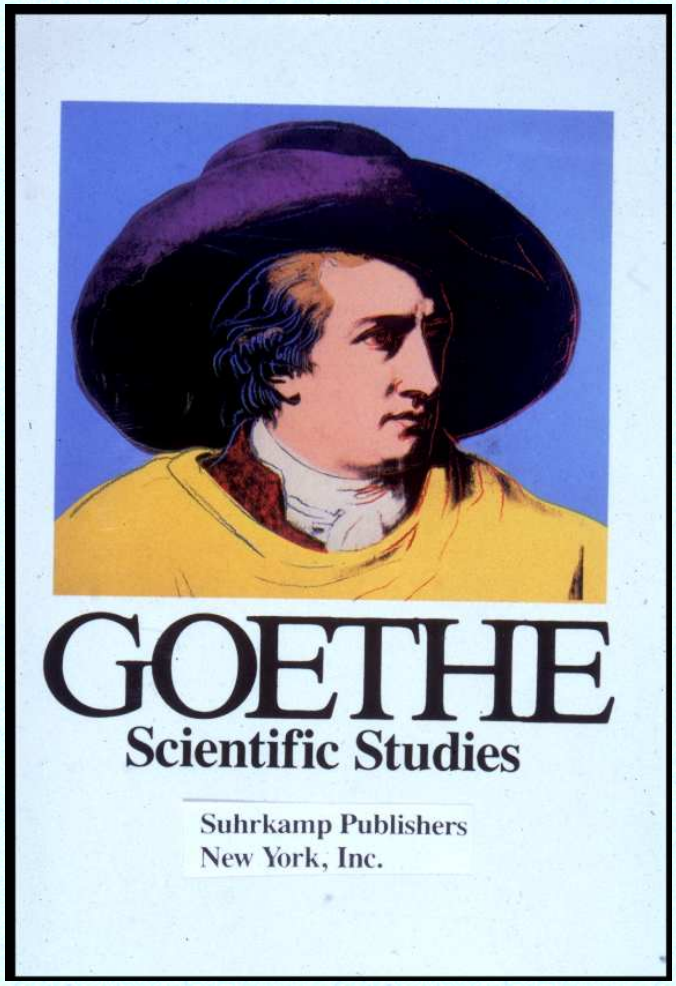
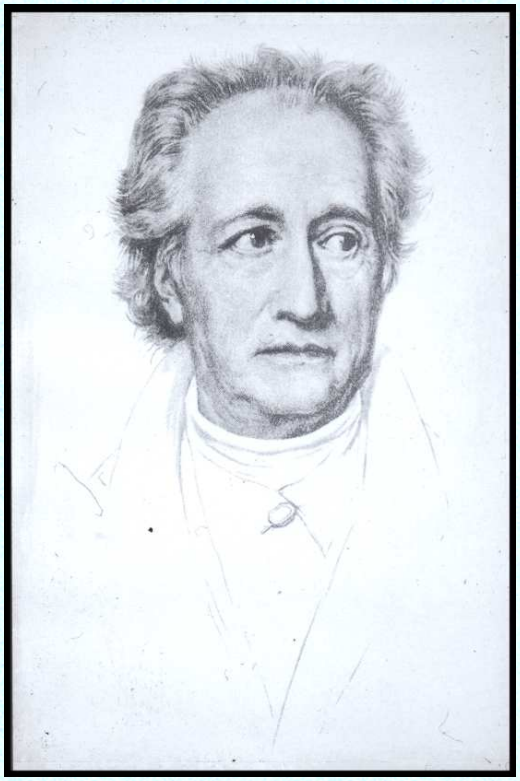


A 12 volume edition is available in English translation.



In 1932, on the 100th anniversary of the death of Goethe,
shown here at age 79, the literature on his
scientific interests contained 4,554 entries.
The intervening decades
have yielded at least as many.

And here, poor fool, I stand once more,
No wiser than I was before.

Were it not for Goethe the poet, would we concern ourselves with Goethe the scientist? The answer, I believe, proceeds in the opposite direction. Is it possible to understand Goethe the man of letters without understanding Goethe the scientist?

Goethe's Scientific Interests

1) *Physical Sciences*

Physics & Chemistry

Minerology, Geology, Meteorology & Astronomy

2) *Biological Sciences*

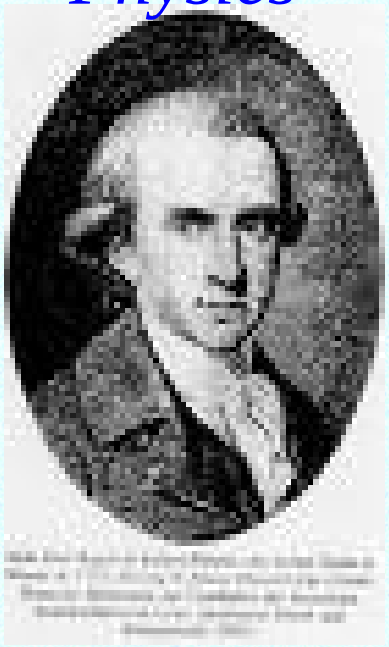
Osteology & Comparative Anatomy

Botany & Plant Morphology

Physiological Optics

Physics and Chemistry

Physics



The Grand Duke

When Goethe accompanied the *Grand Duke of Saxe-Weimar-Eisenach* on a campaign in France, he carried Gehler's physics dictionary to assist him in observing how light was refracted in clear water.

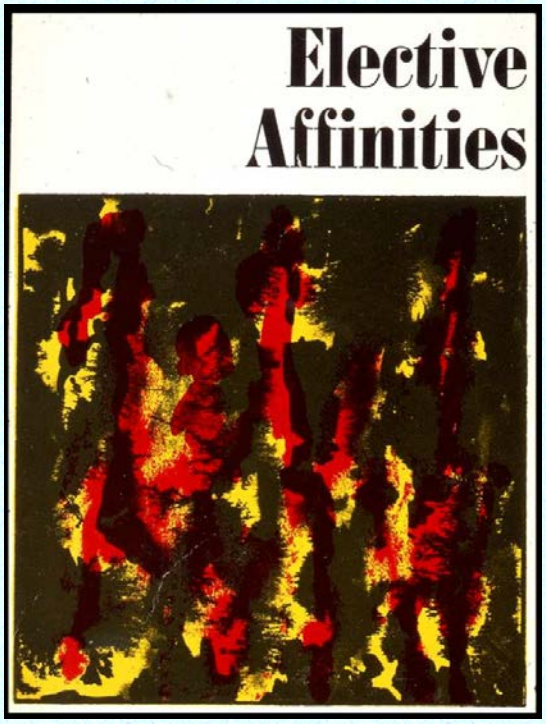
Physics

At the great cannonade at Valmy in 1792 during the French Revolution, Goethe rambled through the bombardment studying the effects of light on dust, and the effects of shock waves on eyesight.

Chemistry

Swedish Chemist
Torbern Bergman 1775

"If we put a piece of limestone (calcium carbonate) in a weak solution of sulfuric acid, the later will take possession of the lime. We are correct in using here the term ***elective affinity***." Goethe's interest in chemical reactions animated his late novel, *Die Wahlverwandshaften---Elective Affinitives*.



Die Wahlverwandtschaften

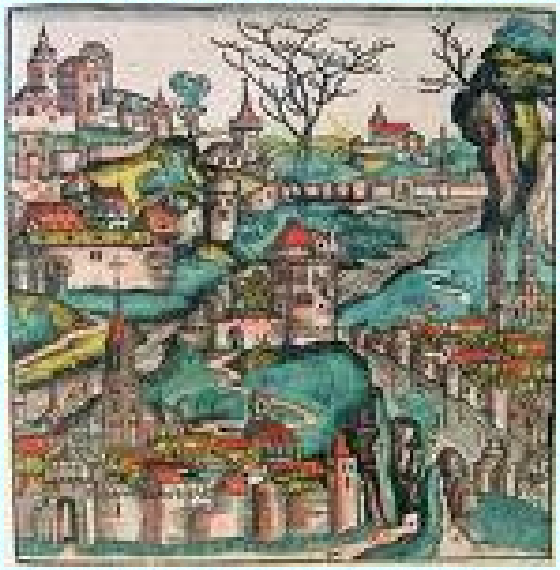
When the conditions of a chemical experiment are controlled, the reaction is predictable, but when the reagents are human beings--Eduard and Ottilie---the experiment cannot be controlled. Free will vs compulsion, the Kantian dichotomy, was explicit in Goethe's novel.

Goethe's Scientific Interests

1) Physical Sciences
   - Chemistry & Physics
   - **Minerology, Geology & Meteorology, Astronomy**

2) Biological Sciences
   - Osteology & Comparative Anatomy
   - Botany & Plant Morphology
   - Physiological Optics

Minerology



Bohemia

Jena

Visits to Bohemia were occasions for gathering minerological materials. Countless specimens were brought home and arranged systematically according to Voight's nomenclature. Thus came into being the collection of over 18,000 items that still delights the visitor to the Goethe House in Jena.

Geology

Granite for Goethe was the archetypal primal rock, the basis of all geological formations, the *Urgestein*. He was one of the first to judge the age of strata and seams by the fossils contained therein, such as the three-toed sloth.

Geology

Goethe proposed that huge rock formations had been transported over great distances by glaciers. He developed the concept of an Ice Age, a prolonged geologic epic of glaciation, and concluded that periods of the earth's history were extraordinarily lengthy.

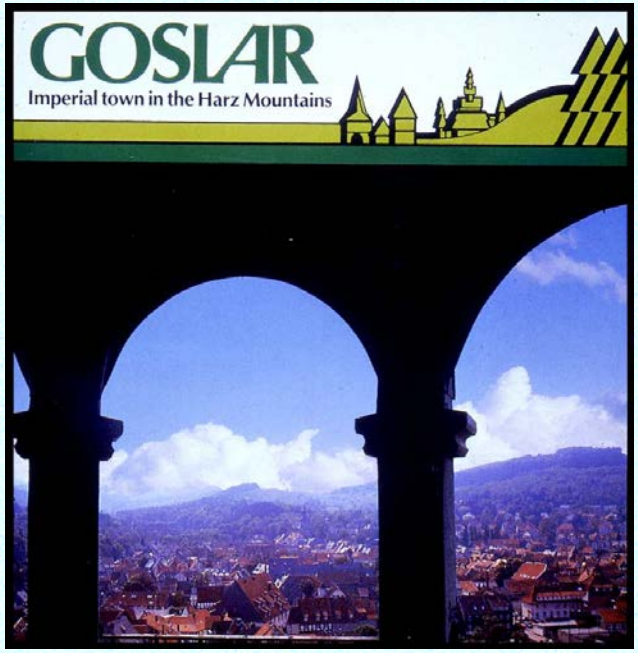
"Never did nature with her living might
Depend on hours or mere day and night.
Each form in gentle temperance wrought,
Nor even the greatest change with violence fraught."

Faust Part 2

Geologic Origin of the Earth's Surface

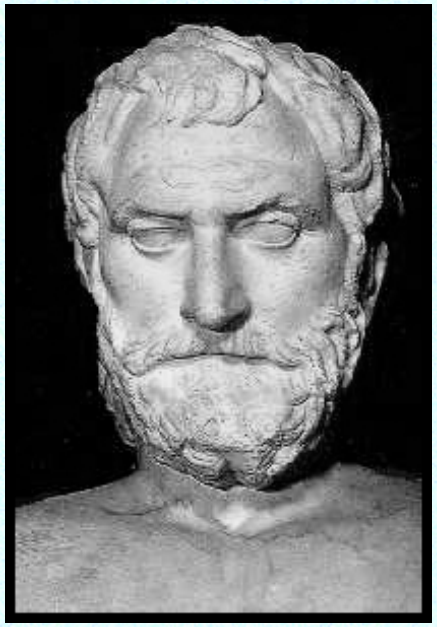
Controversy raged over the configuration of the surface of the earth---*Neptunians vs Volcanists*. The diluvian myths and stories of the great biblical floods made Goethe a *Neptunian*. The grandest picture of the controversy was reserved for the *Walpurgis Nacht*.

