
- The role of alchemy in the Scientific Revolution (16th-17th cent).
- *Cast of Characters:*
  - Geber (Paul of Taranto)
  - Thomas Erastus
  - Andreas Libavius
  - Daniel Sennert
  - Robert Boyle

- *Key issues:*
  - The role of alchemy in providing the experimental basis for the corpuscularian and atomic theories of matter associated with the Scientific Revolution.
  - The role of alchemy in linking the mechanical philosophy of the Scientific Revolution with the Aristotelianism that preceded it.
  - The rehabilitation of alchemy in histories of the Scientific Revolution.
A. The Problematic Place of Alchemy in the Scientific Revolution

- **Late 17th century**: Adoption of corpuscularian/atomic theories of matter.

  "It is in fact impossible to imagine Newton's successes in optics or physics as a whole without the heuristic assumption that beneath the threshold of sense, matter -- and even light -- are composed of discrete and permanent particles rather than a single, mutable continuum." (Newman, pg. 5)

- **Claim**: Alchemy provided corpuscular theories with the experimental means to debunk scholastic theories of perfect mixture and to demonstrate the retrievability of material ingredients.

  "I see Boyle's mechanical philosophy as having been indissolubly linked to his chymical researches..." (Newman, pg. 3)

- **Early 17th century**: "Material change was generally explained not by the association and dissociation of microscopic particles, but rather by the imposition and removal of *inmaterial forms*." (Newman, pg. 4)

  "...it was commonly believed that the ingredients of 'genuine mixtures' -- many of which we would today call 'chemical compounds' -- were not capable of being retrieved from their combined state at all."
Aside: Aristotle's Theory of Change

(a) Doctrine of Hylomorphism:

- A sensible object consists of both matter and form.
- Form determines properties of the object.
  - Properties cannot exist without a subject in which they adhere.
- Matter provides the substratum in which properties adhere.
  - by itself has no properties (neutral substratum).
  - does not exist without form.
  - is the "subject" of form.

Example

- Gold is yellow, cold, malleable, heavy, smooth, etc; determined by its form.
- If all these properties could be stripped away, what would remain would be matter.
(b) Account of Change:

- Permanence through change is provided by matter.
  - When an object changes, its form changes and its matter remains the same.
- Change involves a transition from a potential form to an actual form.

Example:
- An acorn has both an actual form of being an acorn, and a potential form of being a sapling.
- When an acorn changes into a sapling, its potential form transitions into the actual form of a sapling.

(c) Two distinctions:

- matter/form distinction (static)
- potential/actual distinction (dynamic)
  - Pure potency = "Prime Matter".
  - Pure actuality = "Prime Mover" (Aristotle's concept of god).
The Place of Alchemy in Traditional Accounts of the Scientific Revolution

- "[Daniel Sennert]... contributed nothing new to the development of a mechanical philosophy based upon a theory of atoms... [He was] neither original, successful, nor, ultimately, influential." (Boas Hall 1958)

- "[Historians of alchemy are]... tinctured with the same type of lunacy they set out to describe." (Butterfield 1949)

- "[Alchemy was]... the greatest obstacle to the development of rational chemistry". (Hall 1962)

- "In [Boyle's] case, too, alchemy remained what it had always been: a mysterious trifling with impure substances, guided by mystical conceptions and hazy analogies, in which credulity played a considerable part." (Dijksterhuis 1961)
More Recent Cultural Histories of the Scientific Revolution

- Shapin and Schaffer's (1985) *Leviathan and the Air-Pump*.
  - "...explicitly views alchemy as a foil to the experimental science of Boyle and the Royal Society." (Newman, p. 8)

- **Flawed method**: "...consists largely of adding sociological explanations to the preexisting history of ideas rather than subjecting the results of intellectual history to critical analysis."

