitulatur. & alia his ſimilia præſtat iuuamenta.

De OLILIVHQVI, ſeu planta orbicularium foliorum. Cap. XIV.

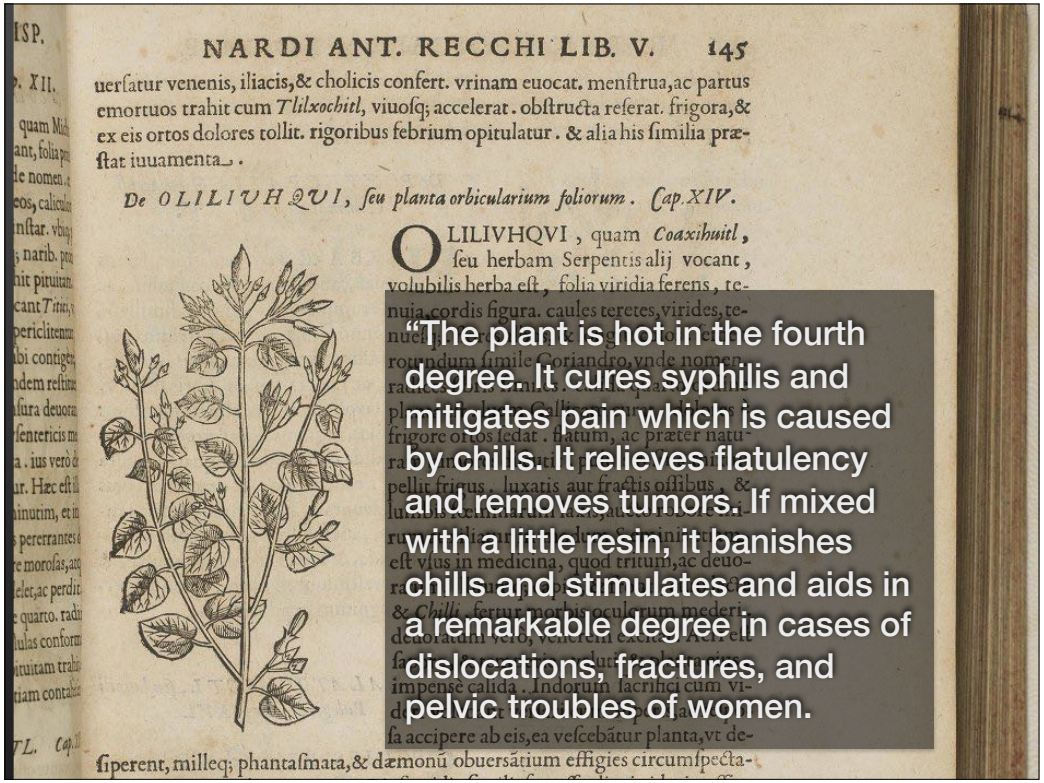
OLILIVHQVI, quam *Coaxihuitl*, ſeu herbam Serpentis alij vocant, volubilis herba eſt, folia viridia ferens, tenuia,cordis figura. caules teretes,virides,tenueſq;. flores albos, & longiuſculos. ſemen rotundum ſimile Coriandro,vnde nomen. radices fibris ſimiles. calida quarto ordine planta eſt. luem Gallicam curat. dolores è frigore ortos ſedat. flatum, ac præter naturam tumores diſcutit. puluis reſina mixtus pellit frigus. luxatis aut fractis oſſibus, & lumbis fœminarum laxis,aucto robore mirum auxiliatur in modum.S eminis etiam eſt vſus in medicina, quod tritum,ac deuoratum, illitumq; capiti, & fronti, cum lacte & *Chilli*, fertur morbis oculorum mederi. deuoratum verò, venerem excitat. Acri eſt ſapore, & temperie, veluti & planta eius, impensè calida. Indorum ſacrifici cum videri volebant verſari cum Superis,ac reſpõſa accipere ab eis,ea veſcebãtur planta,vt deſiperent, milleq; phantaſmata,& dæmonũ obuersãtium effigies circumſpecta-

And here is the earliest detailed account and the first illustration of Peyote.

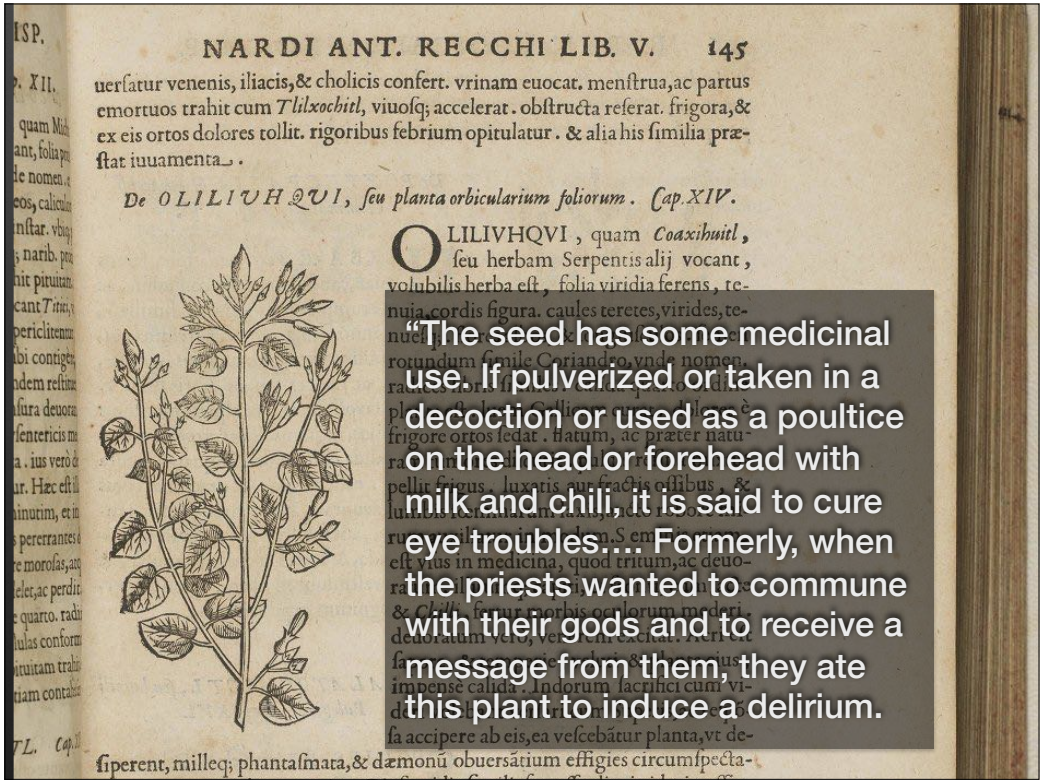
———————

from Zacatecas (soft root), 259.
Peyotl zacatensi
De Oliliuhqui, seu planta orbicularium foliorum, ch. XIV., p145
“Oliliuhqui, which some call coaxihuitl, or snake-plant, is a twining herb with thin, green, cordate leaves, slender, green terete stems, and long white flowers. The seed is round and very like coriander.” In this work, Hernandez describes the preparation of ololiuqui in medicine, where one would grind the seeds to a course powder, then add the ground seeds to Spanish pepper and milk. This concoction was drunk to alleviate pain and heal all sorts of ailments, inflammations, and ulcers” (Hernandez cited in Schultes 1941). Hernandez also claimed that Indian priests embarking on a journey to communicate with the spirit world would eat ololiuqui seeds to induce a state of delirium during which they were able to receive messages from the supernatural and commune with the gods. He reported that these priests saw visions and went into states of terrifying hallucinations while under the influence of the medicine (Hernandez cited in Schultes 1941). Schultes, “Peyote and Plants Confused with It,” p.74.
Excerpt from Schultes and Hofmann's Plants of the Gods: Their Sacred, Healing, and Hallucinogenic Powers, (1992).

“Oliliuhqui, which some call coaxihuitl, or snake-plant, is a twining herb with thin, green, cordate leaves; slender, green, terete stems; and long, white flowers. The seed is round and very much like coriander, whence the name [in Nahuatl, the term ololiuqui means "round thing" of the plant. The roots are fibrous and slender. The plant is hot in the fourth degree. It cures syphilis and mitigates pain which is caused by chills. It relieves flatulency and removes tumors. If mixed with a little resin, it banishes chills and stimulates and aids in a remarkable degree in cases of dislocations, fractures, and pelvic troubles of women. The seed has some medicinal use. If pulverized or taken in a decoction or used as a poultice on the head or forehead with milk and chili, it is said to cure eye troubles. When drunk, it acts as an aphrodisiac. It has a sharp taste and is very hot. Formerly, when the priests wanted to commune with their gods and to receive a message from them, they ate this plant to induce a delirium. A thousand visions and satanic hallucinations appeared to them. In its manner of action, this plant can be compared with Solanum maniacurn of Dioscorides. It grows in warm places in the fields.”
https://www.samorini.it/doc1/alt_aut/sz/schultes-a-contribution-to-our-knowledge-of-rivea-corymbosa.pdf



“The (peyote) plant is hot in the fourth degree. It cures syphilis and mitigates pain which is caused by chills. It relieves flatulency and removes tumors. If mixed with a little resin, it banishes chills and stimulates and aids in a remarkable degree in cases of dislocations, fractures, and pelvic troubles of women…