Walpurgis Nacht



Harz Mountains

In 1777, in appalling weather, Goethe visited Gozlar, an historic town in lower Saxony near the Harz Montains (*Die Harzreise im Winter*) and climbed *Broken* the highest peak, which according to folklore, was the site of the *Devil's Altar* and the haunted scene of the annual satanic *Walpurgis Nacht.*



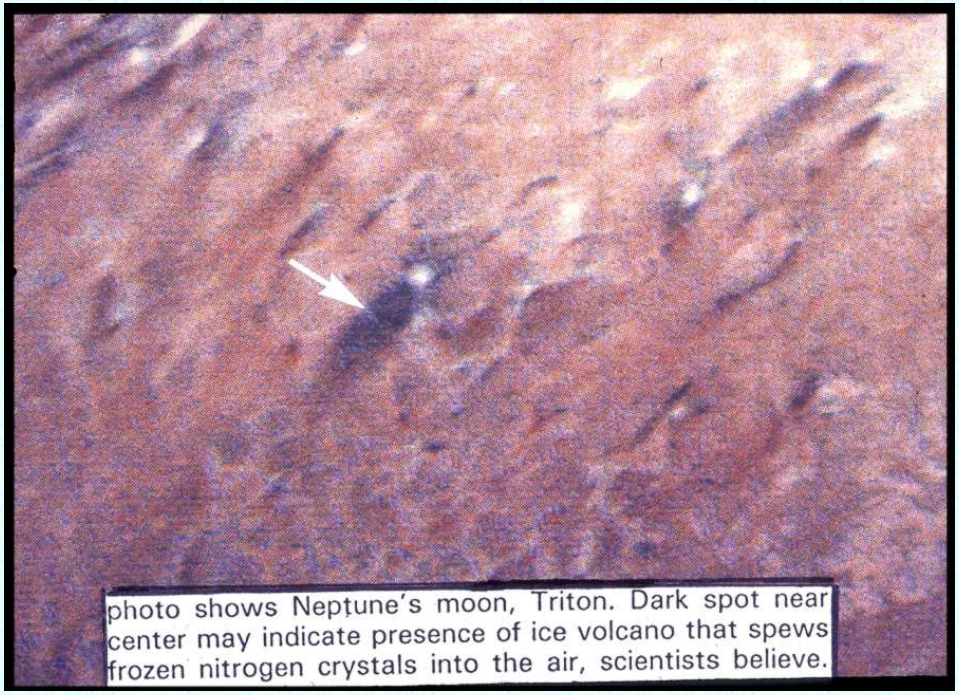
Two pre-Socratic Greeks

Thales

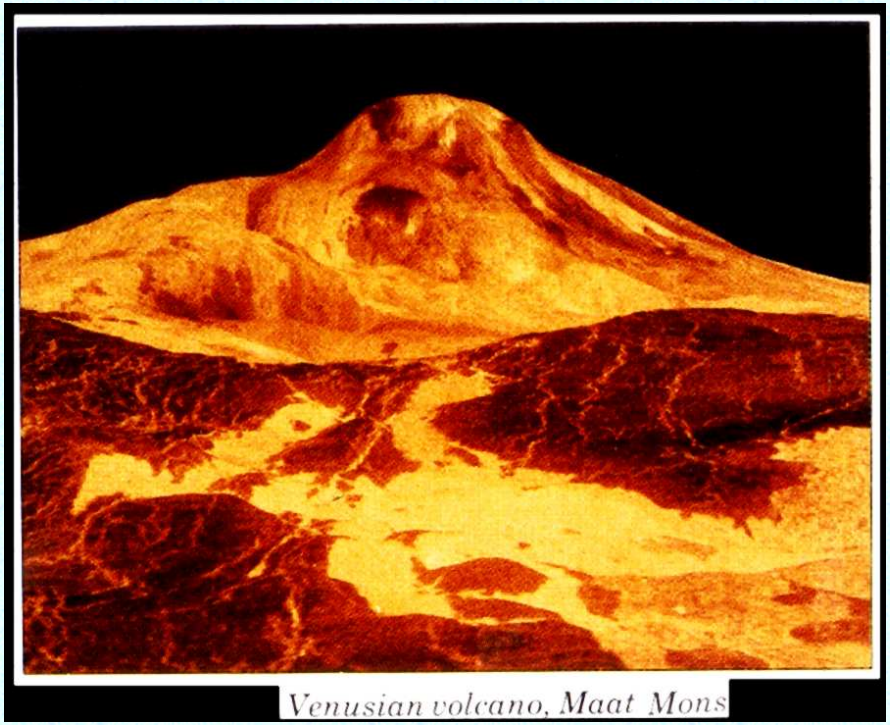
Anaxagoras

In the *Walpurgis Nacht*, Goethe has Thales the Neptunian and Anazagoras the Vulcanist roam the mountains and seas, hotly debating the formation the earth's surface.

In 1982, *Voyager* and NASA's aptly named spacecraft *Galileo* returned planetary data showing over a 100 erupting volcanoes and vast lava flows. The *Vulcanists* were right.



Neptune



Venus

Meterology

Meteorology was one of Goethe's early scientific interests. He Founded weather stations, wrote *The Theory of Weather*, paid careful attention to barometric changes, and praised Luke Howard's cloud formations:

My song takes wing and from the heart
Thanks him who told the clouds apart.

Astronomy

Goethe’s interest in astronomy was underscored by a month of intense observation of the phases of the moon viewed through a telescope in his garden.

Astronomy

Goethe studied the moon's surface as it was then known, and made observations on the planet Saturn shown in this dramatic photograph from *Voyager 2.*

Goethe's Scientific Interests

1) Physical Sciences
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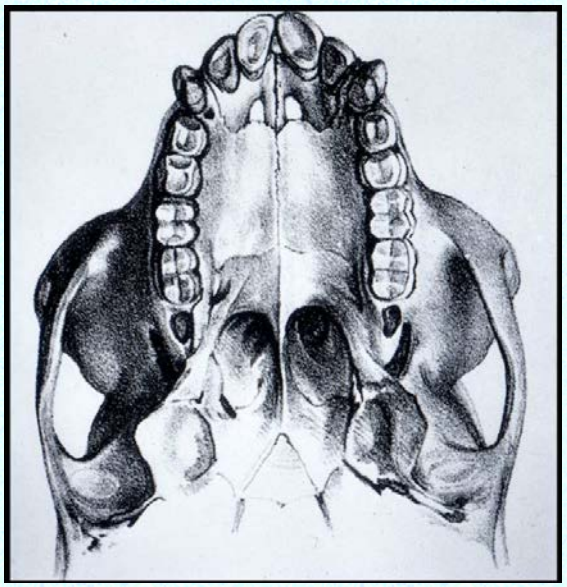
   - Botany & Plant Morphology
   - Physiological Optics

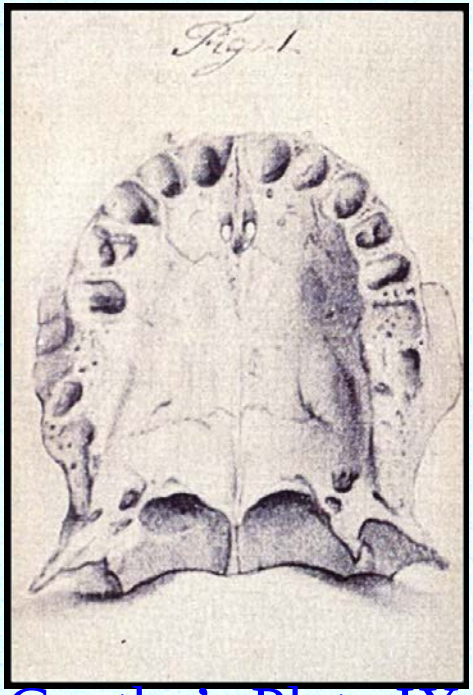
Osteology



Intermaxillary Bone

Each bone in higher mammals had a human counterpart except the *intermaxillary bone*. Orthodoxy held that the very *absence* of an intermaxillary bone was a crucial anatomic distinction between man and the ape. Goethe was convinced of the continuity between man and mammal at a time when theological bias put man and animal further apart. He believed in the unbroken chain of creation in which humanity was the highest form.

Osteology & Comparative Anatomy



Goethe's Plate IX

In March 1784, Goethe made a crucial discovery. "I have found, not gold or silver, but something that makes me much happier--the intermaxillary bone in man. I was comparing human and animal skulls when I got on the trail, and LO! There it was. It's the keystone--everything fell into place, nothing was lacking."

Not content with tracing the intermaxillary bone through mammals to man, Goethe proved it's existence in fish, amphibians, turtles and birds, anticipating by a century Darwinian evolution.

“An Intermaxillary Bone is Present in the Upper Jaw of Man as Well as in Animals”

This document is the first that can properly be called *comparative anatomy*--- a milestone in the history of that discipline.

In Goethe’s museum of comparative anatomy in Jena,

specimens were arranged so that modifications of bones and organs throughout the animal kingdom could be seen at a glance. Darwin would have been pleased.

Goethe's Conception of Evolution and Its Survival in Medical Thought

BY

WALTHER RIESE

[Reprinted from *Bulletin of the History of Medicine*, Vol. XXIII, No. 6, November-December, 1949.]

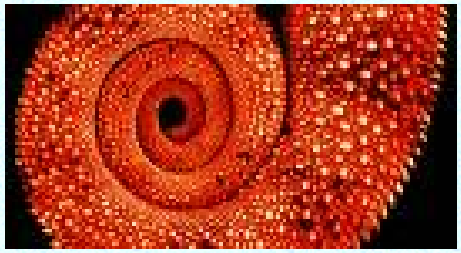
Comparative Anatomy

Loder

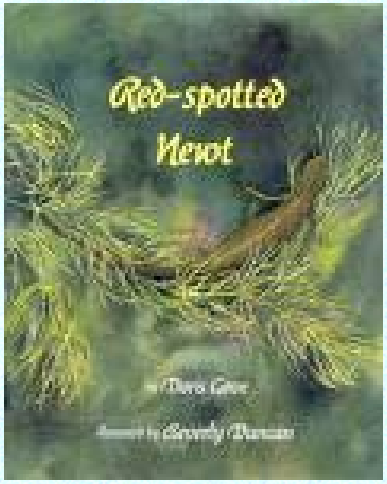
At the University in Jena, Goethe participated in dissecting classes of Professor Justus Christian Loder and delivered anatomical lectures to students at the Weimar Drawing Academy.

In the *Italianische Reise* Goethe returned to the study of human anatomy, especially muscles to deepen his appreciation of Michaelangelo's sculptures.

Regeneration

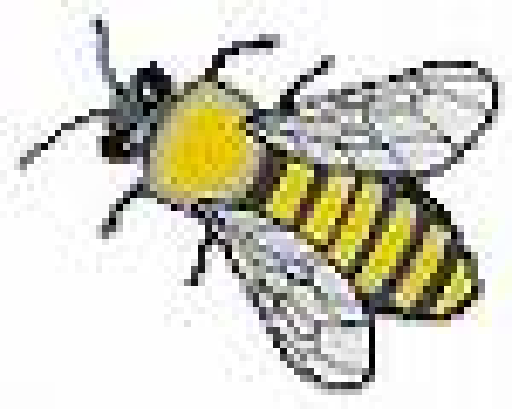


Goethe was interested in *regeneration*---the capacity of animals to replace lost parts, as lizards who readily sacrifice their tails to a predator so the rest of the reptile can escape and live to regenerate the lost part. Goethe correctly argued that animals capable of regeneration occupied a relatively low place in the scale.

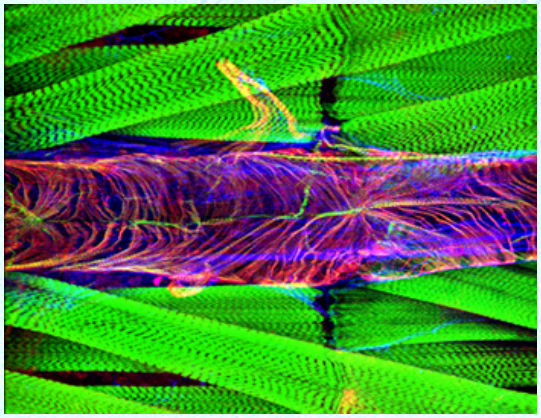


Biologists Remain Fascinated by Regeneration.

Most of the biological world repairs itself quite well. Prune a branch from a tree, and it sprouts new branches. The red-spotted newt re-grows large parts of its heart. Signals that coordinate regeneration of the heart were reported as recently as the November 2006 issue of the journal *Cell*, and the genes of animals that regenerate are currently being studied.



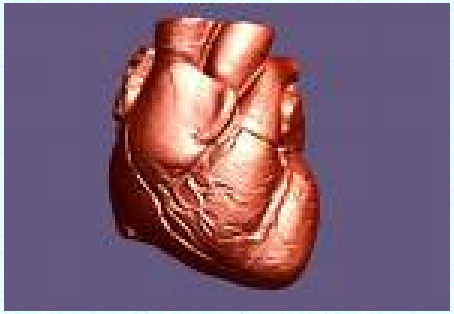
Bumblebee



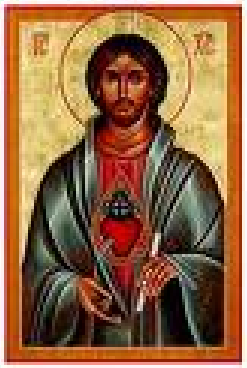
Drosophila Heart

"A long transparent vessel in the bumblebee, running down the entire neck-- *the insect heart* --pulsed vigorously. It continued to pulse for three or four hours after death, until all the moisture had evaporated. When breathed on, it pulsed much faster."