- **Problem**: What happens when the received opinion of historians changes?
  - "All the emphases and prejudices of the vintage histories remain embedded in this new account, with the sole exception that now we can supposedly explain this fixed and rigid picture in terms of categories drawn from a multicolored pastiche of sociology, anthropology, literary criticism, and critical theory." (Newman, p. 11)

- **Bottom Line**: Sociology (as well as philosophy) of science must be informed by critical history of science.
The "Yates Thesis"

  - *Hermetic writings* = collection of essays on Ancient Egyptian thought, Greek philosophy, early Christian doctrine, as well as practical magic, alchemy and astrology.
  - *Misdated:* Written 1st & 2nd cent.; rediscovered during the Renaissance (15th cent) and believed to have originated in Ancient Egypt.

- *Yates's Thesis:* Hermetic writings provided basis for emphasis on experimental techniques during 16th/17th cent. Scientific Revolution:
  - The "magus" as actively engaged in the manipulation and creation of natural phenomena.

- *Newman (pg. 12):* "It is one thing to imbibe from alchemy a general optimism about the human ability to alter nature... and quite another thing to use alchemy to extract from nature the experimental evidence for a corpuscular theory of matter... Yates herself viewed the mechanical philosophy as the antithetical replacement and successor to the magical worldview of which she thought alchemy to be an integral member."
B. The Medieval Tradition of Alchemical Corpuscular Theory

- **1619**: Daniel Sennert's *De chymicorum cum Aristotelicis et Alenicis consensu ac dissensu*.
  - Experimental demonstration of corpuscular theory of matter.
  - Paves way for mechanical philosophy of Robert Boyle and Descartes.

- **Experimental basis**: Dissolves precious metals in acid and then precipitates them out by means of alkalies.

- Combined Greek atomism with Aristotelianism.

---

**Classical Greek atomism (Leucippus and Democritus ~440, ~410 B.C.)**

- *No experimental context*: An attempt to provide an account of change in terms of fundamental material constituents.
  - If a constituent is fundamental, then it cannot change.

- *Being is limited to atoms; change occurs via random movements of atoms in an infinite void.*
  - Atom = indivisible material particle.
- **13th century predecessor**: Geber's (Paul of Taranto) *Summa perfectionis*.

**Geber's Corpuscularianism:**
- 4 elements combine "through the smallest" to form the larger complex corpuscles of *mercury* and *sulfur* in "very strong compositions".
- Mercury and sulfur combine to form corpuscles of various metals.

<table>
<thead>
<tr>
<th>Modern distinction:</th>
</tr>
</thead>
<tbody>
<tr>
<td>mixture = mechanical juxtaposition of particles.</td>
</tr>
<tr>
<td>compound = chemically bond particles.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aristotelian distinction:</th>
</tr>
</thead>
<tbody>
<tr>
<td>mixture (mixis) = homogeneous combining of ingredients.</td>
</tr>
<tr>
<td>compound (synthesis or compositio) = mere juxtaposition of uncombined parts.</td>
</tr>
</tbody>
</table>

- **Geber**: "very strong composition" = corpuscular juxtaposition.

<table>
<thead>
<tr>
<th>Observational basis for corpuscular nature of mercury and sulfur:</th>
</tr>
</thead>
<tbody>
<tr>
<td>The sublimed mercury and sulfur collect in a vessel as tiny droplets (mercury) or minutely divided powder (&quot;flowers&quot; of sulfur).</td>
</tr>
<tr>
<td>Both can be sublimed intact such that they leave little or no residue in the bottom of the vessel.</td>
</tr>
</tbody>
</table>
• **Aristotle on mixtures**: Every part of a mixture is the same as the whole (homogeneity).

• **Geber on mixtures**: "...the juxtaposed particles retain their own identity but are united with sufficient cohesion that they resist the analytical agents at the alchemist's disposal..."  (Newman, p. 31)

  o Homogeneity of mercury and sulfur is due to the uniform size of their minute corpuscles.