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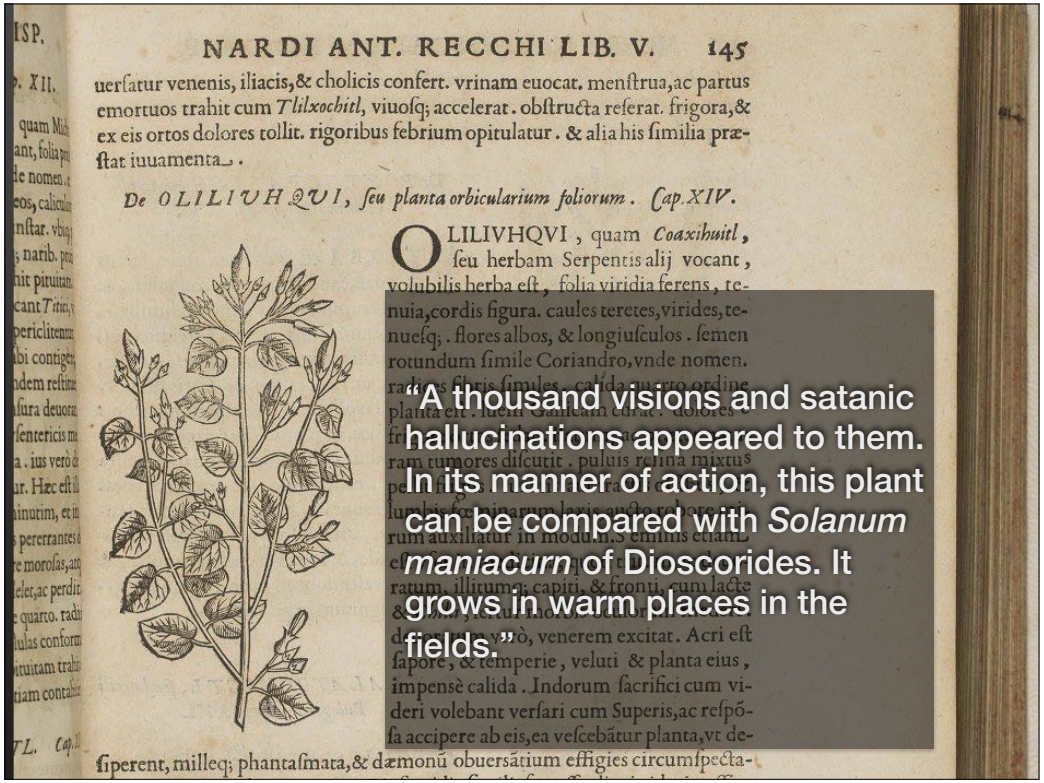
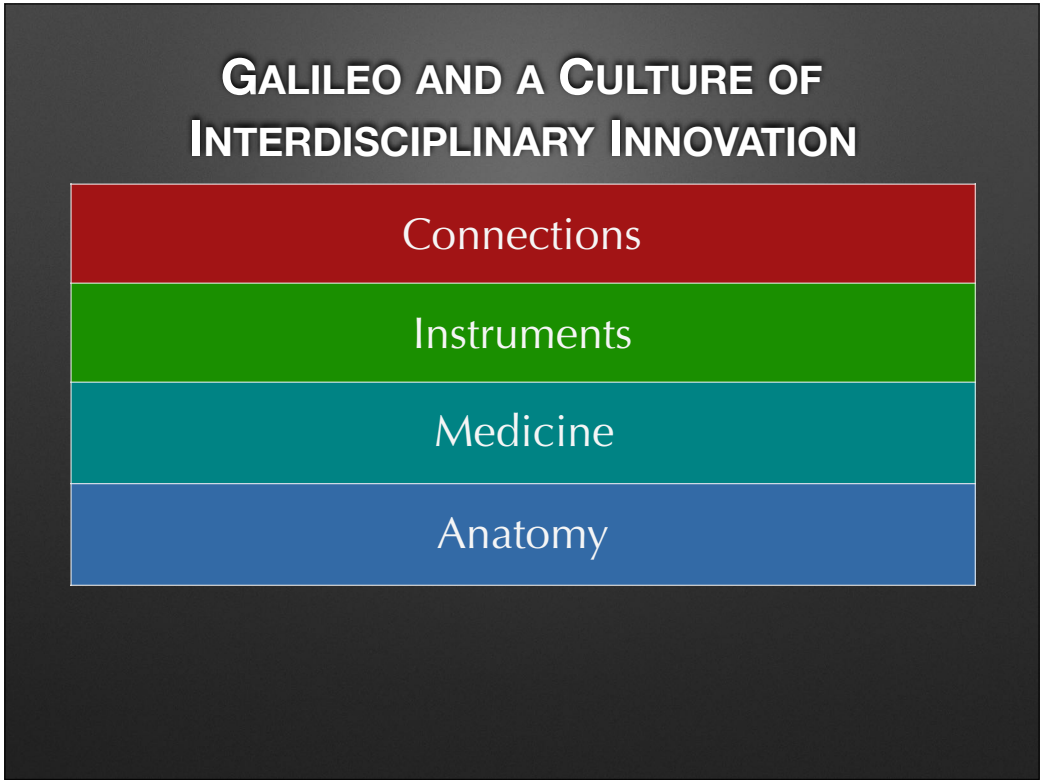
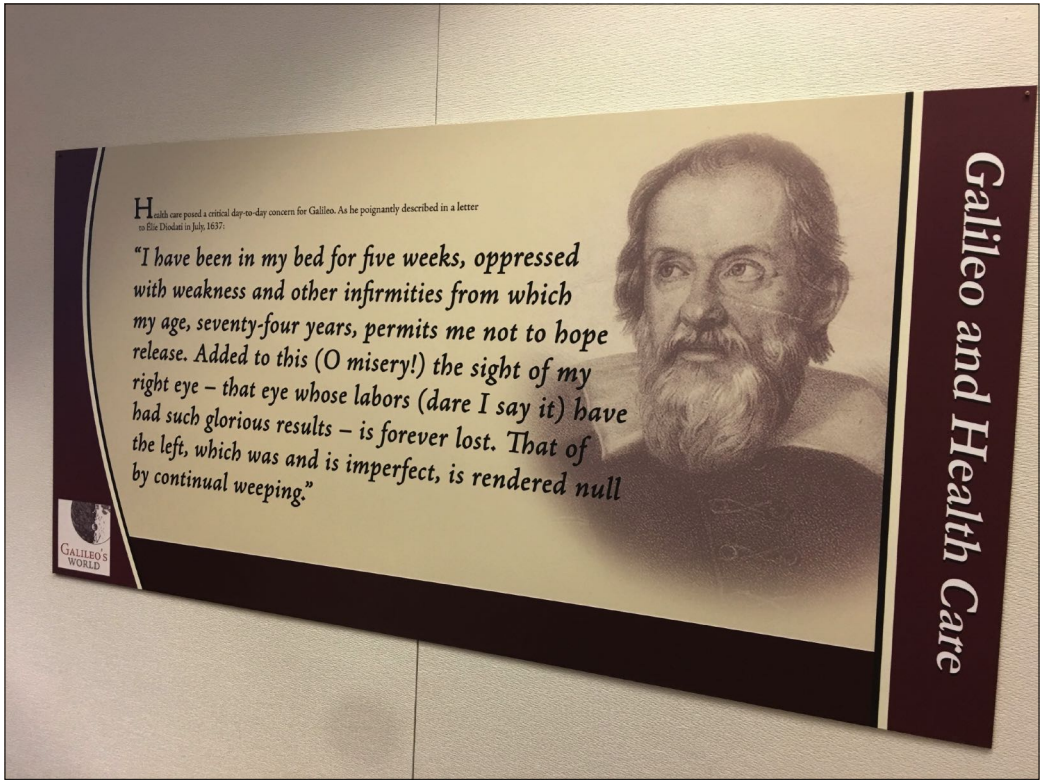


A thousand visions and satanic hallucinations appeared to them. In its manner of action, this plant can be compared with *Solanum maniacurn* of Dioscorides. It grows in warm places in the fields.”

The Lynx edition of Hernandez transformed Old World natural history and medicine. Its influence appears as late as the botanical works of Erasmus Darwin, grandfather of Charles Darwin, who cited its description of manzanilla, or chamomile. After Hernandez, European medicine could never be the same. It became necessarily global.



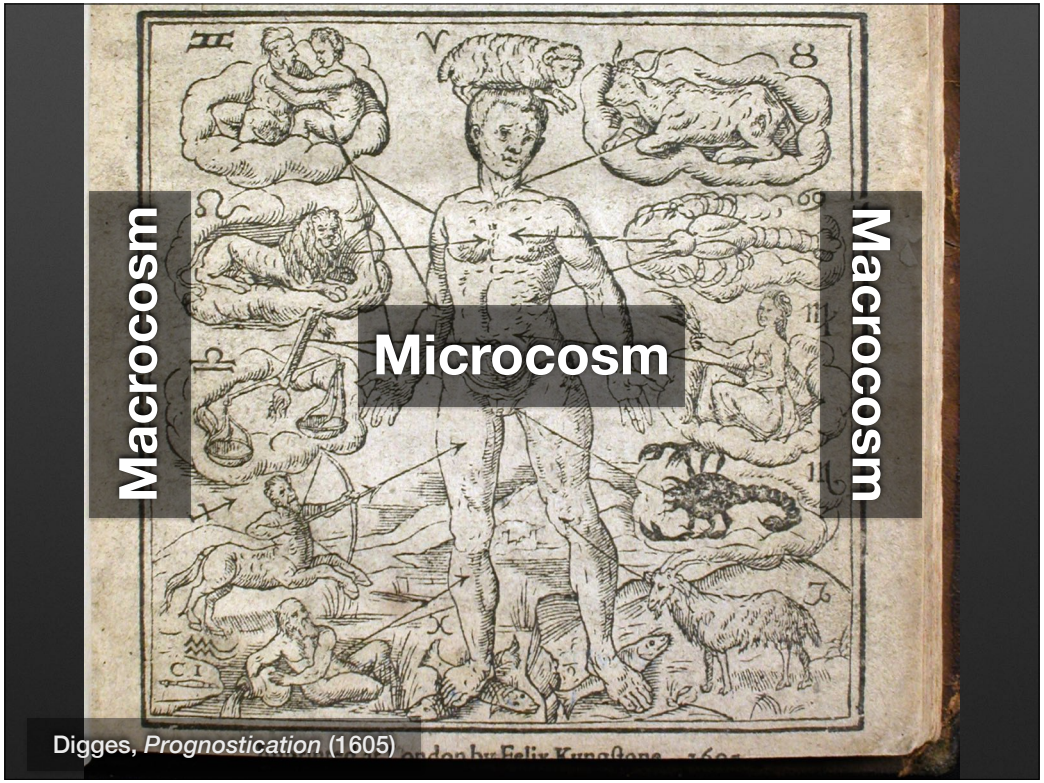
So that's Medicine and the story of Hernandez. Now let's turn to Galileian innovations in Anatomy. But first, since Galileo's extensive involvement with the world of medicine is relatively unknown, we'll preface this section with some general remarks about that.



Galileo poignantly wrote:
"I have been in my bed for five weeks, oppressed with weakness and other infirmities from which my age, seventy four years, permits me not to hope release. Added to this (O misery!) the sight of my right eye — that eye whose labors (dare I say it) have had such glorious results — is for ever lost. That of the left, which was and is imperfect, is rendered null by continual weeping."
On the most basic level, health care affected everyone. Publication of Galileo's Dialogo was held up for years due to an outbreak of plague. Galileo's daughter served the health care needs of many, including sisters in her abbey and Galileo himself. Yet Galileo's engagement with the health sciences was extensive, as we have already seen with the thermoscope, the microscope, and the story of the Hernandez.

———————————

Galileo, Letter to Élie Diodati (4 July 1637), trans. Mary Allan-Olney, The Private Life of Galileo, p. 278.

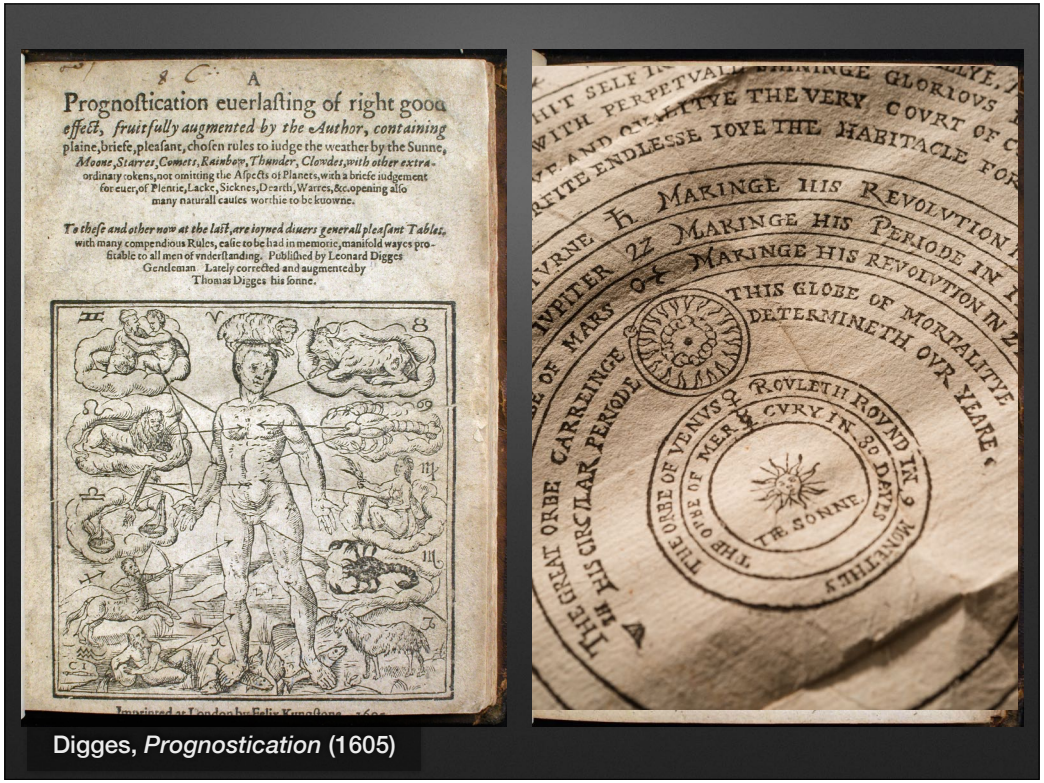


Why did physicians study astronomy? This Zodiac Man diagram portrays a human body surrounded by the 12 signs of the Zodiac. Zodiac Man diagrams explained the hidden correspondences that were believed to connect the • organs of the body (the microscosm) and • the influences of the stars and planets (the macrocosm).

http://lynx-open-ed.org/node/266
Leonard Digges, A Prognostication Everlasting of Right Good Effect…; Lately corrected and augmented by Thomas Digges his sonne (London, 1605)

Digges, *Prognostication* (1605)

This zodiac man was published in a book of astronomy and meteorology that also included



Digges, *Prognostication* (1605)

the first published defense in England of the Sun-centered system of Copernicus.

Here's another zodiac man. The ability to perform technical astrological calculations was one characteristic which distinguished university-educated physicians from other health-care practitioners. In most universities, astronomy at an advanced level was taught within the medical school. In this light it is not surprising that Galileo entered the University of Pisa to study medicine. Like many astronomers, Galileo himself was professionally trained in medicine.