The Human Heart



"…the most diverse, most fluid, most changeable, most versatile part of creation."



Hibernation

Goethe's interest in *hibernation* focused on the *caterpillar* that took no nourishment during pupation, posing the question, "On what did the caterpillar subsist?" Careful weighings disclosed progressive weight loss, indicating that the creature was living on its own substance.

Ovid *metamorphosis* emphasized a universal principle to explain the nature of the world:

Troy falls, Rome rises. Nothing is permanent.

Goethe's Interest in Metamorphosis

Caterpillar

Pupa

Butterfly

Goethe was interested in metamorphesis was focused, not universal ---caterpillar into pupa and butterfly---and was concerned with factors that promoted or inhibited that remarkable process.

Preformation

Nothing can grow except what already exists.

The 18th Century view of embryology meant nothing more than elaboration of a tiny prefiguration---the *Homunculus* or little man.

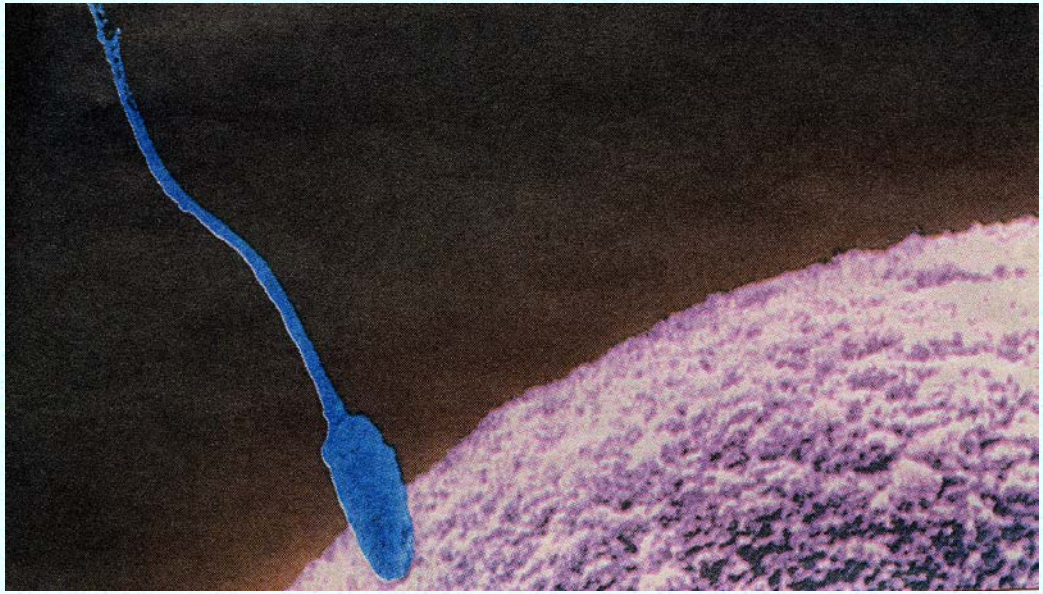
Leipsig Codex circa 1400

Faust and Homunculus

Stirrest by everlasting norms
In thousand upon thousand forms
And hast much time till thou art man.

The bizarre figure was included in the *Walpurgis Nacht* in which the ocean was named the origin of *Homunculus*.

Homunculus in the 21st Century



Coloured Scanning Electron Micrograph of a human sperm about to penetrate an egg.

Four Day Old Embryo

Where is Homunculus?

Goethe's Scientific Interests

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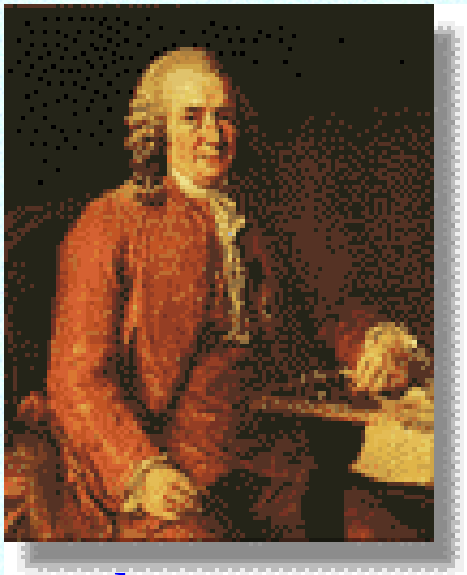
   - ***Botany & Plant Morphology***
   - Physiological Optics

Botany and Plant Morphology



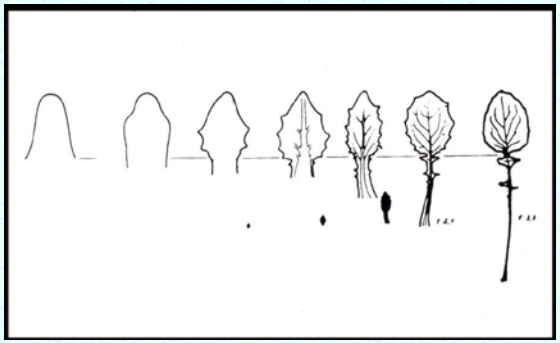
Carolus Linnaeus

The 18th century Swedish taxonomist, Linnaeus, taught that the various species of plants existed from the beginning of creation. Goethe proceeded in the opposite direction, focusing on features that plants had in common, then reducing the infinite variety into a unified system, progressing from simple to complex. Goethe sought intermediate links---transition forms---contrary to Linnaeus immutable species.

While in Italy, Goethe conceived the idea of a generalized plant so elementary that all other forms could be traced to it---the archetypal plant or *Urpflanze*, a theoretical construct not found in nature.

Plant Morphology

Goethe studied the germination of seeds, the growth of seedlings until they assumed definitive *form---the Archetypal Leaf & the continuum from leaf to petal*---the cultivation of plants from cuttings, and the generative capacities of plant parts. His hypothesis of "inward causes" uniquely embodied the idea of "metabolism" that influences organic structure. Development in the same plant from cotyledon to fully developed corolla is illustrated in Goethe's *proliferative rose.*



Archetypal Leaf

Tulip showing continuum between leaf and petal

Proliferative rose

Goethe's Scientific Interests

1) Physical Sciences
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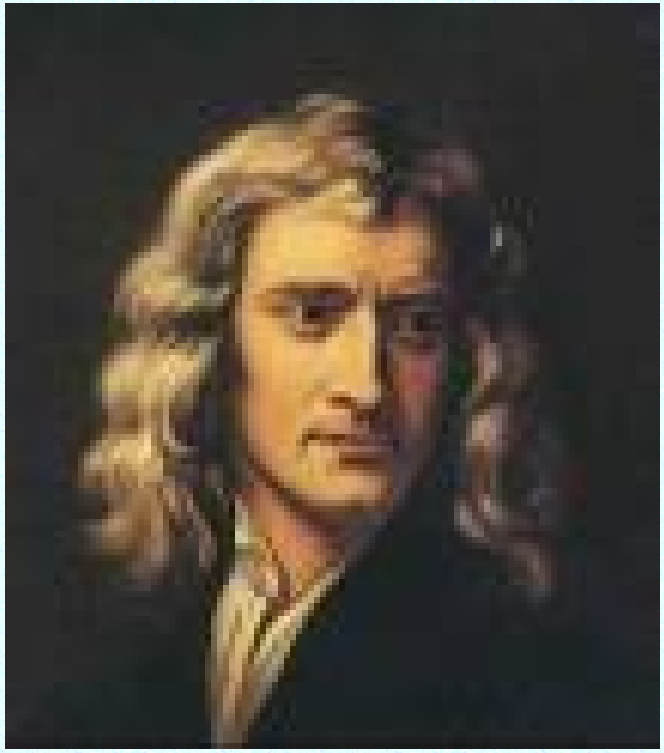
SIR ISSAAC NEWTON

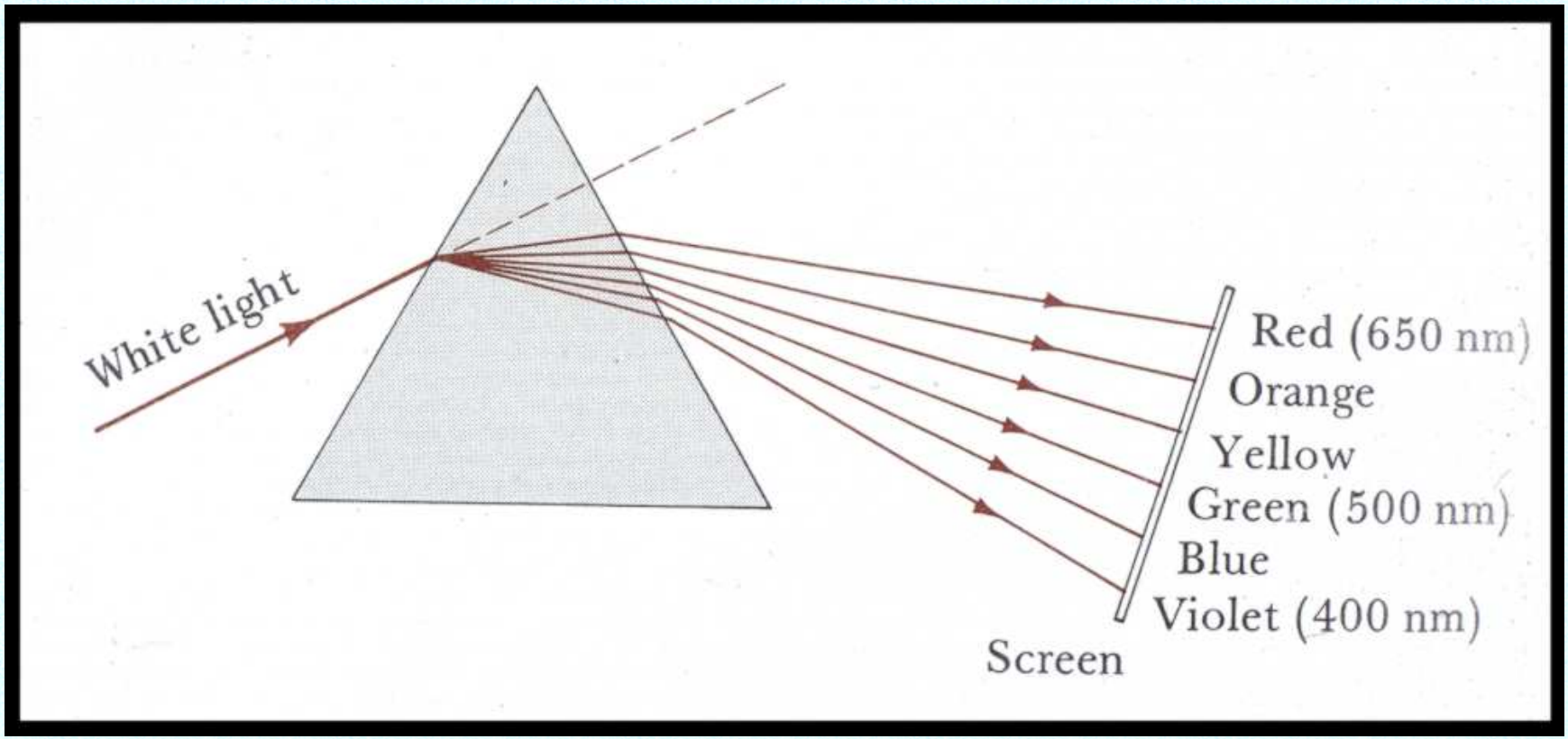
In a Single Year

1) The binomial theorem
2) Differential and integral calculus
3) Theory of gravitation
4) The spectrum of colors



No other 17th century investigation better illustrates the power of experimental enquiry animated by powerful imagination and controlled by rigorous logic than Newton's observation that *colors correspond to wavelengths*, that white light can be separated by refraction into its *wavelengths--the spectrum of colors*.