**Why iron and copper calcify when exposed to fire but gold doesn't:**

  o Metals are made of uniformly small particles of mercury and sulfur.
  o And: Iron and copper are less tightly packed than gold.

**Geber on the "philosophers's stone" ("mercury-alone" theory):**

  o Transmutation of a base metal into gold ("chrysophoeia") = process in which very small mercury particles penetrate the microstructure of the base metal.
Geber's (Paul of Taranto) *Theorica et practica*

- A rebuttal of Aquinas's arguments against alchemy.

- **Substantial form** = individual form of an object that is unique to it.
  - implicit in Aristotle; explicit in Galen (2nd cent.) and Aquinas (1270s).

- **Unitists** = a given object can only have one substantial form.
- **Pluralists** = a given object can have more than one substantial form.

---

**Aquinas's Unitist theory of matter**

- Matter consists of the 4 elements which contain 4 primary qualities: hot, dry, cold, wet.
- Pairs of these qualities together with undifferentiated "prime matter" constitute the fundamental stage of analysis.
- *Mixis* can only occur if a new substantial form (*forma mixti*) is imposed on the 4 elements.
  - Imposition of new *forma mixti* destroys 4 elements, but leaves their qualities behind ("the generation of one is the corruption of another").
- **And**: No intermediate forms between the *forma mixti* and the prime matter (*unity* of the substantial form).
• **Consequence:** No place for Geberian intermediate ingredients of mercury and sulfur in metals.

• **Geber/Paul's reconstruction of Thomistic argument:**

"...when a certain metal is generated, it is first resolved up to its simple elements, from which the metals themselves, just as all things, are generated... Therefore, when a metal is generated, something else is corrupted in its substantial form by which it was in act, lest two substantial forms be said to be in the same thing at once."

"It seems necessary that no preceding fixed nature should be assigned as a principle of the metals, except either the four elements or the prime matter itself..."
• **Geber/Paul's Response:** Adopt pluralist view. Mercury and sulfur persist beneath the substantial form of a complete metal.

"This is expressly proven by certain experiments of this art... But if there were a complete resolution to the simple elements and not to certain mineral or metallic principles which are nearer than the first simple bodies, the metal or such and such a body would no more return from them upon [its exposure] to fire than anything else made up of the simple elements, and gold would no more return from gold than would stone or wood [return from gold]..."

• **Newman:** Foreshadows Sennert's later *reductio in pristinum statum* ("reduction to the pristine state") defense of atomism.

  ○ *Experiments show that a metal dissolved in acid (or calcified) can be reduced back into a metal.*
  
  ○ *And:* This would be impossible if the metal had been resolved down to the 4 elements, as opposed to intermediate principles (mercury and sulfur).

  Corpse analogy:

  ○ "...the fact that a corpse remains after someone dies is not due to the sudden imposition of a form of the human body on the elements at the moment of the rational soul's departure. Instead, another form was there all along beneath the rational soul, and this accounted for the persistence of the body." (Newman, p. 42)
C. Erastus and the Critique of Chymical Analysis

- 1572: Erastus's *Disputationes de nova Phillippi Paracelsi medicina* ("Disputations concerning the New Medicine of Phillippus Paracelsus").
  - A critique of alchemy and Paracelsus.

- Phillippus Aureolus Theophrastus Bombastus von Hohenheim (1493-1541).

"Let me tell you this: every little hair on my neck knows more than you and all your scribes, and my shoe-buckles are more learned than your Galen and Avicenna, and my beard has more experience than all your high colleges."

- *Tria prima* = principles of mercury, sulfur and salt.
- Emphasis on alchemical process of separation (*Scheidung*).
  - "...the Paracelsian insistence on the possibility of retrieving initial constituents by means of analysis flew in the face of scholastic theories that denied their ability to remain in a mixture." (Newman, p. 45)
- *Spagyria* = alchemy based on *Scheidung.*
Two sources of 16th-17th century resistance to laboratory analyses

- The artifactual nature of the products arrived at by laboratory operations.
- The Aristotelian tradition of *mixis* versus *synthesis*.
  - "How could a chymist separate the ingredients of a genuinely homogenous substance since the very acquisition of the homogeneous state was widely assumed to mean that the diverse ingredients that had gone into it had lost their discrete character?"