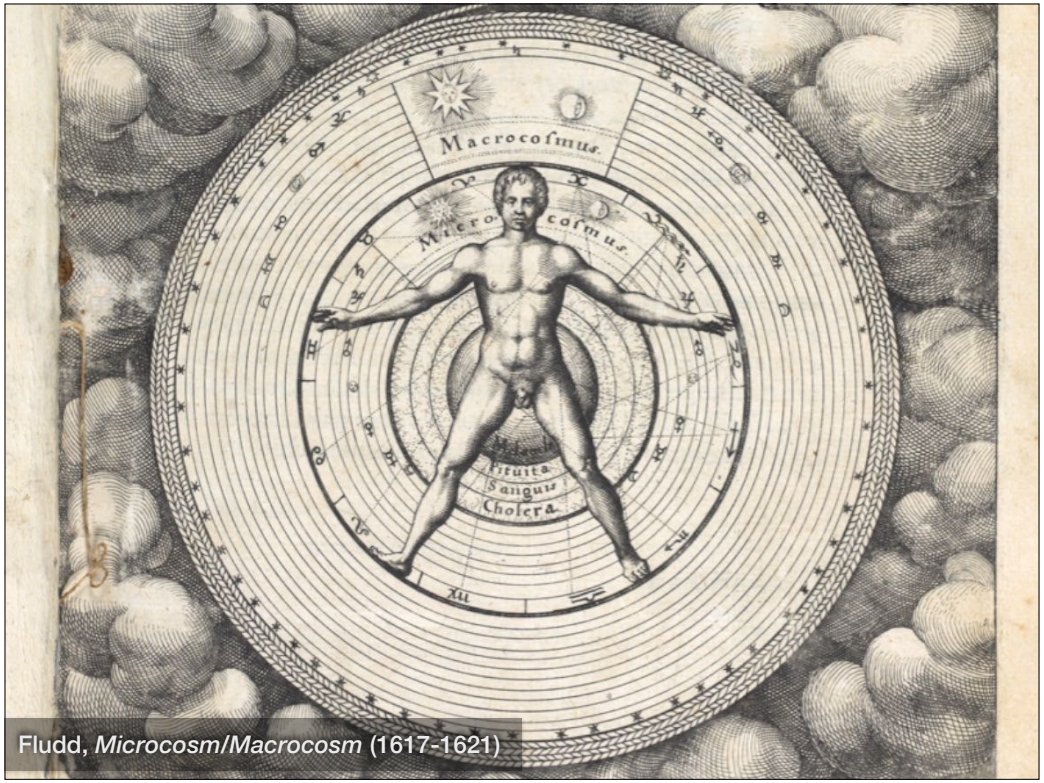
— — —

[Does ATSU have a professor of astronomy? Probably not, but many of your patients may still practice some form of astrology, such as reading their horoscopes.]
http://lynx-open-ed.org/node/619

Fludd, *Microcosm/Macrocosm* (1617-1621)

Robert Fludd was a London physician contemporary with Galileo.

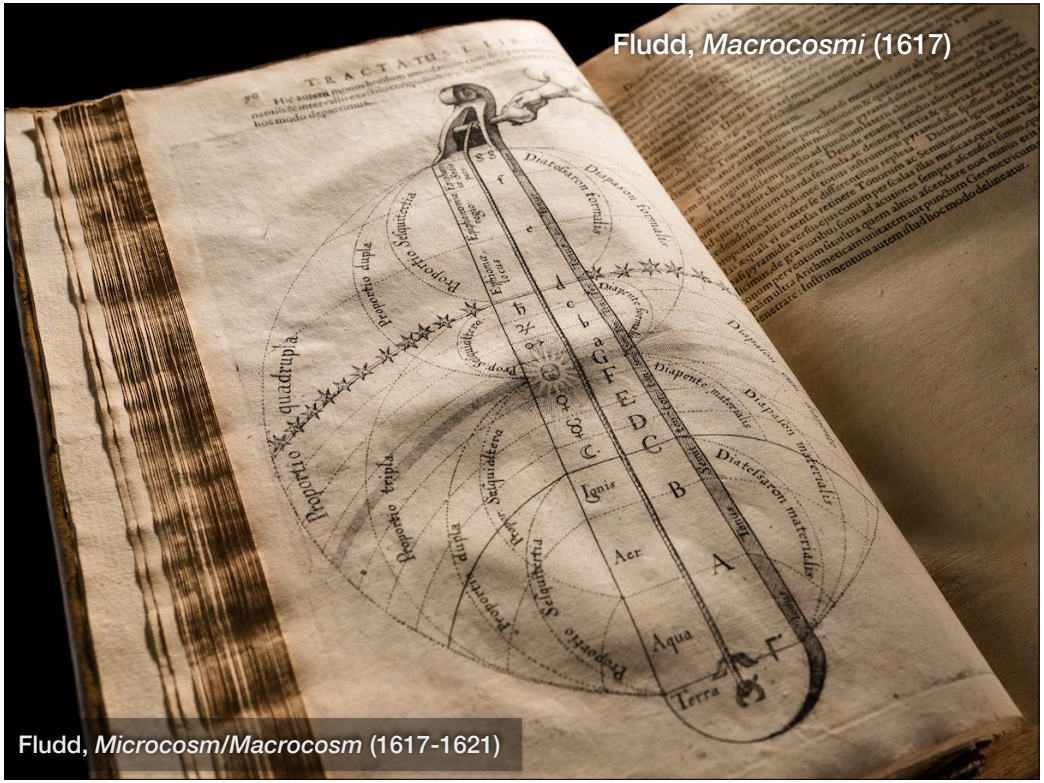
http://lynx-open-ed.org/node/219
Robert Fludd, Utriusque cosmi maioris scilicet et minoris (Oppenheim, 1617-21)



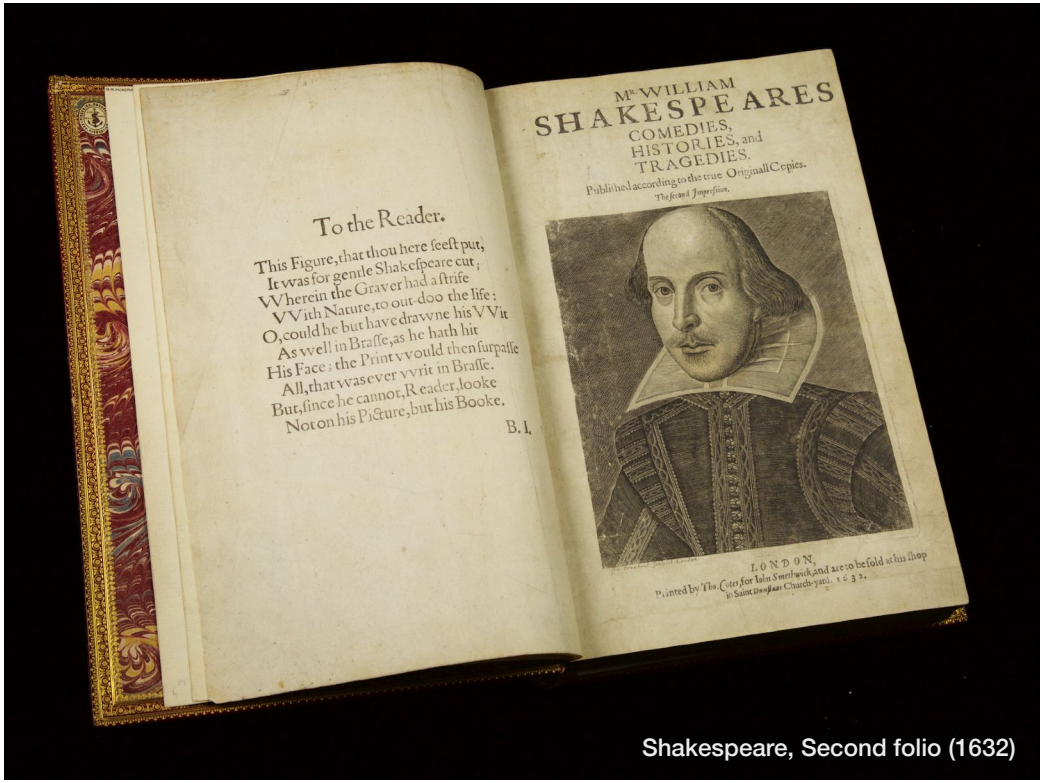
Fludd, *Microcosm/Macrocosm* (1617-1621)

In this work, Fludd explored correspondences and influences between the macrocosm and the microcosm.

http://lynx-open-ed.org/node/219
Robert Fludd, Utriusque cosmi maioris scilicet et minoris (Oppenheim, 1617-21)



According to Fludd, the universe itself is a musical instrument, a monochord. The universe can only be understood through music. Likewise an understanding of medicine depends upon the physician's comprehension of astronomy and music, both of which affect the temperament or tuning of the human body. Does ATSU have a professor of music and astronomy?



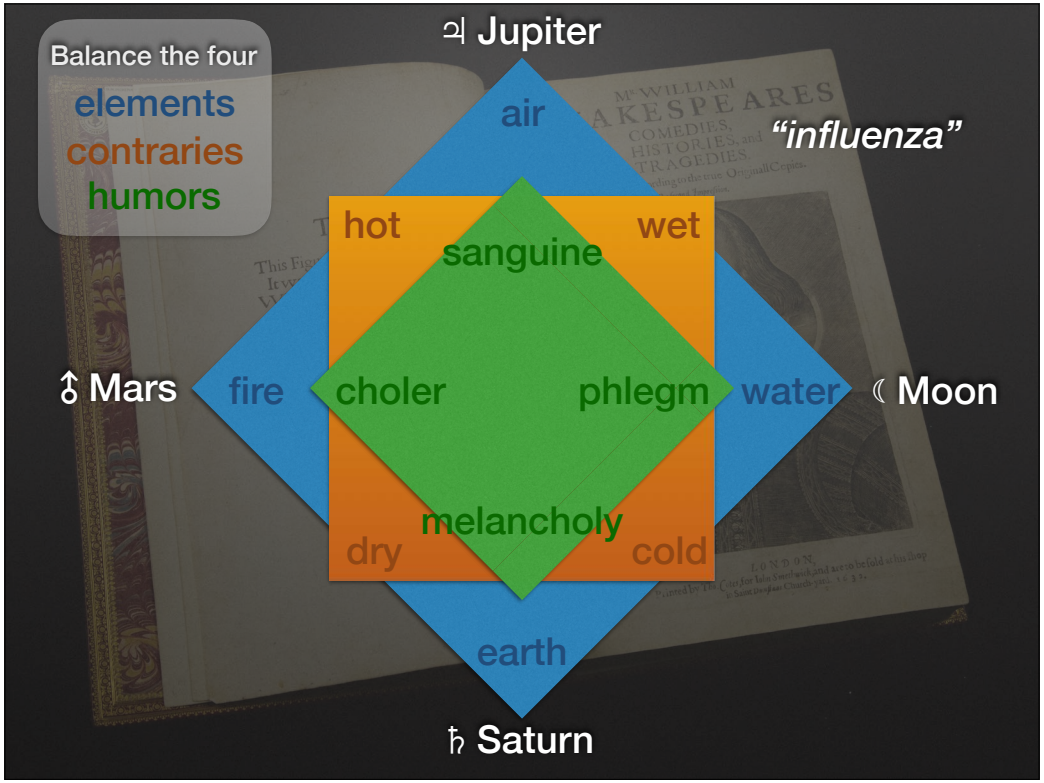
Shakespeare, Second folio (1632)

Let's consider Shakespeare, a contemporary of Galileo. Another reason medical students mastered astronomy was the entire framework of humoral medicine evident in Renaissance literature. According to the ancient medical traditions of Aristotle, Hippocrates, and Galen, the human body, like other bodies beneath the Moon,

Shakespeare, Comedies, Histories, and Tragedies (London, 1632)
http://lynx-open-ed.org/node/226