Newton's Spectrum of Colors

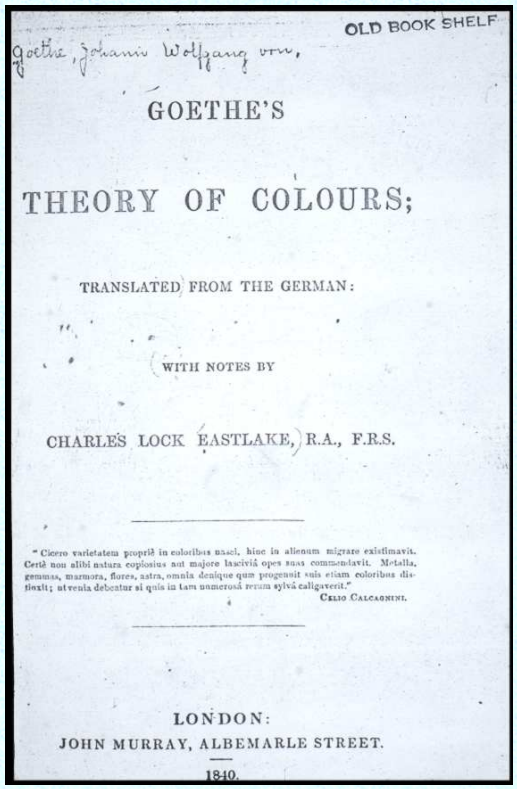


"All wavelengths undergo a similar directional change, but by their unequal refractions must be severed and dispersed from the least refracted scarlet to the most refracted violet."

The Physics vs the Physiology of Color

Although he had not properly performed Newton's experiments, Goethe nevertheless concluded that the Newtonian account of color was wrong, that the prism was extraneous. In view of his insistence on the primacy of observations in nature, it is ironic that Goethe failed to recognize the color phenomenon that not only spectacularly demonstrated Newton's theory of refraction, but did so in a perfectly natural setting: *The Rainbow*

My heart leaps up when I behold a rainbow in the sky.
Wordsworth, not Goethe.


OLD BOOK SHELF

Goethe, Johann Wolfgang von,

GOETHE'S

THEORY OF COLOURS;

TRANSLATED FROM THE GERMAN:

WITH NOTES BY

CHARLES LOCK EASTLAKE, R.A., F.R.S.

"Cicero varietatem proprie in coloribus nasci, hinc in alienum migrare existimavit. Certè non alibi natura copiosius aut majore lasciviâ opes suas commendavit. Metalla, gemmas, marmora, flores, astra, omnia denique quæ progenuit suis etiam coloribus distinxit; utrevia delectur si quis in tam numerosâ rerum sylvâ caligaverit."

CELIO CALCAGNINI.

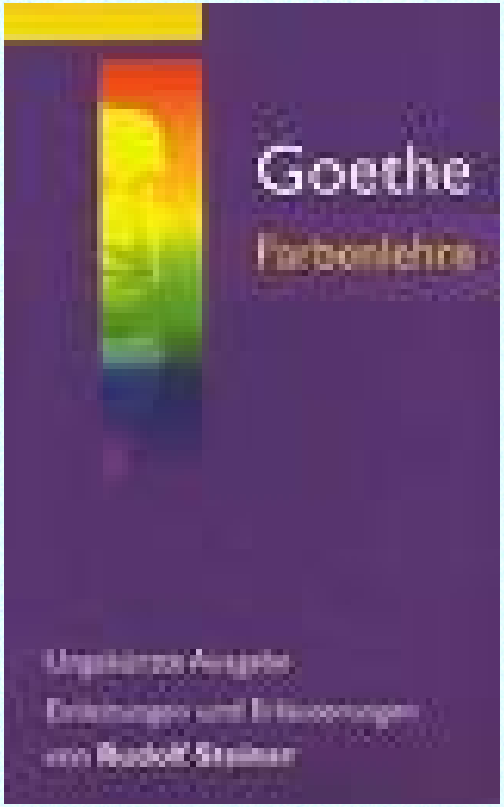
LONDON:

JOHN MURRAY, ALBEMARLE STREET.

1840.

Physiological Optics.

Considered in isolation, light and the eye's perception both appear magical and mysterious; considered together they create a coherent system of vision.



Goethe considered the *Theory of Color*, the *Farbenlehre*, his most noteworthy scientific achievement that accomplished far more than any of his literary works. Still preserved are prisms, mirrors, polarizing devices, flint glass, and colored papers used in his experiments.

Nobel Prize in Physics 1932

Werner Karl Heisenberg

In his 1941 Budapest lecture, *The Teachings of Goethe and Newton on Color in Light of Modern Physics*, Heisenberg said that "Newton's theory makes possible a certain control over the phenomena of light and their practical use," but went on to say that the physical theory was of little or no practical assistance to a better understanding of the world of color surrounding us.

It was that world of color that fascinated and misled Goethe.

1795

Seeing the Light: Goethe's *Marchen* as Science---
Newton's Science as Fairy Tale

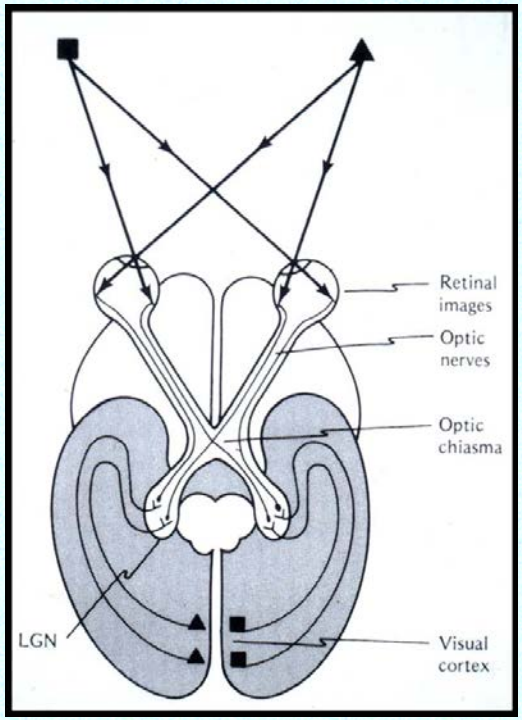
Goethe Yearbook

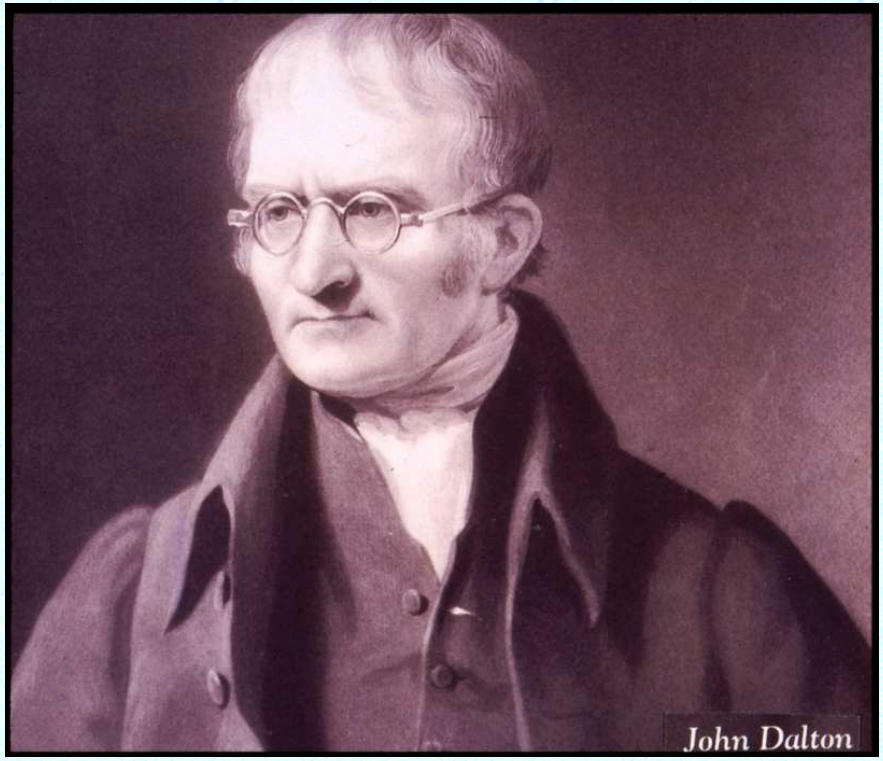
Volume XIV

2007

There is No Color Apart From Perception

Goethe argued correctly that color as a perception was not primarily a question of physics that characterized light entering the eye. Instead, the *perception of color* resulted from responses that extended from the retina to and throughout the visual cortex.