- *Erastus on cheese and worms:*
  - Cheese and corpses aren't made of worms, even though they can be resolved into them.
  - Likewise, metals can be resolved in the lab into oils, waters, cinders, etc., but no thinking chymist would agree that they are composed of these.

- *Erastus on chickens and eggs:*
  - Chickens are initially made from eggs, and eggs from chicken blood; but who would want to argue that a chicken can be reduced to an egg, or an egg to chicken blood?
  - If an initial product naturally leads to a final product, it does not follow that the initial product still exists within the final as an actual ingredient.
• **But:**  
"Let us define the element in bodies as that into which other bodies may be analysed."  *(De caelo 3 302a15-18)*

• **Basis for alchemist maxim:**  "The things into which composites can be dissolved are the things out of which they are made."

• **Erastus's response (the "reditus principle"):**  "A return from privation to a habit [or form] in natural generations is not conceded."

"A return from habit or form to privation is not conceded: nor does nature proceed in reverse, but always continues forward, and by proceeding in a sort of circle she completes mutations from the elements by means of infinitely varied mixtures and temperations."

• **Basis in Aristotle:**  *Metaphysics H* 1044b34-1045a6 -- Vinegar cannot become wine again, nor a dead animal be restored to life without a total corruption to its matter.
Further basis in Aristotle: *De generatione et corruptione, Book 2* -- No return except for cyclical elements.

- "...elemental generation and corruption can be seen as a circle without end, whereas human birth and death is a linear process with a definite starting point and terminus... there can be no immediate return from privation to a habit except in the case of the four elements considered as isolated substances." (Newman, pg. 51)

**Transformations between elements:**

- *Contrary forms* = two forms that cannot both be present in the same thing.
- Forms change *via* transitions between contraries.

<table>
<thead>
<tr>
<th>cold ↔ hot</th>
<th>wet ↔ dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>water ↔ air</td>
<td>water ↔ earth</td>
</tr>
<tr>
<td>earth ↔ fire</td>
<td>air ↔ fire</td>
</tr>
</tbody>
</table>

- fire → hot → air → wet → dry
- dry → earth → cold → water

Diagram:

```
    fire
   /    \
hot    air
   \    /
    dry
   /    \
water → earth → cold → water
```
• **So:** *Reditus* Principle forbids the possibility of resolving a metal into anything other than the elements.

• **But:** Does Aristotle really intend this?

"it is clear that the ingredients of a mixture first come together after having been separate and can be separated again." (*De generatione et corruptione*)

• **How to read Aristotle as underwriting the Reditus Principle:**
  ○ Augment him with the doctrine of substantial forms!
  ○ **Recall:** Unitists (like Aquinas) held that there can be no intermediate forms between the *forma mixti* of a mixture and its prime matter.
  ○ **But:** This makes interpreting Aristotle difficult.
  ○ What about a pluralist interpretation of substantial forms?

*Was Erastus a unitist or a pluralist?*
Relevant questions for Erastus:

○ "...are the ingredients of a mixture unable to undergo recapture for the reason that the generation of a *forma mixti* requires the corruption of the preexisting forms of the ingredients up to the elements or even to the prime matter?"

○ "Does Erastus's denial of such reduction to the initial ingredients after mixture mean in effect that a given mixt does not have intermediate principles between its own substantial form and the four elements or the prime matter?"

"For it cannot happen by any created power that two different forms inhere in one matter... It is therefore necessary that what the chymists affirm, that they resolve the metals into that same matter out of which [the metals] were immediately transmuted, is false. For two substances differing in species or genus cannot generate the numerically identical thing."