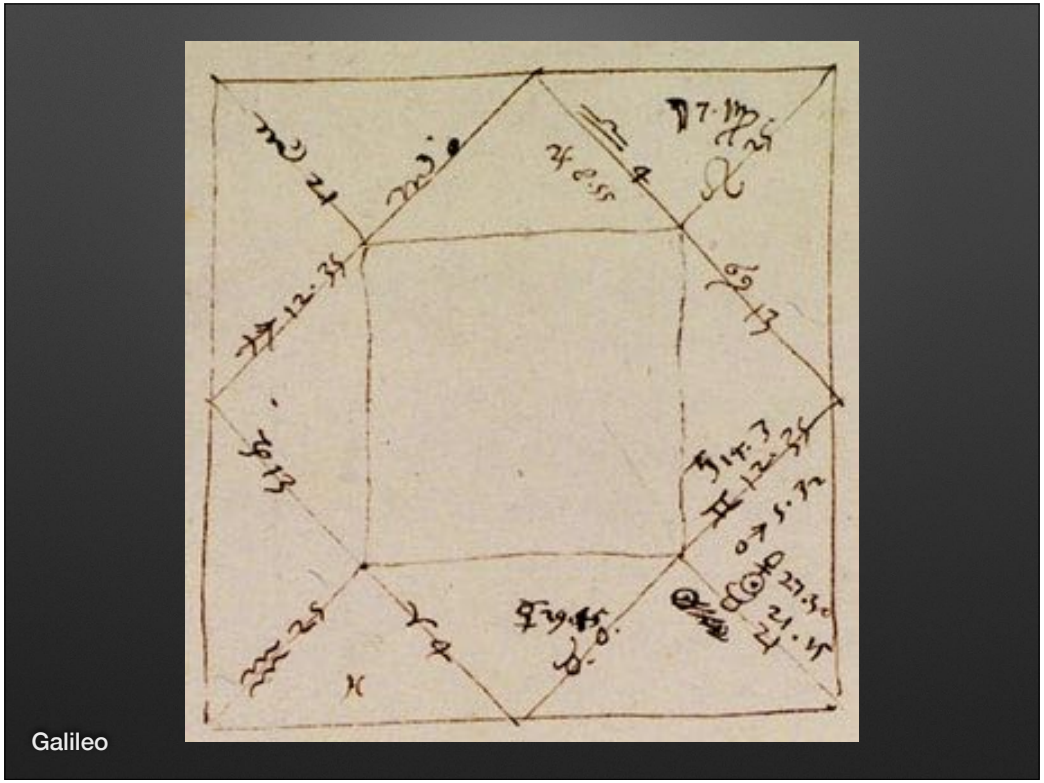
This book is OU's copy of the Second Folio. In January, 2016, the Sam Noble Oklahoma Museum of Natural History hosted the traveling exhibition First Folio! The Book that Gave Us Shakespeare. The First Folio, published in 1623, was the first printed collection of Shakespeare's plays. The copy displayed at the Sam Noble is one of only 233 surviving copies of this significant work. The traveling exhibit program is the result of a partnership between the Folger Shakespeare Library, the Cincinnati

Museum Center, and the American Library Association.

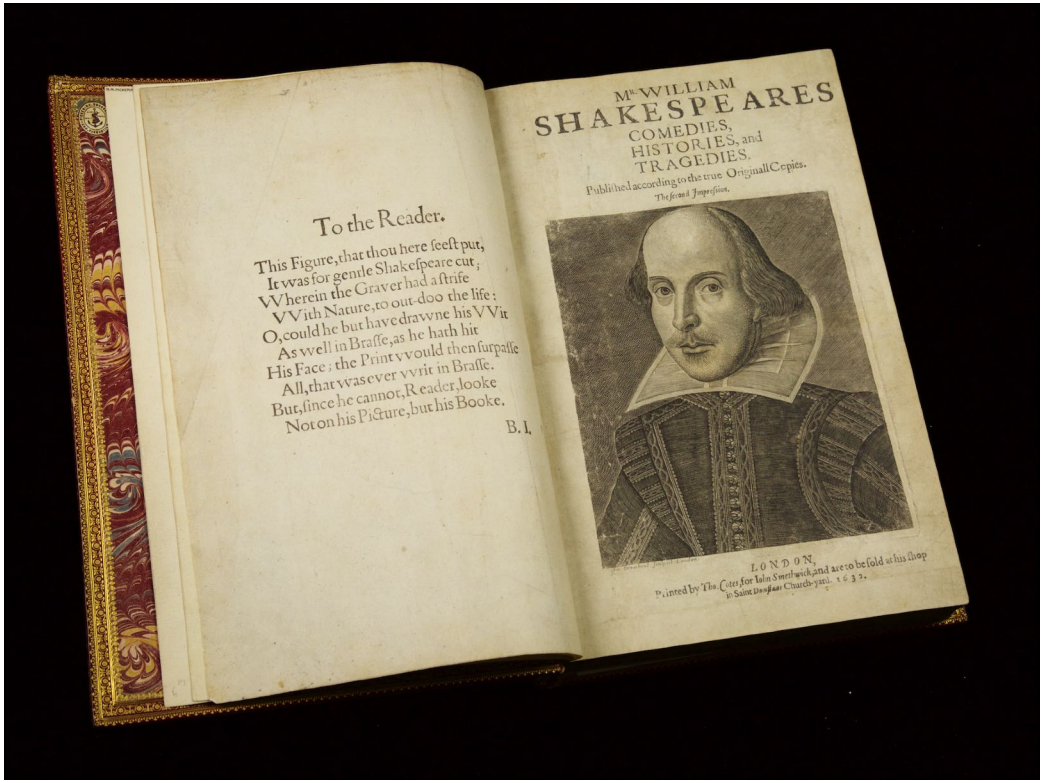


is made of the four sublunar elements: earth, water, air and fire. In the physical world, these four elements arise from

- the four “contraries”: hot, cold, dry and wet. In the human body, the contraries give rise
- to the four “humors”: hot and wet make sanguine (blood); hot and dry make choler (yellow bile); cold and wet make phlegm (cough); cold and dry make melancholy (black bile). Health prevails when the four humors are tempered in harmony (hear the connection with music?). Persons are said to possess choleric, melancholic, phlegmatic or sanguine “temperaments” (or tunings) when their distinctive balance is tuned toward one or other particular humor. In contrast, Shakespeare described Brutus in Julius Caesar as possessing the elements equally mixed.
- Planetary and stellar *influences* affect one’s physical temperament, so one must take steps not to catch the melancholic “influenza” of Saturn. Galileo once served as an expert medical witness at court, giving testimony pertaining to melancholia.
- Or there is the choleric influence of Mars • and the phlegmatic influence of the Moon. • Far better is the sanguine influence of Jupiter.



This is why Galileo cast horoscopes, such as this one for Cosimo Medici. Galileo cast horoscopes of his family and friends to help them understand and better manage their temperaments.



So educated readers believed that a planetary influence, or influenza, might affect the course of health and disease. University-educated physicians depended upon their ability to prognosticate planetary positions. They used mathematical astronomy to prescribe the appropriate times for bloodletting, administering medicines and other therapeutic measures. Coming down with the flu? Take two pills each morning with the rise of Jupiter. [No wonder Aztec remedies were difficult to assimilate into the theory of European medicine.]

Shakespeare, Comedies, Histories, and Tragedies (London, 1632)
http://lynx-open-ed.org/node/226

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Galileo, *Difesa* (1607)

Galileo's second printed work was a defense of his compass, which had been plagiarized by a former student.
——-

Galileo, Difesa contro alle calunnie & imposture di Baldessar Capra (Venice, 1607), title page photograph
http://lynx-open-ed.org/node/603

Defense against the Calumnies and Impostures of Baldasar Capra!
Galileo inscribed a book to one of his physician friends in Venice:

Galileo's connections with medicine were extensive. Not only did Galileo enter the University of Pisa in 1581 to study medicine, but physicians and health care providers remained among his friends the rest of his life.

Galileo's second printed work was a defense of his work on the geometrical and military compass, which had been plagiarized by a former student. He inscribed the OU copy to a friend who was a Venetian physician. Galileo's handwriting in this copy was verified by Stillman Drake. This book is bound with his Compasso, displayed on the 5th floor of Bizzell Memorial Library.

Galileo, *Difesa* (1607)

I mention it here because he inscribed the OU copy to a friend who was a Venetian physician. Galileo moved in medical circles in Venice.

Santorio, *Commentaria* (1646)

We have already mentioned another physician friend of Galileo's in Venice, Santorio Santorio, in our earlier discussion of the thermoscope.

— — — — — — — —

Santorio Santorio, Commentaria in canonis Avicennae (Venice, 1646)
http://lynx-open-ed.org/node/604

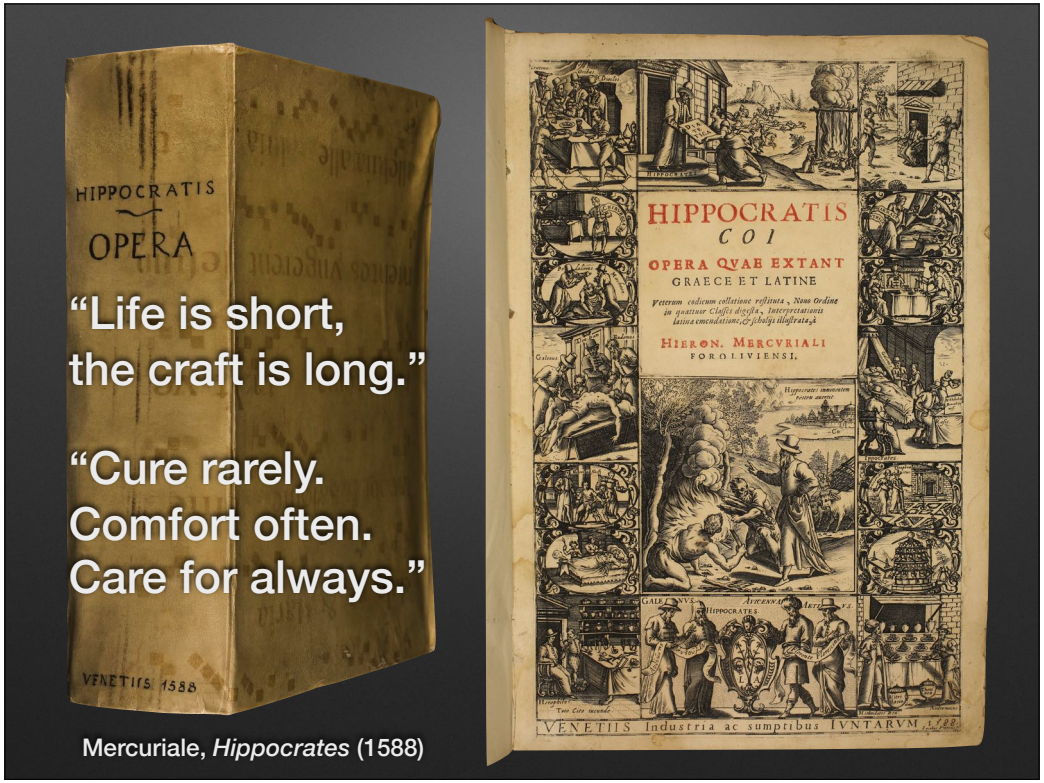
Commentary on the Canon of Ibn Sina (Avicenna)
Galileo's physics, applied to medicine:

Santorio designed a number of instruments which applied the principles of mechanical physics to medicine:

• Santorio invented a pulsilogium which measured more than a hundred different patterns of the pulse. This device was an ancestor of the blood pressure cuff and EKG machine.

Santorio, *Commentaria* (1646)

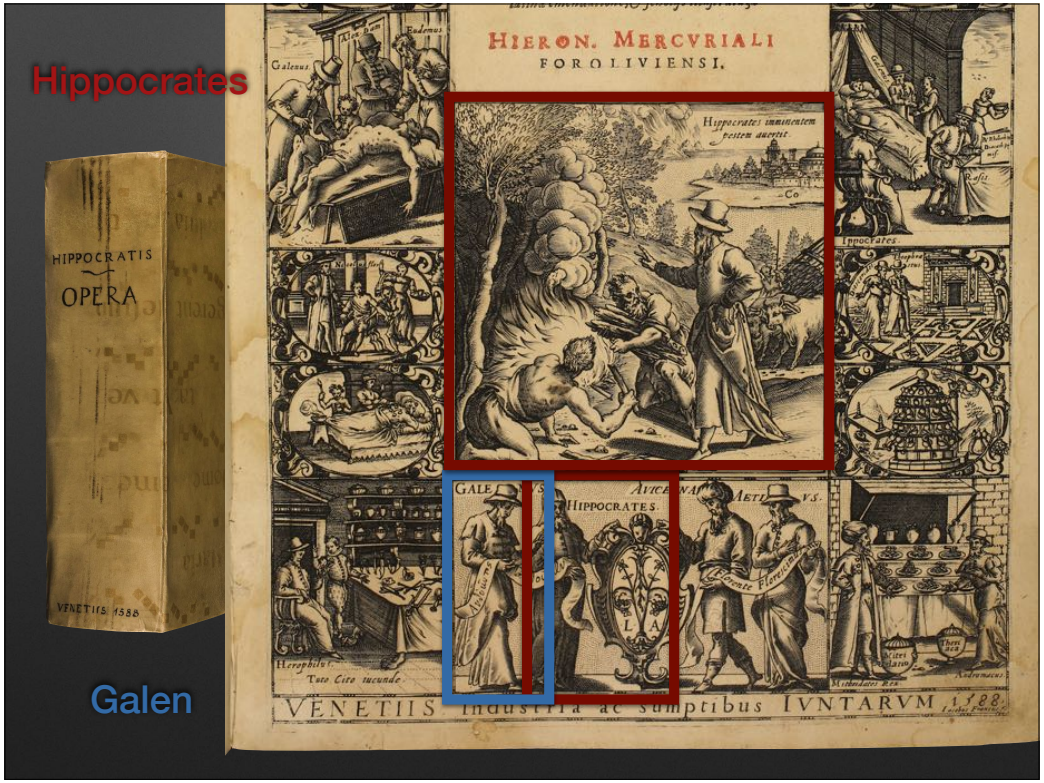
Santorio is also known for pioneering quantitative studies of metabolism. Santorio designed a weighing chair, suspended from an enormous balance, to standardize body weight measurements. He scrupulously weighed his dietary intake, urine and feces over a period of several decades, and concluded that the greater part of the weight one consumes must leave the body through insensible pathways. Quite a science project!