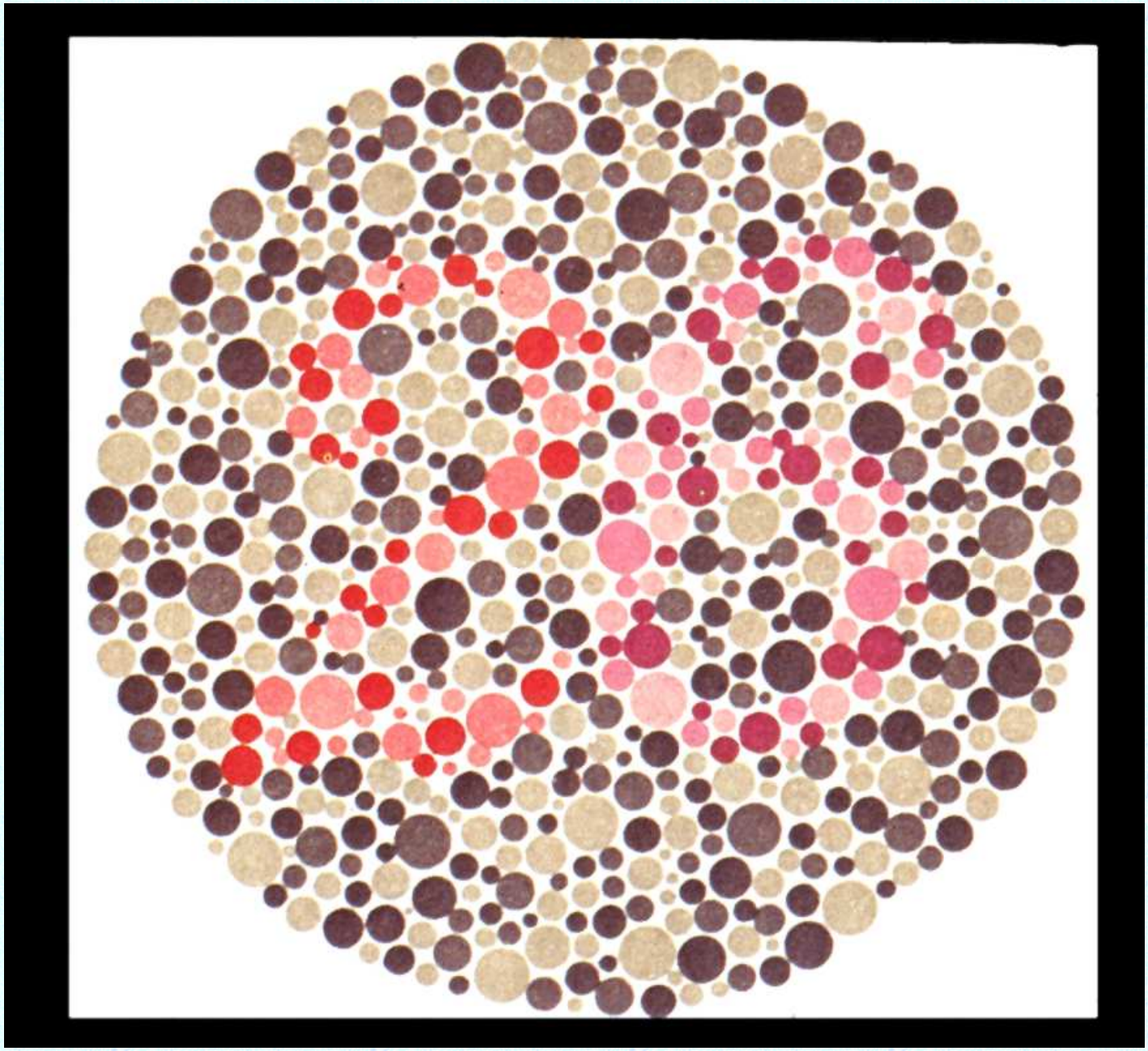


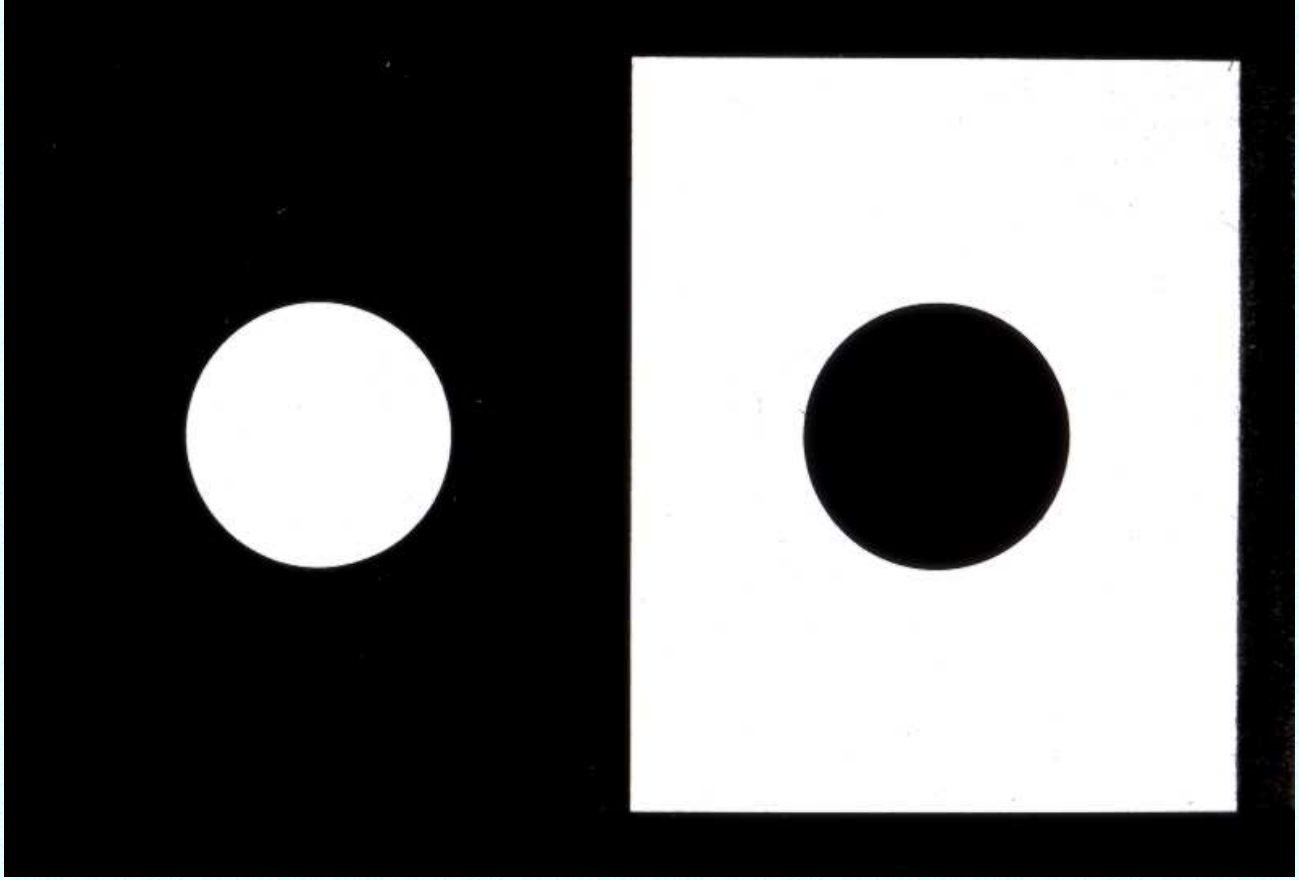


Color blindness was described by John Dalton in England in 1794.
In the same year, Goethe independently investigated
two cases of color blindness.

The Chemistry of John Dalton's Color Blindness

Dalton described his own color blindness. In common with his brother, he confused scarlet with green and pink with blue. Dalton believed that his vitreous humor was tinted blue, selectively absorbing longer wavelengths. He instructed that his eyes should be examined after his death, but the examination revealed that the humors were perfectly clear. DNA extracted from his preserved eye tissue showed that Dalton lacked the middlewave retinal photopigment.



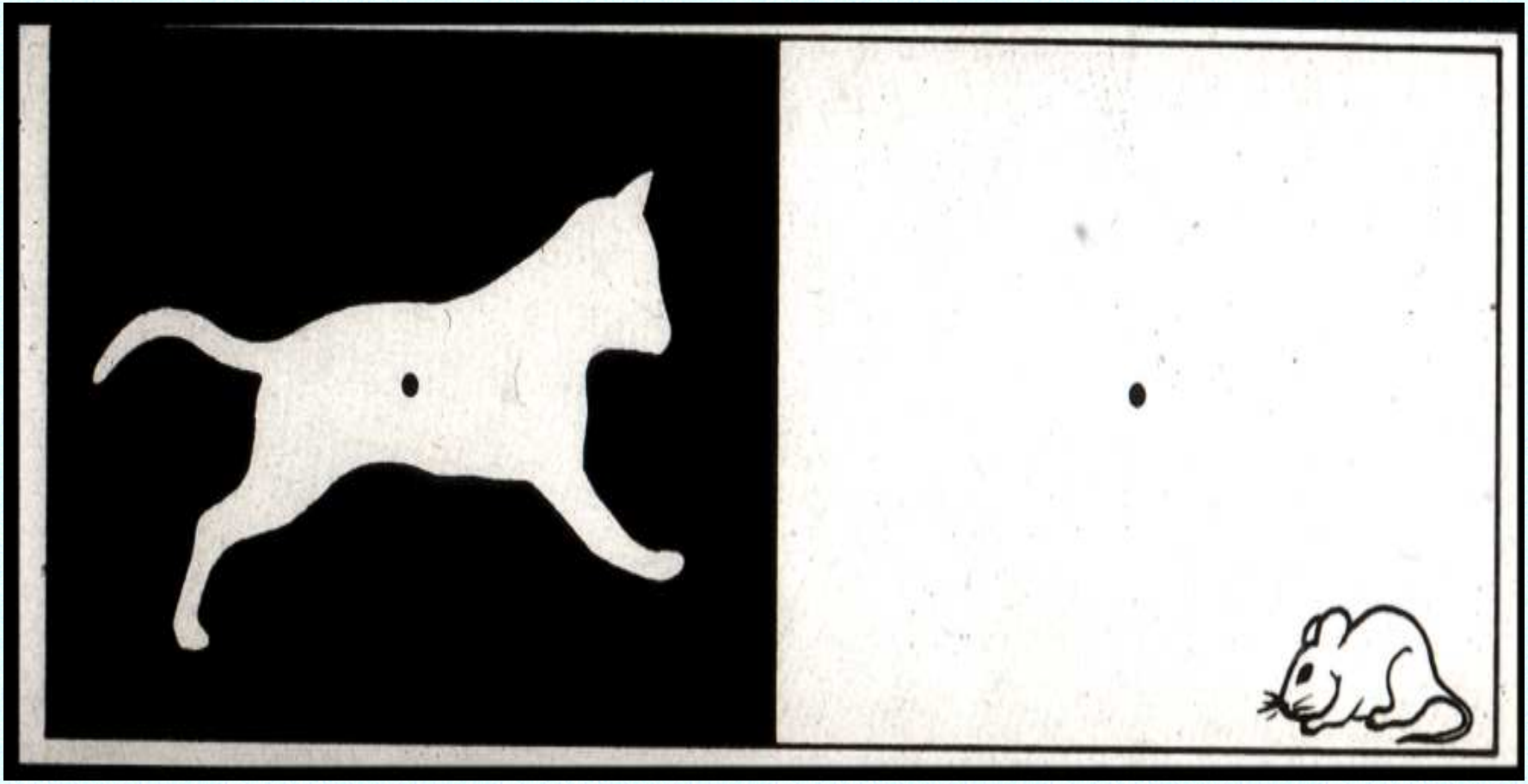


Black and White Images

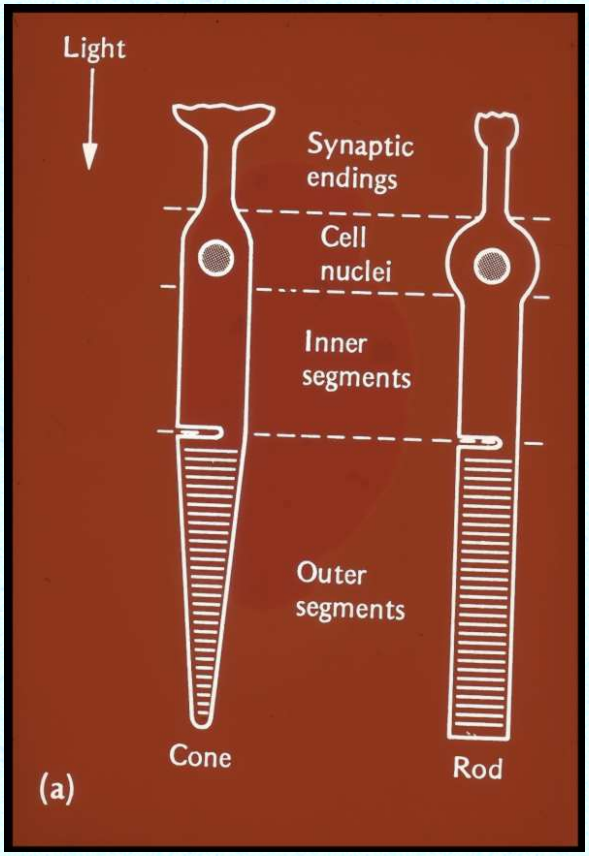
Goethe instructed: “Let us view two round forms of the same diameter placed side-by-side, one white placed on a black background (left), and the other black placed on a white background (right). We will see the latter as about a fifth smaller than the former. If we enlarge the black form by a fifth, the two will seem equal in size.”

Goethe pointed out that black clothing makes a person appear thinner, an observation used to advantage by the fashion industry.

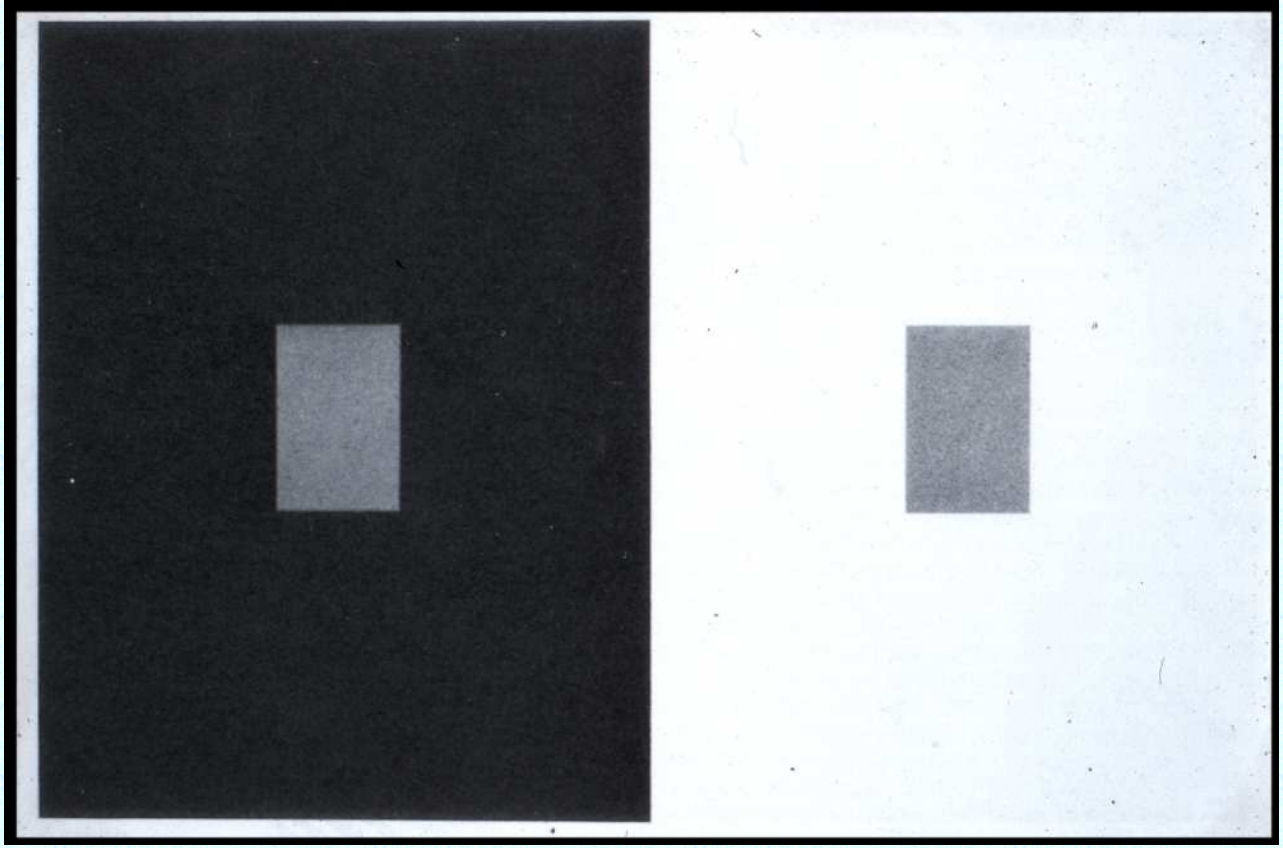
Positive After Images



"If the eye fixes on a black image on a white ground (left), and then looks at a white surface (right), what is seen is a fleeting black image on the white ground."