- **Unitists sympathies**...
- **But**: Elsewhere, Erastus claims: "...every substantial form must have its own properly disposed matter, which differs from the matter informed by any other substantial form, and this matter must consist only of the four elements." (Newman, p. 56)
- **And this suggests**: "The four elements then provide the proximal matter in which that substantial form can inhere, not sulfur and mercury."
• **So:** Erastus straddles the fence.
  
  ○ *Unitist sympathies:* The generation of a new substance requires any preexisting *forma mixt* within it to be corrupted.
  
  ○ *Pluralist sympathies:* Allows for resolutions up to the four elements, as opposed to the prime matter. (Suggests a given *mixt* has more than one substantial form; in particular, its *forma mixti* and the forms of the 4 elements.)

• **Thus:** "...the *reditus* principle and the destruction of previous 'forms of the mixture' prohibit any resolution of [a mixture] other than the absolute return into the four elements." (Newman, p. 60)

• **So:** When alchemists think they are demonstrating resolutions of metals into mercury and sulfur and then back into metals in their laboratories, they are not working with genuine mixtures.

"For these [apparent alchemical mixtures] are conjoined by art, which is the ape of nature: it cannot make substances: but it effects something *per accidens* from many [ingredients] artificially conjoined..."
D. Aristotelian Corpuscular Theory and Andreas Libavius

- **Early 17th Century**: Libavius links Paracelsian *spagyria* to atomism via the intermediary of Aristotle's *Meteorology*.

- **Corpuscular theory of Meteorology**: appeals to "pores" and "corpuscles" as explanatory devices.

- **Libavius on spagyria**:

  "The moderns call it *spagiria*... But most celebrated is that *synkrisis* and *diakrisis* of the old, called "coagulation" [and] "solution" by our artisans [i.e., chymists]. For the latter tear apart the structures of mixed bodies and break them up with their ingenious techniques and apparatus. Penetrating into the inner chambers of composite things, into the bedrooms and sanctuaries of their essences, they congregate and unite the homogeneous, while separating the heterogeneous. That is, in Greek *span* and *ageirein*.''

- **Newman**: Aristotle uses the terms *diakrisis* and *synkrisis* in a critique of Democritus and Leucippus
  - *diakrisis* = separation of atoms from one another
  - *synkrisis* = combination of atoms.
• **Libavius on criticisms of chemical (Paracelsian) medicine:**

> "You ridicule atomic corpuscles and their concretion and segregation. But I say do tell, you jocular philosophers, why it is that when you generate man by means of a segregation from a liquor or from an evaporation of the humidity which Aristotle stated to come about in the body of the offspring, you do not see any such thing in the liquor beforehand?... In the same fashion when even very thick things are dissolved in sharp waters they do not appear to the eyes, although they reappear once the humidity is removed."

• **Newman (p. 70):** "Libavius is keen to show here that Aristotle himself employs the notion of associating and dissociating particles to explain such processes as human generation."
Libavius on Democritean atoms and Aristotelian mixts:

- Each Democritean atom is a perfect Aristotelian mixt.
- Macrolevel bodies are a combination of Democritean atoms and the four elements.
- Elements are "wrappings" or "shells" which hide the secret "first principles" or seeds (*semina*); i.e., atoms.
- The *semina* are transmitted from the heavens and fall into the elements, which act as wombs in which they mature.

"all mixts are therefore essentially from the heavens; but in order to be sensible, they bear the bodies of the elements with themselves, from which they can never be totally separated."

- **Goal of chymistry:** The separation of the *semina* from the crude impurity supplied by the four vulgar elements.

- **Advantage of Libavius's view:**
  "Now one could employ the structural explanations offered by Geberian alchemy while also providing an account of qualitative differences [in terms of the *semina*] that evaded a simple corpuscular description." (Newman, p. 81)