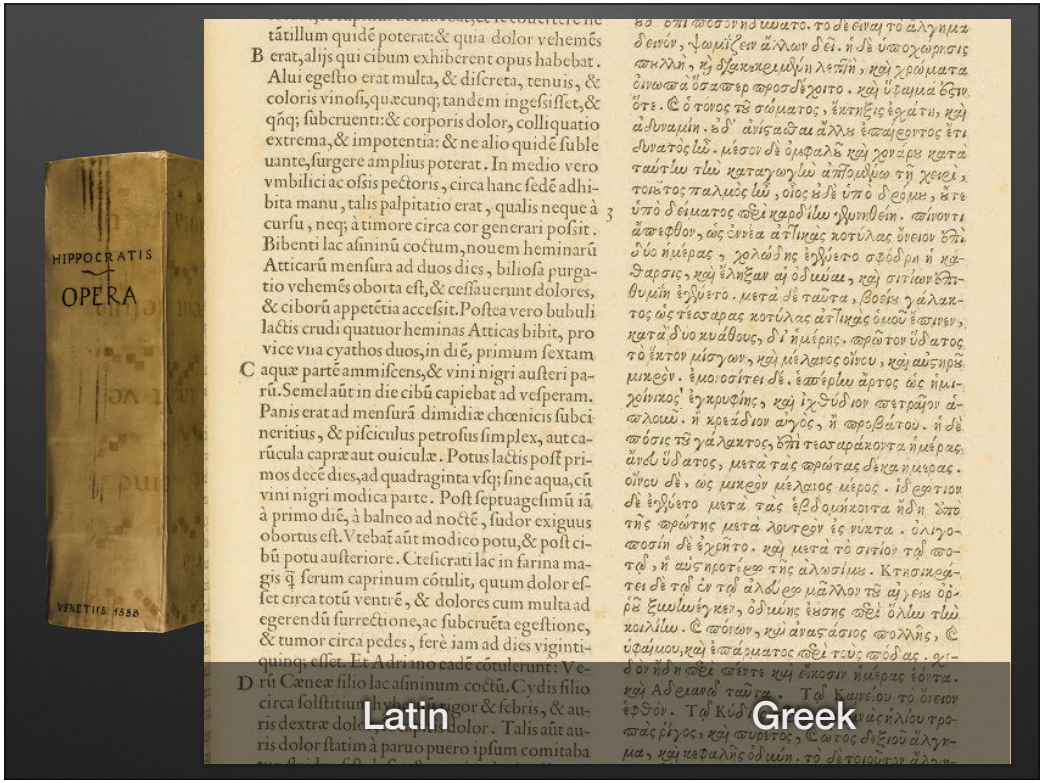
Mercuriale, *Hippocrates* (1588)

This is the first printed edition of the collected works of Hippocrates, collected and edited by Girolamo Mercuriale, a leading physician. Hippocrates was famous for his many aphorisms, including

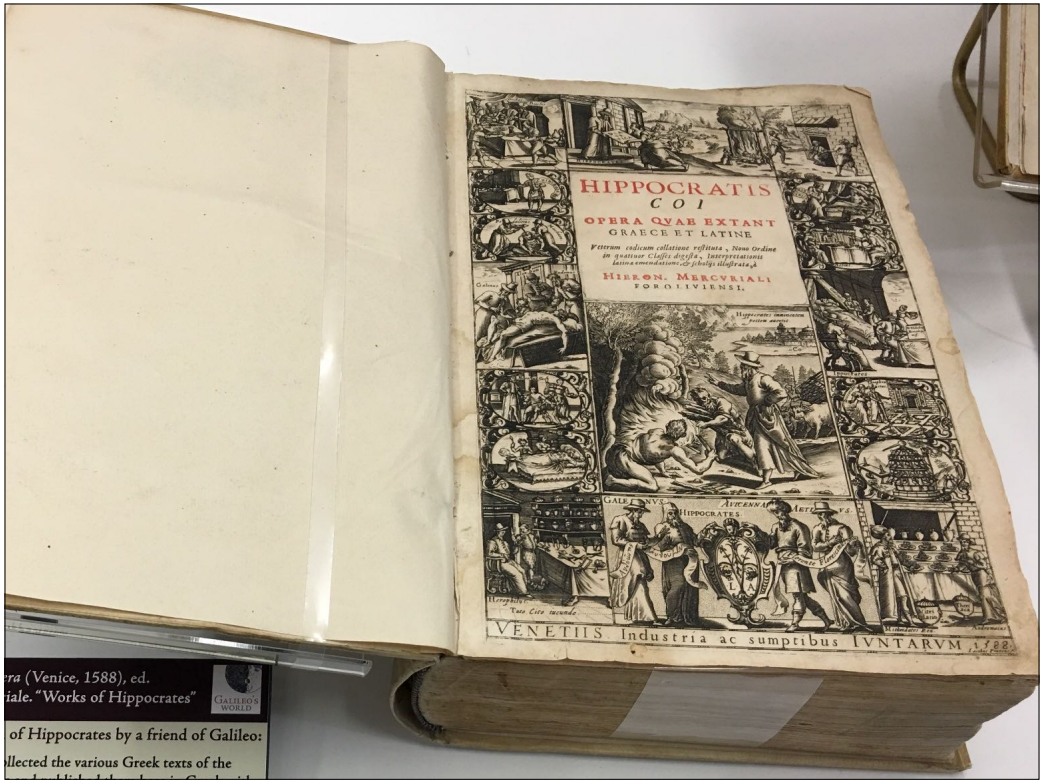
- “Life is short, the craft is long.”
- And “Cure rarely, comfort often, care for always.”



The title page illustrates various figures of ancient medicine, • including Galen and • Hippocrates. The Hippocratic corpus • was written in the 5th century BCE by many authors, over a more than a century, who were associated with a center for health care located on the island of Kos.



Mercuriale collected the various Greek texts of the Hippocratic writings, and published a critical edition, with parallel Latin translation.



A professor of medicine at the University of Padua, Mercuriale was also an acquaintance of Galileo. He recommended Galileo for a Chair of Medicine at the prestigious University of Bologna. Galileo didn't get the position. But would there be a position at ATSU for Galileo? In any case, I hope I've illustrated the extensive involvement of Galileo with the world of medicine.

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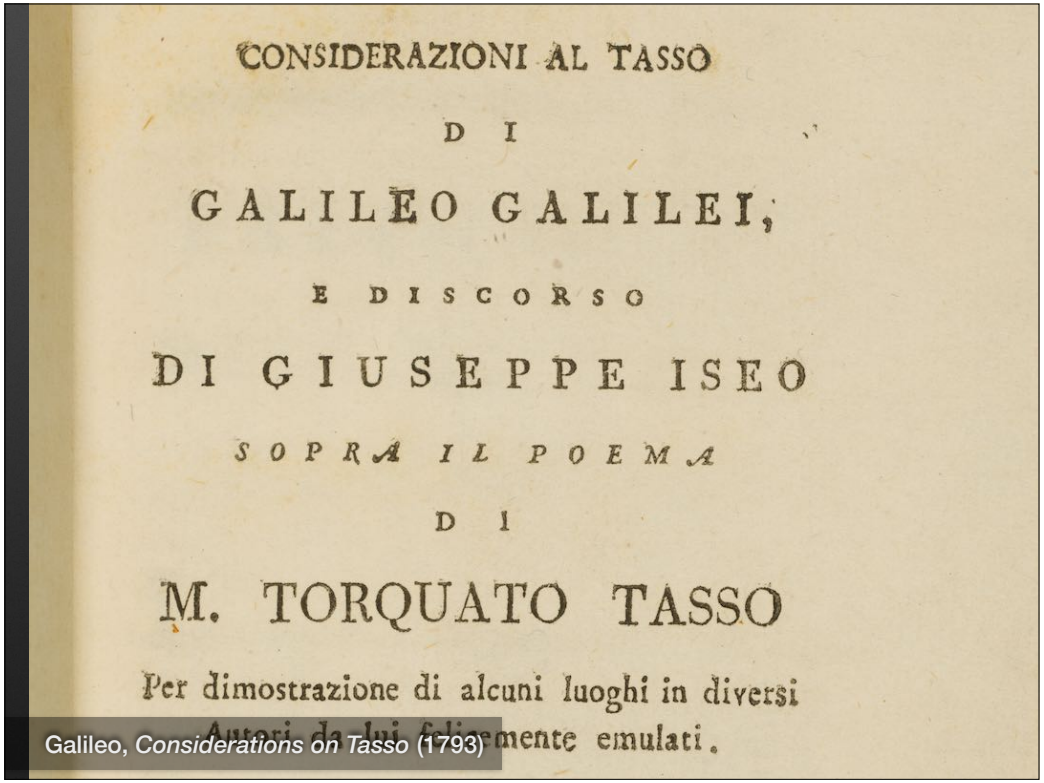
Hippocrates, Opera (Venice, 1588), ed. Girolamo Mercuriale.
http://lynx-open-ed.org/node/613

Mercuriale's many other works include discussions of sports medicine, women's health, children's diseases, and the black plague.



Galileo, *Considerations on Tasso* (1793)

We now turn to Galileo's contributions to anatomy by referring to an unlikely source: a book of literary criticism. Here Galileo critiqued giant tales by popular writers of the day such as Tasso. Using his understanding of comparative anatomy and the physics of weight, Galileo refuted the literary description of giants with physically impossible proportions. (BTW, Galileo also gave public lectures on Dante.)

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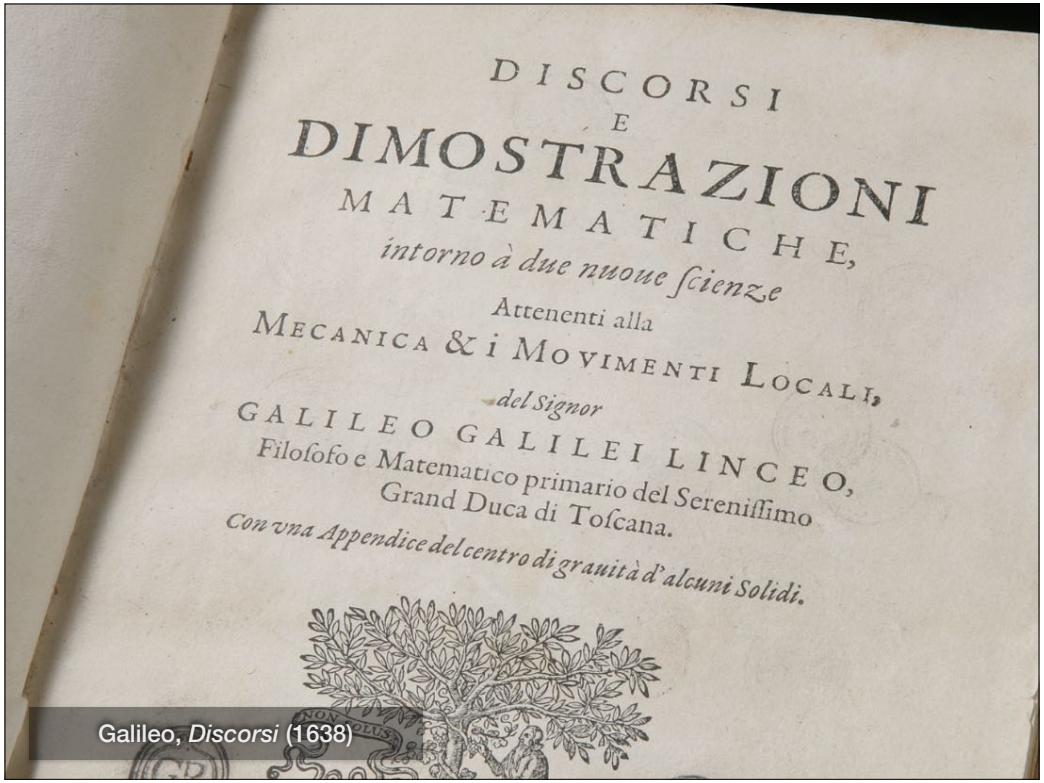
Galileo, Considerazioni al Tasso (Venice, 1793), octavo.
http://lynx-open-ed.org/node/563

Galileo employed his scientific acumen to engage in the literary debates of the day. Here he considered the merits of Tasso and Ariosto, comparing both with Dante, his fellow Florentine.