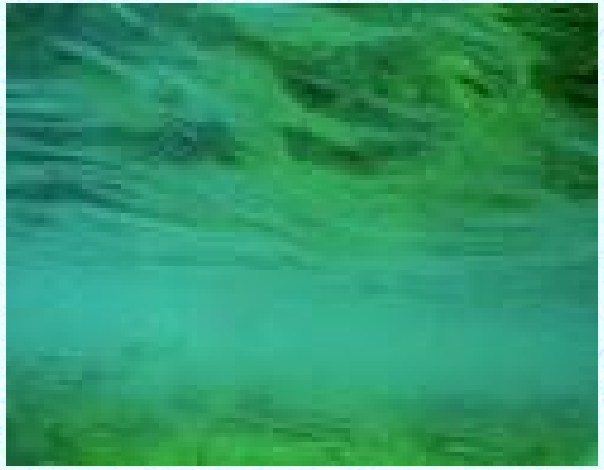


Goethe explained that when we look fixedly at a black-and-white surface, those portions of the retina upon which the black image falls remain at rest, while those portions struck by the white image become fatigued, their sensitivity reduced---*dark-adapted rods light-adapted cones*.

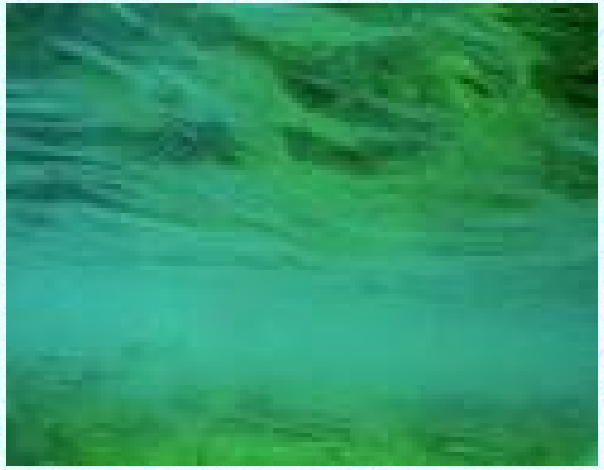


"A gray object on a black background (left) appears much brighter than the same object on a white background (right). If both objects are seen together, the spectator can hardly persuade himself that the two grays are identical."

Goethe interpreted this observation as an expression of *simultaneous contrast*---the process of induction that takes place from one portion of the retina to another, modifying sensitivity.



“On one occasion I stopped at an inn toward evening. Presently there entered an attractive young woman with a radiantly white face and black hair who wore a scarlet bodice. From a distance I looked at her intently in the dim twilight. When she left, I saw on the white wall opposite me a black face surrounded by a bright glow. The clothing of the clearly outlined figure appeared in a beautiful sea green.”



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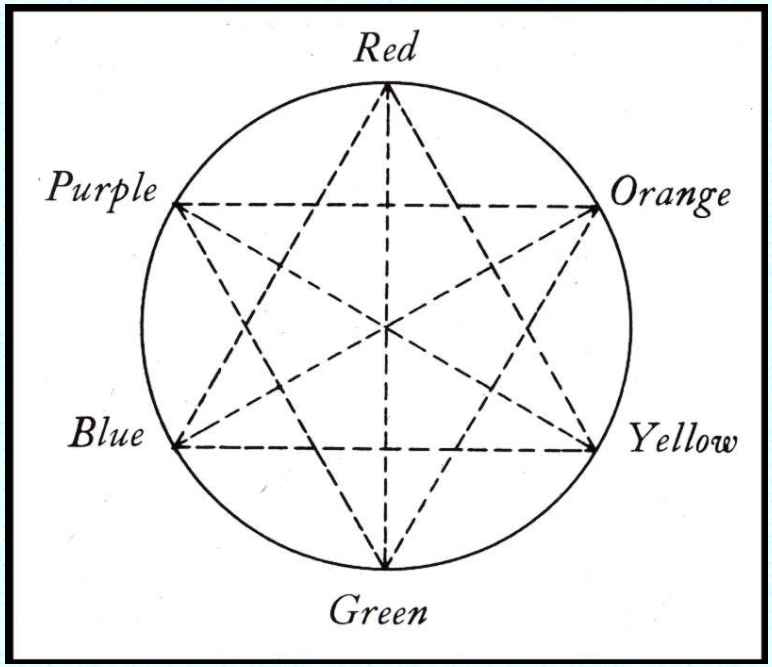
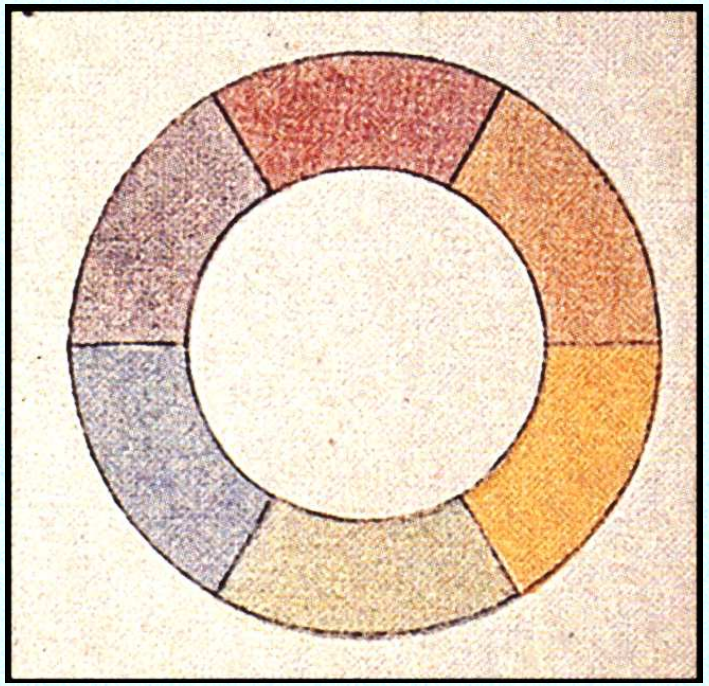
Complementary Colors

Observations such as those at the Inn, prompted Goethe to construct his color circle from which complementary colors could be derived. Colors that *demand* one another occupy opposite positions.

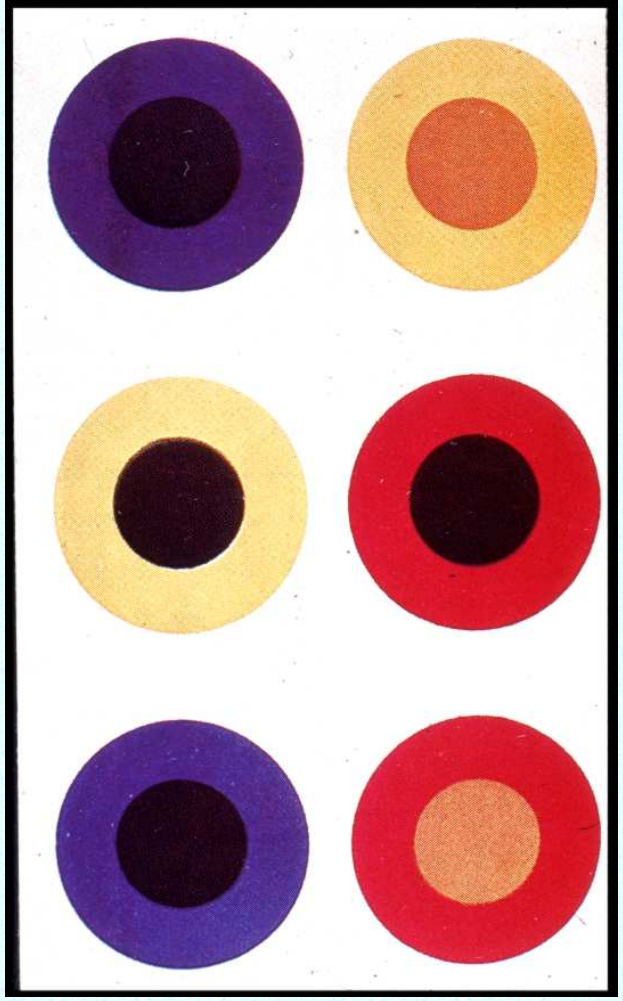
On the right is the color wheel from the *Farbenlehre*.





Jasper Johns

Color After-images



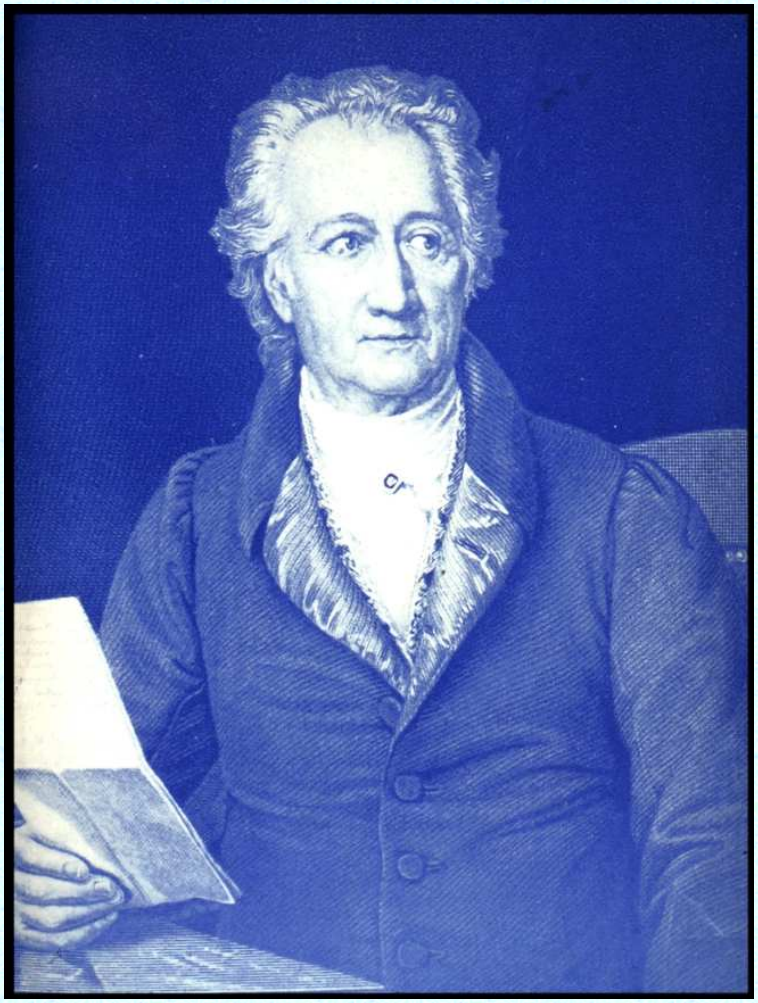
Goethe emphasized that when complementary colors are juxtaposed, each enhances the brilliance of the other, a point familiar to painters. This illustration from the French scientist M.E. Chevreul (1860) shows the simultaneous contrast effects of surrounding color on a central dot, and of a central dot on surrounding color.

Louis Bleriot

Across the English Channel
July 1909

Homage to Bleriot 1914

Robert Delaunay applied Chevreul's principle of simultaneous color contrast.



Goethe’s optical experiments were followed by further studies of color blindness, by studies of sound including the human voice and the physiology of the ear, the numerical proportions of vibrating strings, the qualities of musical instruments, and a theory of musical harmony.

No one can doubt the seriousness of Goethe's commitment to his scientific interests, the range and depth of his scientific knowledge, his immense intellectual versatility, and his prodigious powers of observation, all of which are inseparable from and indispensible to his literary achievemants.

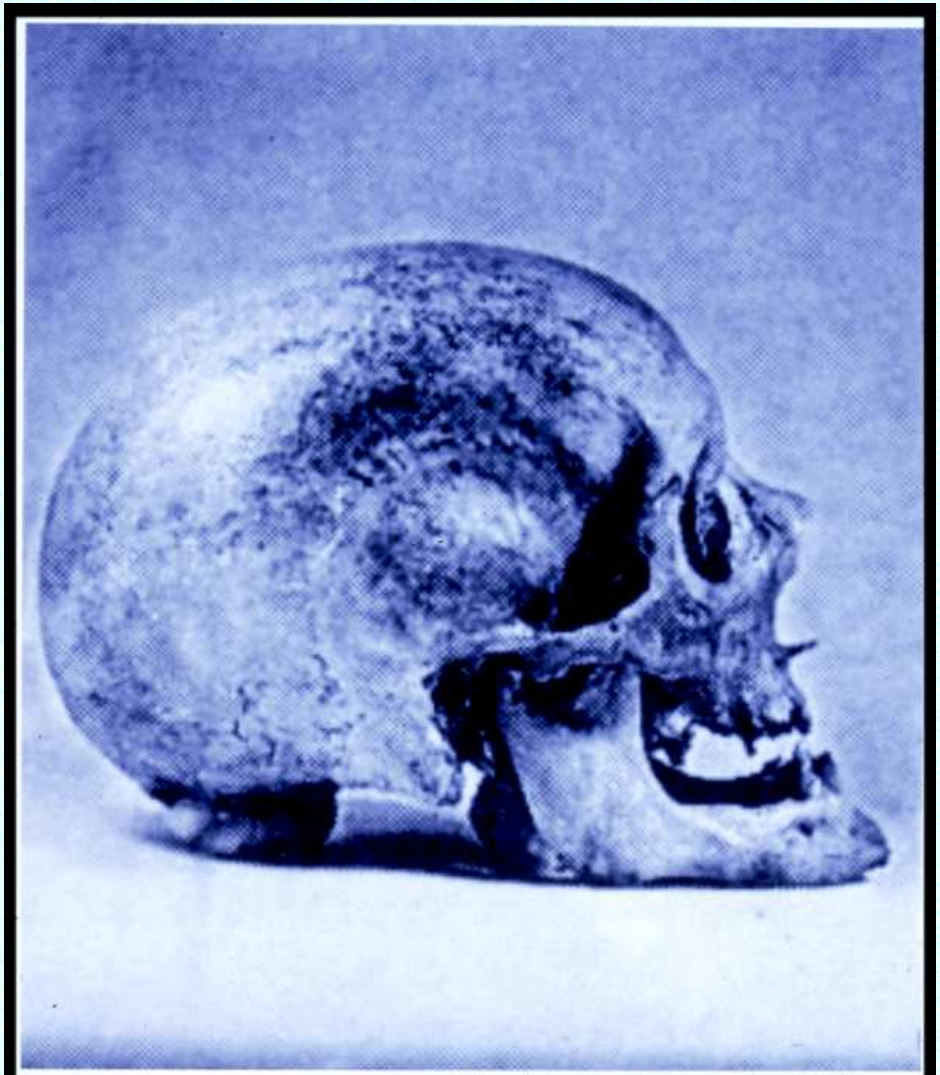
Herman von Helmholtz---one of the 19th century's greatest scientific figures---the *conservation of energy, thermodynamics, entropy, electromagnitism, experimental psychology, sensory physiology, the ophthalmoscope, muscle metabolism, a physiologic basis for the theory of music.*

In 1853, Helmholtz published "*On Goethe's Scientific Researches*" in which he argued that scientists at their best must have some of the artist's imagination. It might also be argued that artists at their best must have some of the scientist's power of observation.

In Goethe, these two qualities merged.

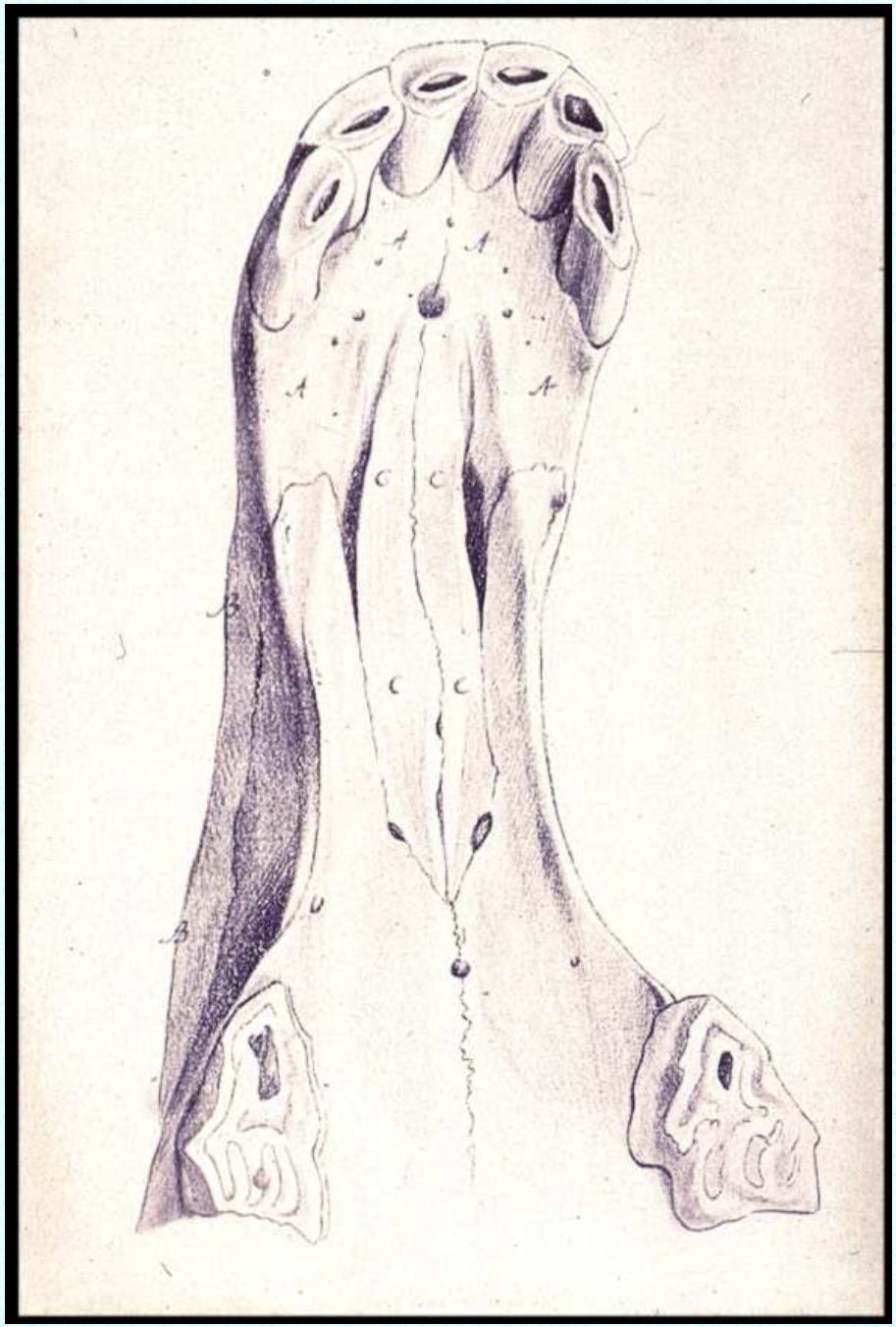
Thank You

Das Ende



Frankfurter Allgemeine Zeitung

skull as it was photographed
in 1970 by the East Germans.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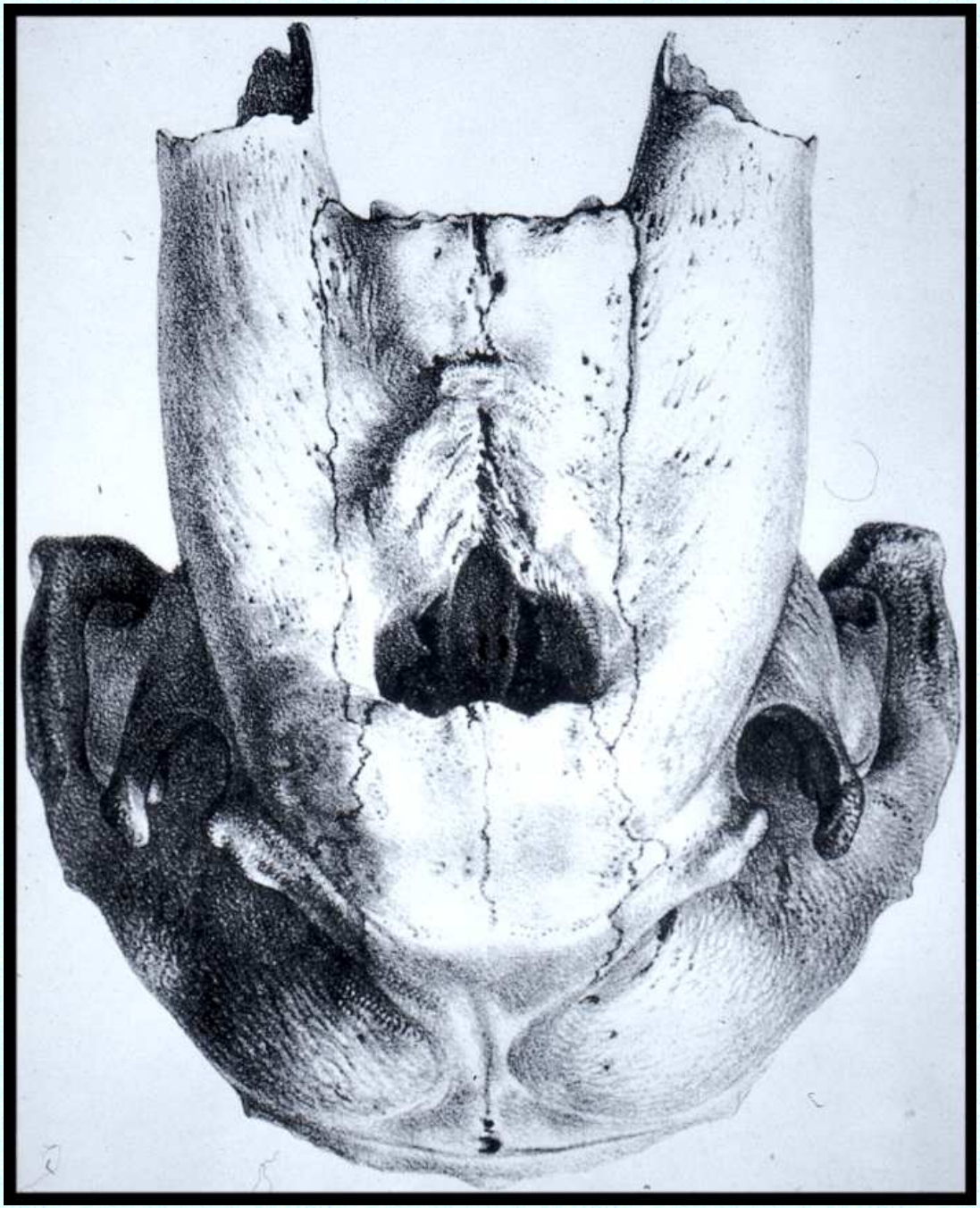
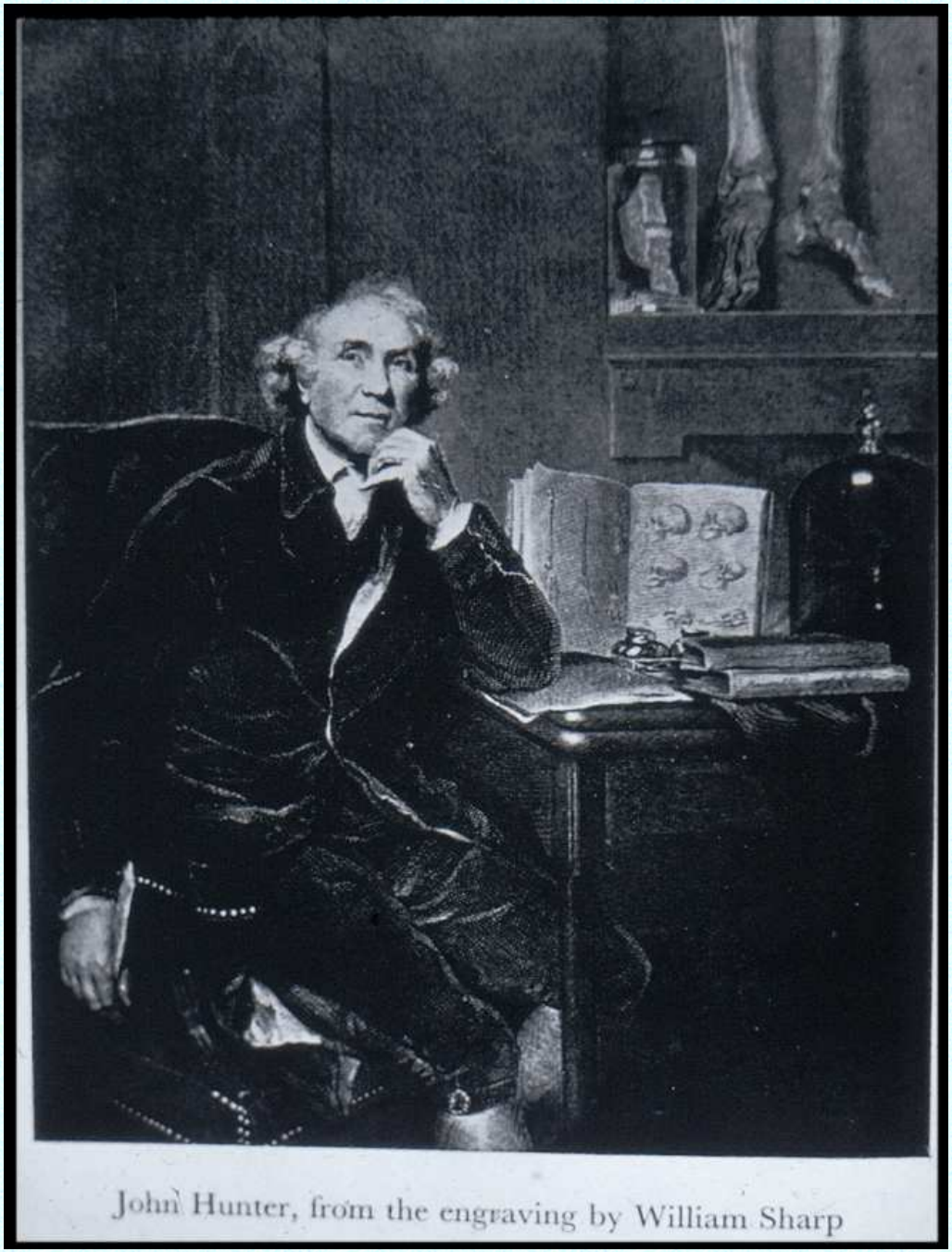
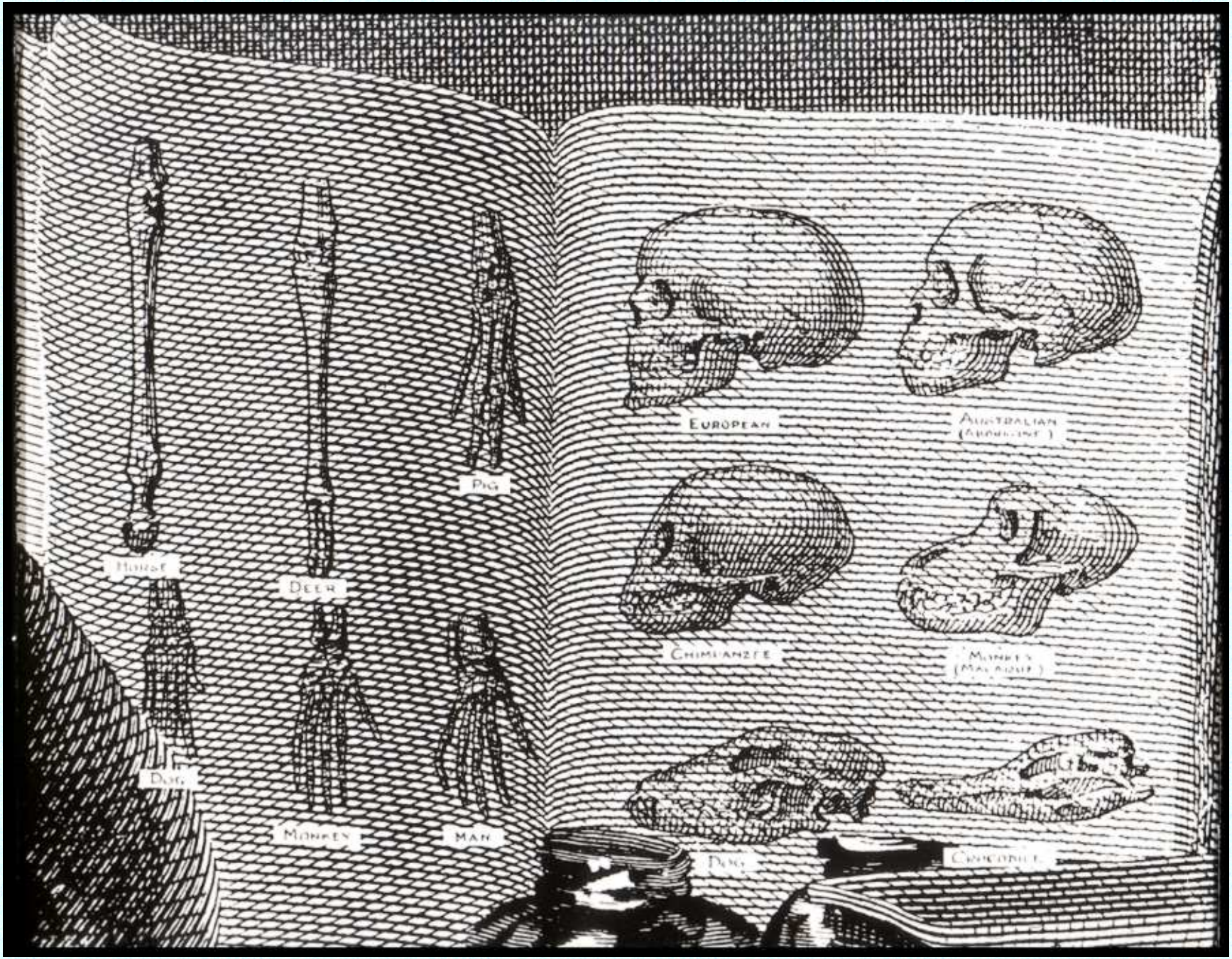
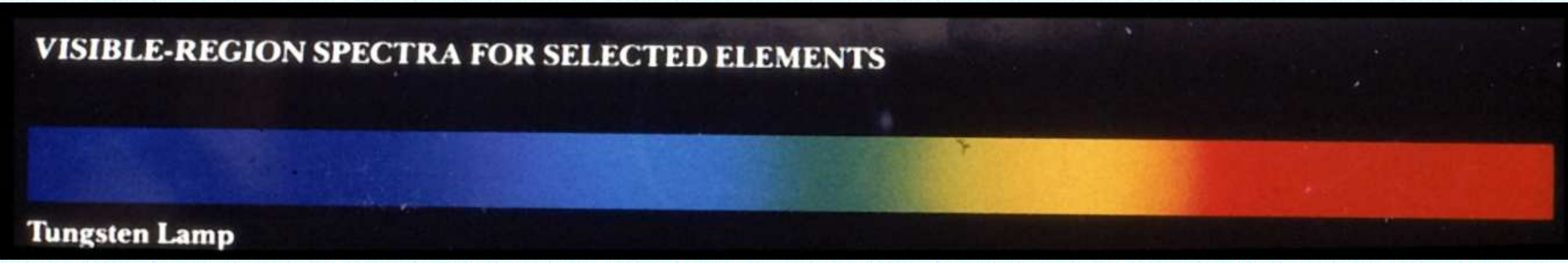