Galileo urged a principle of verisimilitude, that wondrous things be described in a realistic manner. For example, using his new physics of tensile strength, Galileo refuted the literary description of giants with physically impossible proportions. Galileo also gave lectures on Dante, employing the techniques of Archimedes to analyze the dimensions of Dante's hell.

This is the 1st edition, small format. Galileo's work on Tasso was published posthumously. The OU History of Science Collections holds both small and large format editions published in the same year.



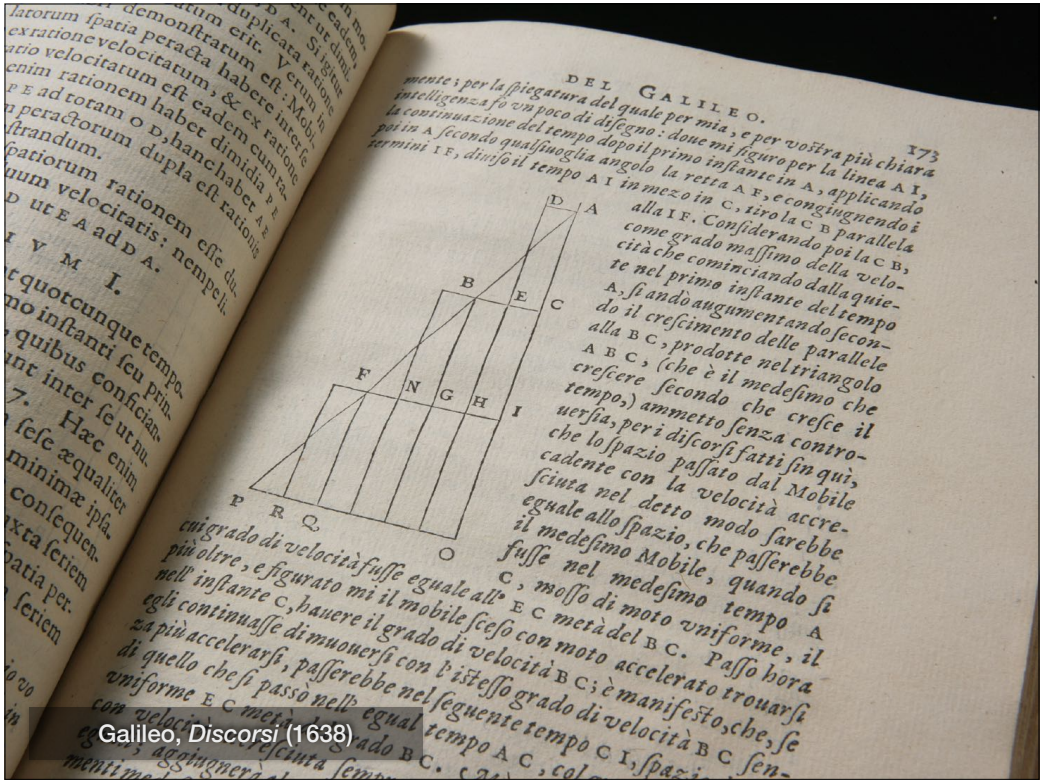
Galileo, *Discorsi* (1638)

Earlier we mentioned Galileo's Discorsi, the Discourse on Two New Sciences. The two sciences concern tensile strength and motion.

———————

Galileo, Discorsi à Due Nuove Scienze (Leiden, 1638)
http://lynx-open-ed.org/node/560

Galileo's science of tensile strength contains a critique of giant tales. He articulated what would become a central tenet of comparative anatomy: homologous structures of animals of different sizes will take on different shapes rather than just appear larger, because the force of weight scales in a non-linear fashion. When scaling up, one can't just make things bigger. In other words, the bones of a giant will not look the same, except larger, as those of an ordinary human. They will need to be thicker. Eventually, a large enough giant would simply collapse under his own weight. Thus, giants as described in the tales of imaginative writers must be rejected by the principles of the new science of tensile strength.

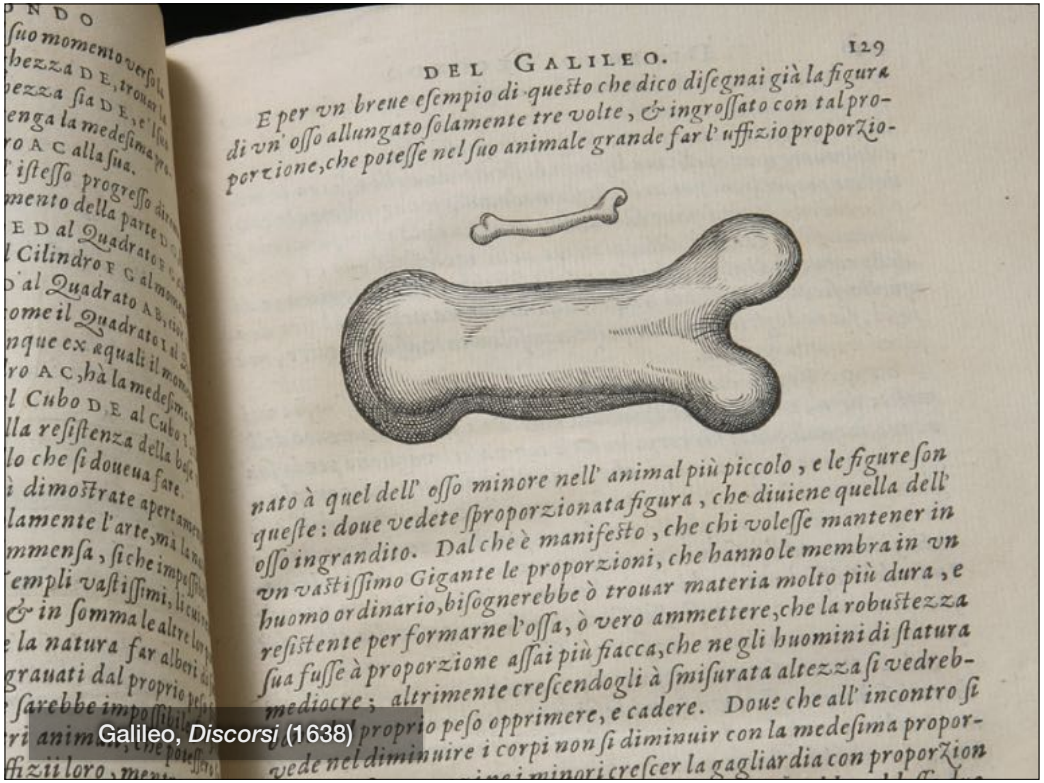


Galileo, *Discorsi* (1638)

We noted earlier that the science of motion includes the parabolic motion of projectiles and the law of falling bodies.

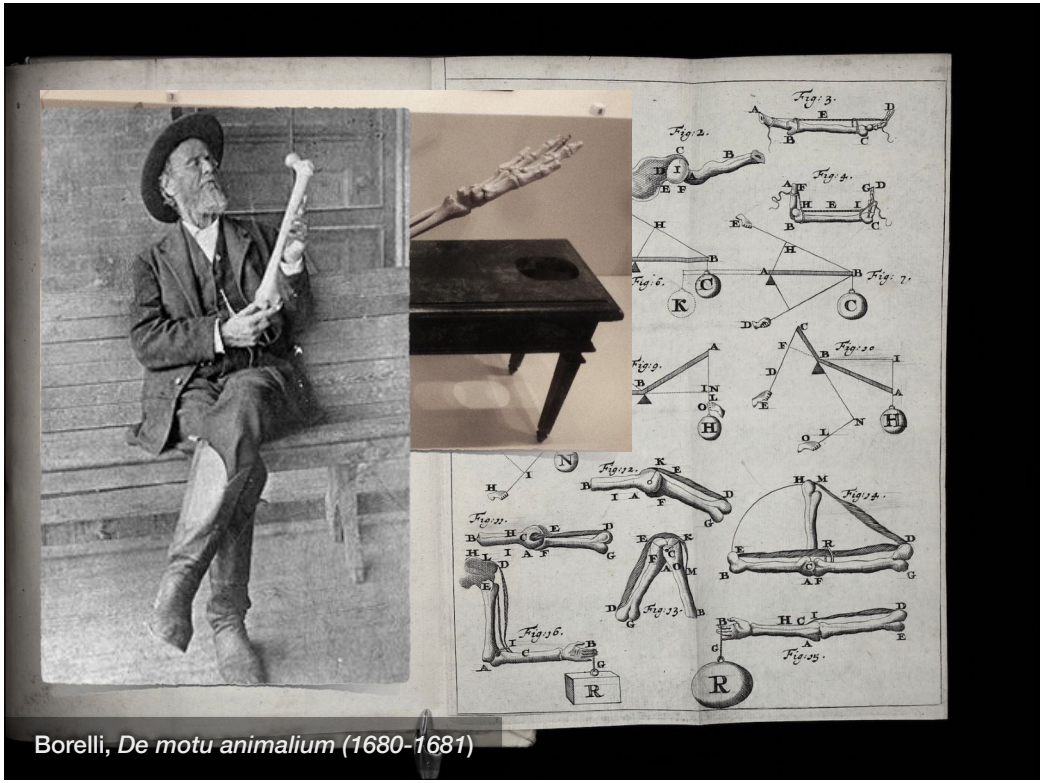

Galileo, *Discorsi* (1638)

But we passed over the science of tensile strength, which occupies the first part of the book. Galileo articulated what would become a central tenet of comparative anatomy: homologous structures of animals of different sizes will take on different shapes rather than just appear larger, because the force of weight scales in a non-linear fashion.



Galileo, *Discorsi* (1638)

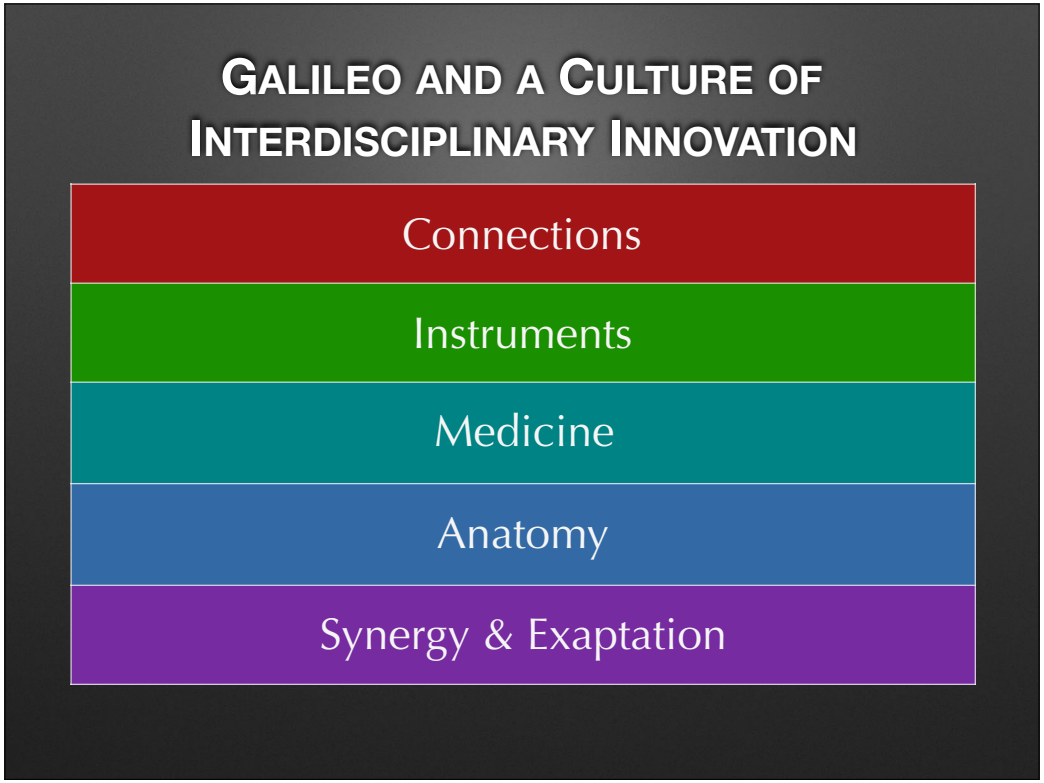
When scaling up, one can't just make things bigger. In other words, the bones of a giant will not look the same, except larger, as those of an ordinary human. They will need to be thicker. Eventually, a large enough giant would simply collapse under his own weight. Thus, giants as described in the tales of Tasso and other imaginative writers must be rejected by the principles of the new science of tensile strength.



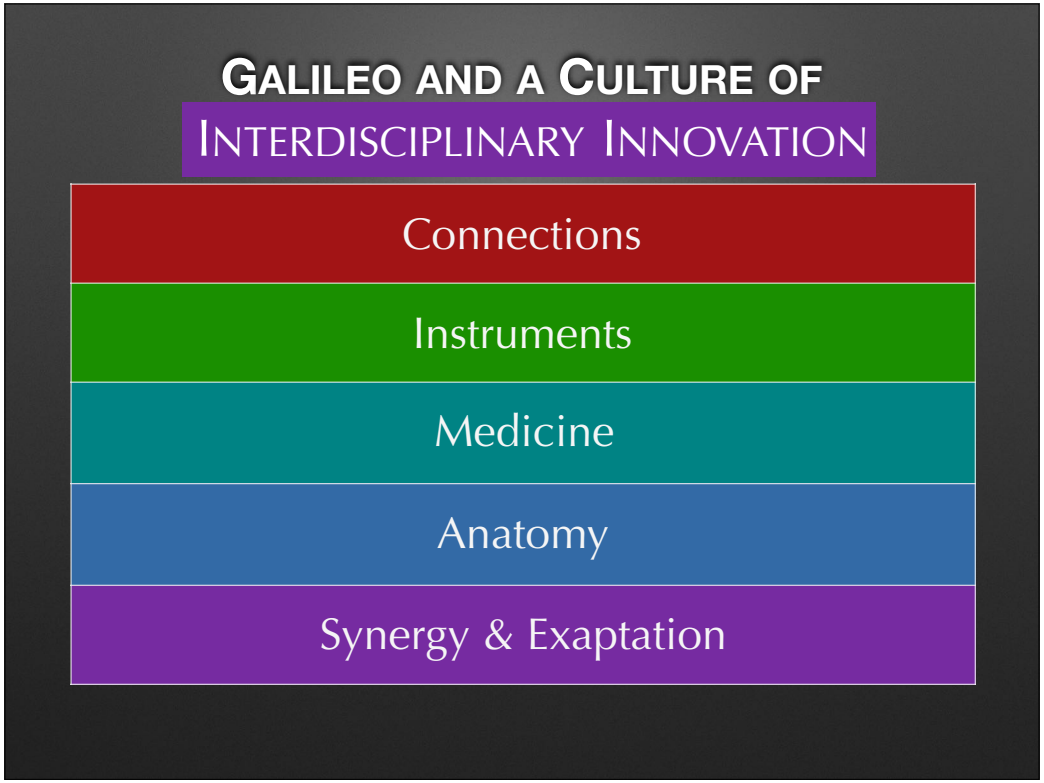
Borelli, *De motu animalium (1680-1681)*

Borelli analyzed the musculoskeletal system in terms of the mechanics of the lever and other simple machines. Borelli, a practicing mathematician and engineer as well as a physician, studied under Galileo's student Castelli. He was a member of the Academy of Experiment in Florence.

- The Museo Galileo in Florence has preserved an anonymous 18th-century Borelli-like model of the arm as a third-order lever. (A third order lever is one in which the effort lies between the fulcrum and the load.)
  Physicians such as Santorio and Borelli,
- and shall we say, A. T. Still, applied to medicine and anatomy the physical principles which occupied Galileo.



So that's Anatomy. Now let's conclude with a few reflections on innovation by Synergy and Exaptation.



Synergy and Exaptation are two forms of interdisciplinary innovation. However…

[But why not just say interdisciplinary innovation and leave it at that? Interdisciplinarity and innovation can become buzzwords. If we're not careful, they will do our thinking for us.]

- Just because something is interdisciplinary doesn't mean it is helpful. The imposition of disciplinary expertise outside its proper domain can be imperialistic and overbearing.
- Innovation is not easy to define. Innovation does not mean simply trying something new. Nor is innovation at first easy to recognize when it does occur. Innovation often only becomes evident in retrospect. Innovation is not a management technique that directs immediate outcomes. Rather, innovation arises from a *culture* that creates possibilities for synergy and exaptation over time.
- To clarify our thinking, let's focus on two concrete and specific forms of interdisciplinary innovation. Synergy and exaptation made interdisciplinary connections in Galileo's world so innovative.

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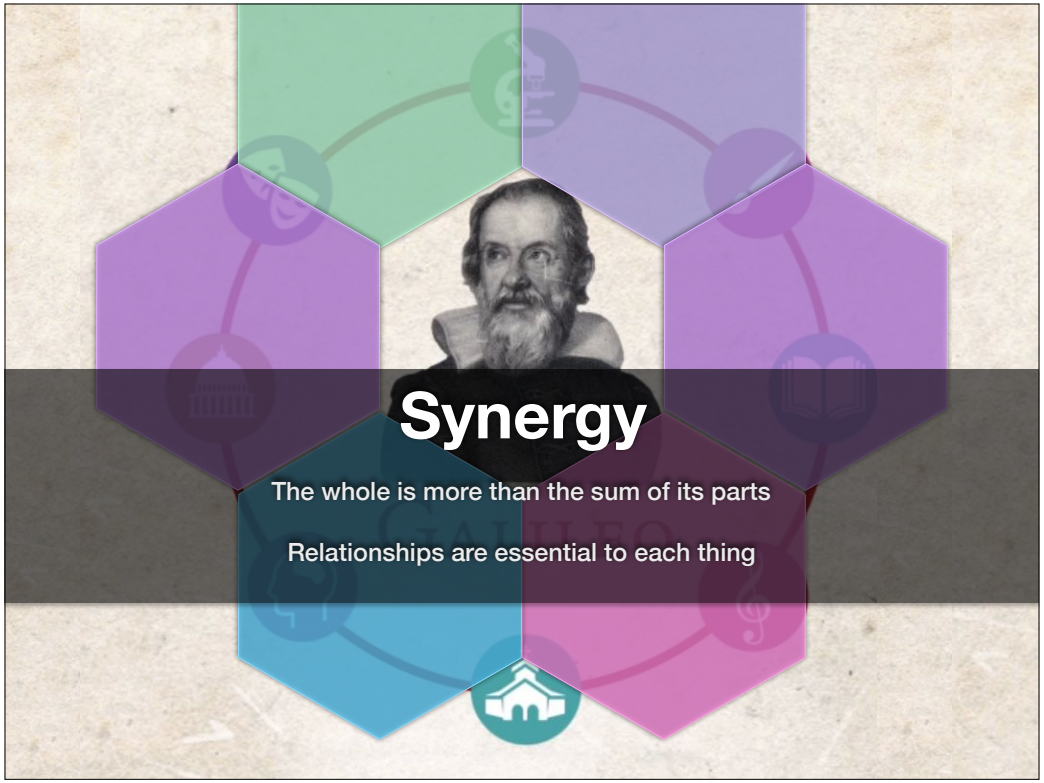
True interdisciplinarity and true innovation are *hard,* as you well know. Research is intensely challenging and involves us as whole persons.



When we have spoken of connections between the whole circle of subject areas, we're thinking in the holistic terms of synergy.

- The whole is more than the sum of the parts because the relationships are essential to each thing. No discipline exists on its own in isolation from other disciplines. Rather, the whole is to some degree present within each part.

  Synergy is a more familiar concept than

Exaptation

- Productive transfer between two domains.
- When a methodology, technique, skill, concept, question, kind of evidence, data set, or area of expertise arising from one discipline is heuristically applied, and then discovered to be [illegible]ally effective, in another.

Heat regulation
Display…
…Flight

Ornithomimid dinosaur, Alberta, Canada
Science, Oct 25, 2012

Exaptation. Exaptation originated as a term in evolutionary biology for a trait such as feathers, initially used for heat regulation, or for display,

• but which was later co-opted for flight.

- So exaptation has come to refer to the productive transfer of traits or ideas between two different domains. The hawk is an admirable example of innovation by exaptation.
- So here's a longer working definition: READ.

Exaptation is receiving widespread attention these days. We can now attend international conferences on exaptation, such as “Exaptation 2018,” held on the coast of Italy. Sign me up!

———-

They describe exaptation as a process of “serendipitous expansion of technologies and products in new domains.”
https://sites.google.com/view/exaptation2018/introduction

We can now read articles about “Exaptation as a source of creativity, innovation, and diversity” in literature such as this Oxford academic journal.
https://academic.oup.com/icc/article/25/1/115/2449848

So how did a culture arise in Galileo’s world capable of creating the possibility of exaptation? Let’s consider the Academia del Disegno, a renowned Academy of Drawing in Florence.

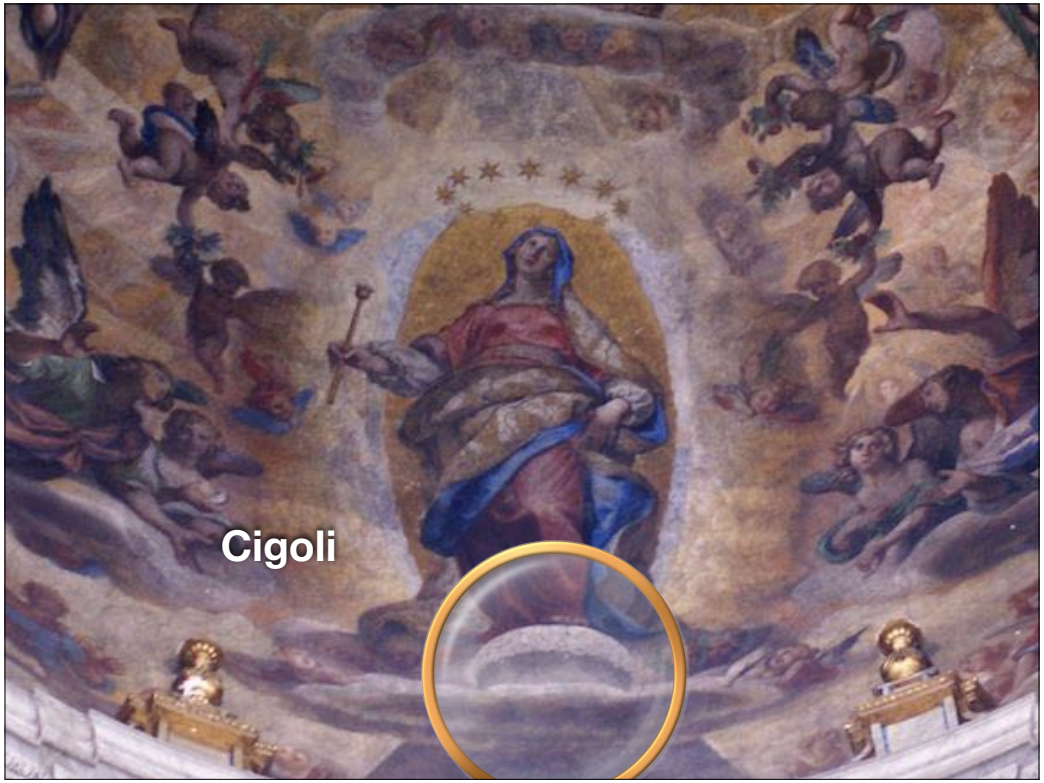
- Sirigatti, considered earlier, taught at the Academia del Disegno.
- At that time in Tuscany, many young men enrolled in artisan workshops such as this one.