John Hunter, from the engraving by William Sharp


Horse
Deer
Pig
Dog
Monkey
Man
European
Australian
Chimpanzee
Monkey
Dog
Crocodile


VISIBLE-REGION SPECTRA FOR SELECTED ELEMENTS
Tungsten Lamp

REMARKS ON COLOUR

Ludwig Wittgenstein

Edited by

G.E.M. ANSCOMBE

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The Poet and the Scientist

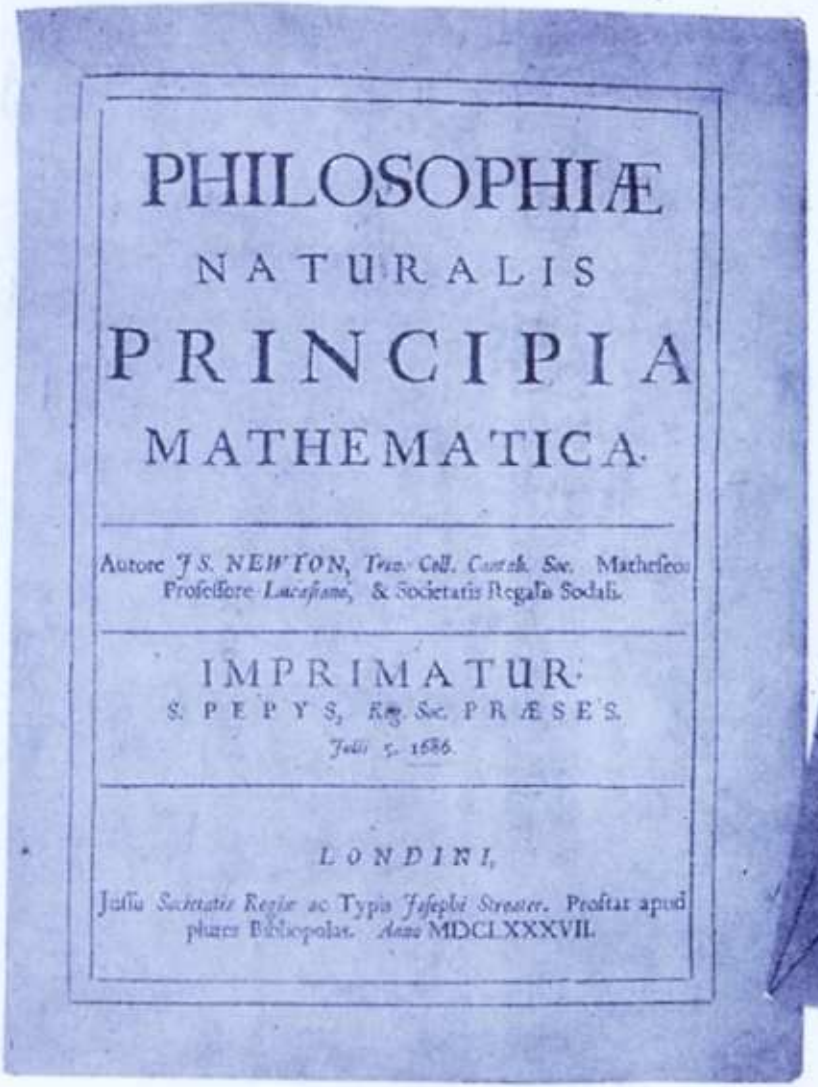
Johann
Wolfgang
Goethe

Jan
Evangelista
Purkyně

V. Kruta 1968

Translation L. Pantůčková 1968

Printed in Czechoslovakia



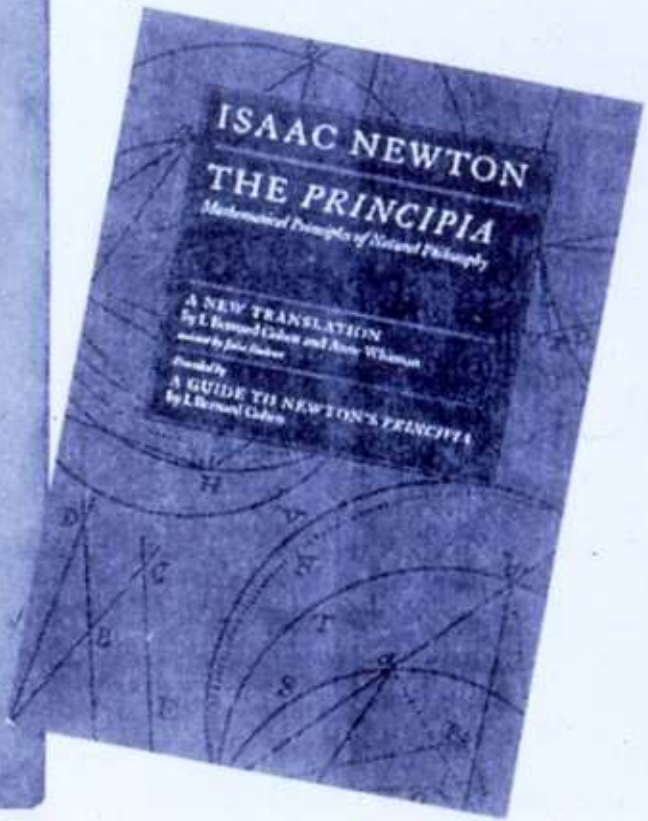
PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore *J S. NEWTON*, *Trin. Coll. Cantab. Soc.* Matheseos Professore *Lucasiano*, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, *Reg. Soc.* PRÆSES.
Julii 5. 1686.

LONDINI,
Justu *Societatis Regiæ* ac Typis *Josephi Streater*. Prostat apud plures Bibliopolas. *Anno* MDCLXXXVII.

The title page of the first edition of Newton's "Principia," left, and the cover of the first new translation of the landmark work in 270 years.



PHILOSOPHICAL PROBLEMS OF QUANTUM PHYSICS

(Formerly Titled: Philosophic Problems of Nuclear Science)

WERNER HEISENBERG

Muller

Purkyne

Response to the *Farbenlehre* was mixed. The physiologist Johannes Muller and the Czech physician Jan Purkyne were sympathetic if not laudatory.

Nobel Prize in Physics 1932

Werner Karl Heisenberg

In his 1941 Budapest lecture, *The Teachings of Goethe and Newton on Color in Light of Modern Physics*, Heisenberg said that "Newton's theory makes possible a certain control over the phenomena of light and their practical use," but went on to say that the physical theory was of little or no practical assistance to a better understanding of the world of color surrounding us.

It was that world of color that fascinated and misled Goethe.