———————

The polymathic character of Galileo's work illustrates the capacity of mathematics to contribute to subject areas beyond astronomy and physics, including engineering, art, music, and even literary criticism. As a young man, he appears to have studied in the artisanal workshop of Bernardo Buontalenti in Florence where the curriculum emphasized geometry (Valleriani 2010, 13). Fellow students became painters, sculptors, architects, or engineers, depending on their capstone projects. In this connection, perhaps it is not surprising that Galileo's friend, the painter Cigoli, who also studied in Buontalenti's workshop, regarded Galileo as his master in perspective drawing. Historians of art suggest that Galileo's discovery of mountains on the surface of the moon depended as much on his artistic training as on the primitive optics of his early telescope (Edgerton 2009). there were profound connections in the educational training of artists and engineers

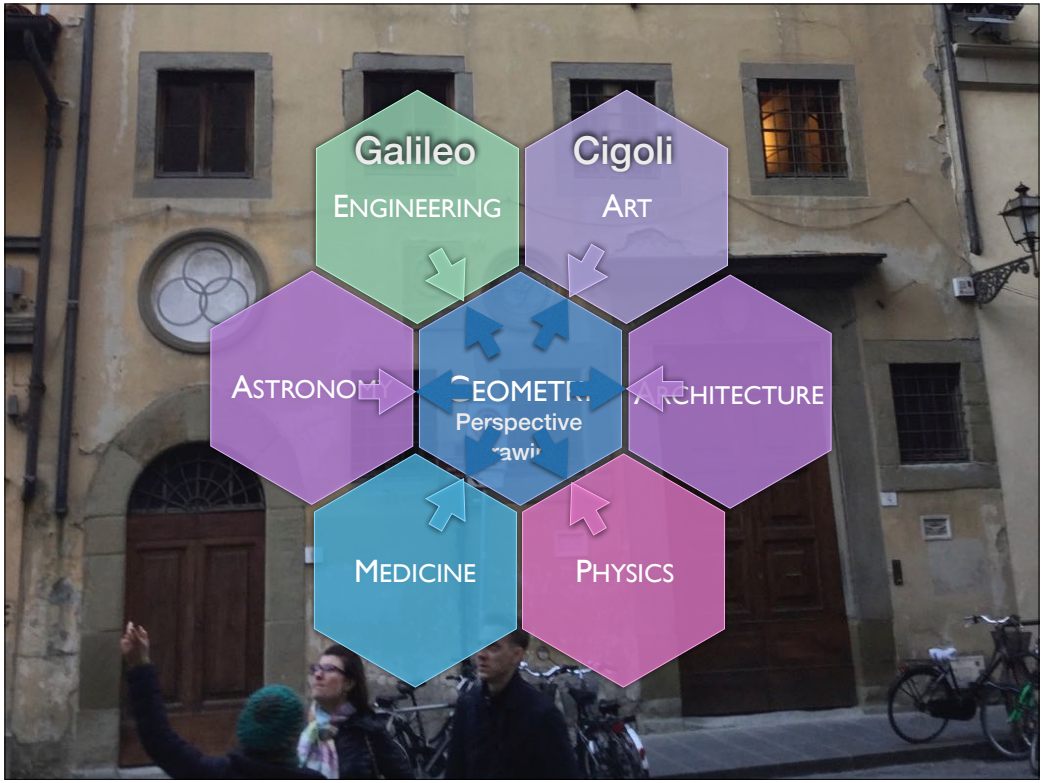
In these artisan workshops they would study Euclidean geometry in a hands-on way by practicing the techniques of perspective drawing. Later in life, Galileo became an honorary member of the Academia del Disegno.

As a young man, Galileo studied in the artisan workshop of Buontalenti. Lectures there were also attended by Galileo's friend, the painter Cigoli.

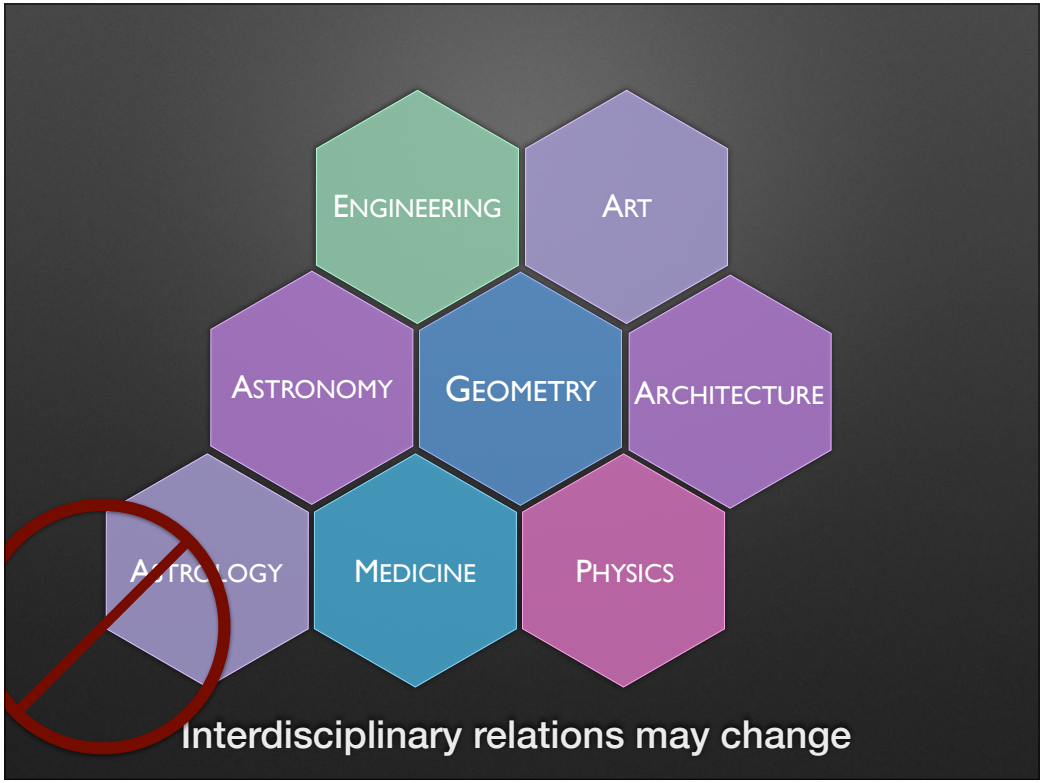


This is a painting by Cigoli in Rome, of the Virgin standing on the Moon.

• But the Moon shows craters, as it appeared through Galileo's telescope. They had known one another since Buontalenti's workshop. Amazingly, it is reported that Cigoli regarded Galileo as his master in perspective drawing.

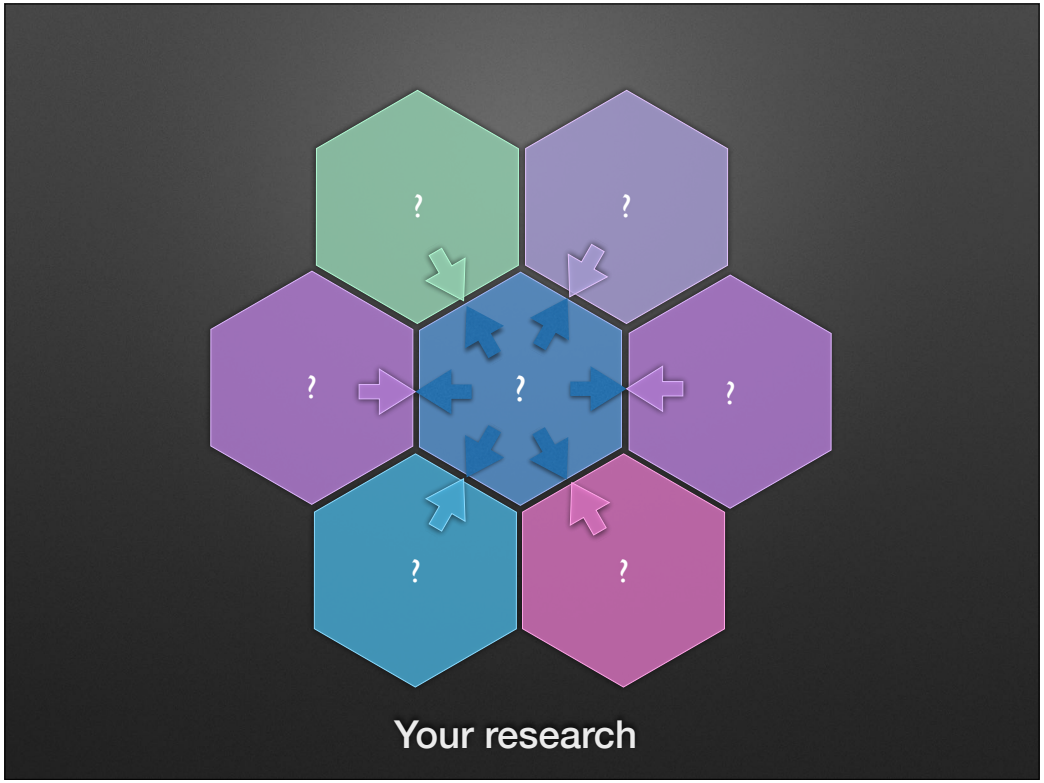


For their capstone project, students in these artisan workshops would apply their perspective drawing skills to a project in • art such as a painting or sculpture, and go on to become artists. • Or they might make a blueprint, and go on to be architects. • Or they might create a design for a complex machine, and go into engineering, as did Galileo. In artisan workshops, • future artists like Cigoli and engineers like Galileo studied geometry side by side. • Medicine and physics were also transformed by methods of perspective drawing. • And Galileo took the radically innovative step of applying perspective drawing to the telescope. Innovative contributions were made in each of these fields because of their synergistic relation with each other, • and because of the exaptation or transfer of perspective drawing from geometry.



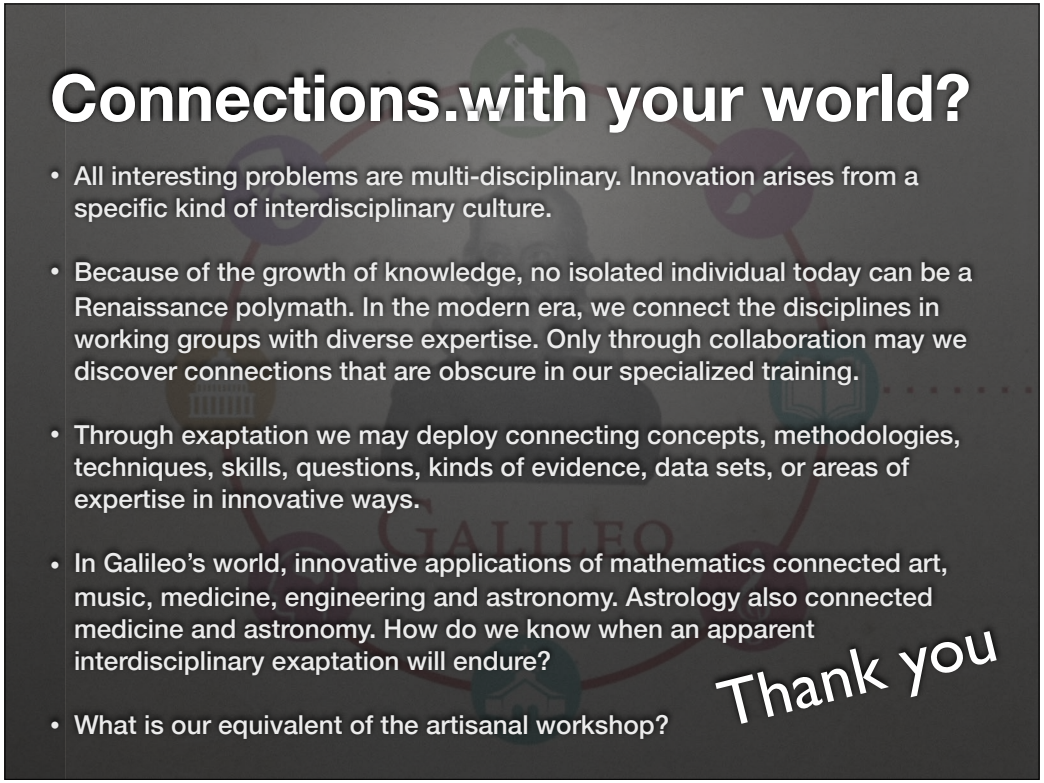
Yet interdisciplinary relations may change in the course of research:

- in Galileo's day, astrology was successfully applied to medicine,
- but such an interdisciplinary connection has not endured to the present day.



What is the circle of subject areas

- that come together in your research?
- Where are your opportunities for exaptation?



Perhaps we can imagine some connections… (read)

• Do the stories we've heard today from Galileo's world connect with your world? Perhaps in these ways? Perhaps others? I welcome your comments now in discussion.

• Thank you.