LIVES IN THE 17TH CENTURY

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INTRODUCTION[1]

Human history as cultural history

We need to reform our teaching of history so that the emphasis will be placed on the gradual growth of human culture and knowledge, a growth to which all nations and ethnic groups have contributed.

This book is part of a series on cultural history. Here is a list of the other books in the series that have, until now, been completed:

- Lives in the Ancient World
- Lives in the 18th Century
- Lives in the 19th Century
- Lives in Biology
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[1]This book makes some use of my previously-published book chapters, but most of the material is new.

Contents

Chapter 1

PAINTING IN THE 17TH CENTURY

1.1 Rubens

Rubens' early life

Sir Peter Paul Rubens (1577-1640) was born in the German Westphalian town of Siegen, where his parents had fled to avoid religious persecution. His father was a prominent lawyer, Jan Rubens, and his mother, Maria Pypelinckx, an author. Jan Rubens had been the legal advisor to Anna of Saxony, with whom he had an affair and an illegitimate daughter. Anna was the second wife of William the Silent of Holland. As a result of the scandal, Jan Rubens was locked up in Dillenburg Castle, where he feared he would be executed. However his wife, Maria, pleaded for his life, and he was released, following payment of a large bail, on the condition that he should not leave Siegen. Thus Peter Paul Rubens was born in the town.

Following the death of his father in 1587, Peter Paul Rubens and his mother moved to Antwerp, where he was raised as a devout Catholic. Here he received a humanist education, studying classical literature in Latin. At the age of 14 he began his training as an artist, as an apprentice with Tobias Verhaech.

Diplomat and artist

Wikipedia says of Rubens, **"He is considered the most influential artist of Flemish Baroque tradition. Ruben's highly charged compositions reference erudite aspects of classical and Christian history. His unique and immensely popular Baroque style emphasized movement, colour, and sensuality, which followed the immediate, dramatic artistic style promoted in the Counter-Reformation. Rubens specialized in making altarpieces, portraits, landscapes, and history paintings of mythological and allegorical subjects.**

"In addition to running a large studio in Antwerp that produced paintings popular with nobility and art collectors throughout Europe, Rubens was a classically educated humanist scholar and diplomat who was knighted by both Philip IV of Spain and Charles I of England. Rubens was a prolific artist. The catalogue of his works by Michael Jaffé lists 1,403 pieces, excluding numerous copies made in his workshop."

Rubens spent the years 1600-1608 in Italy, where he was very much influenced by great painters of the Italian Renaissance, especially by Leonardo da Vinci, Michelangelo and Raphael. He also studied Roman and Greek art, and was especially influenced by the dramatic statue of *Lacoön and His Sons.* On a visit to Venice, he saw paintings by Titian, Veronese and Tintorino. At the end of this period Rubens received news that his mother was very ill. He hurried back to Antwerp, only to find that his mother had died before his arrival.

Rubens was now so financially successful that in 1635 he was able to buy an estate with castle, Chateau de Steen, where he spent the last five years of his life.

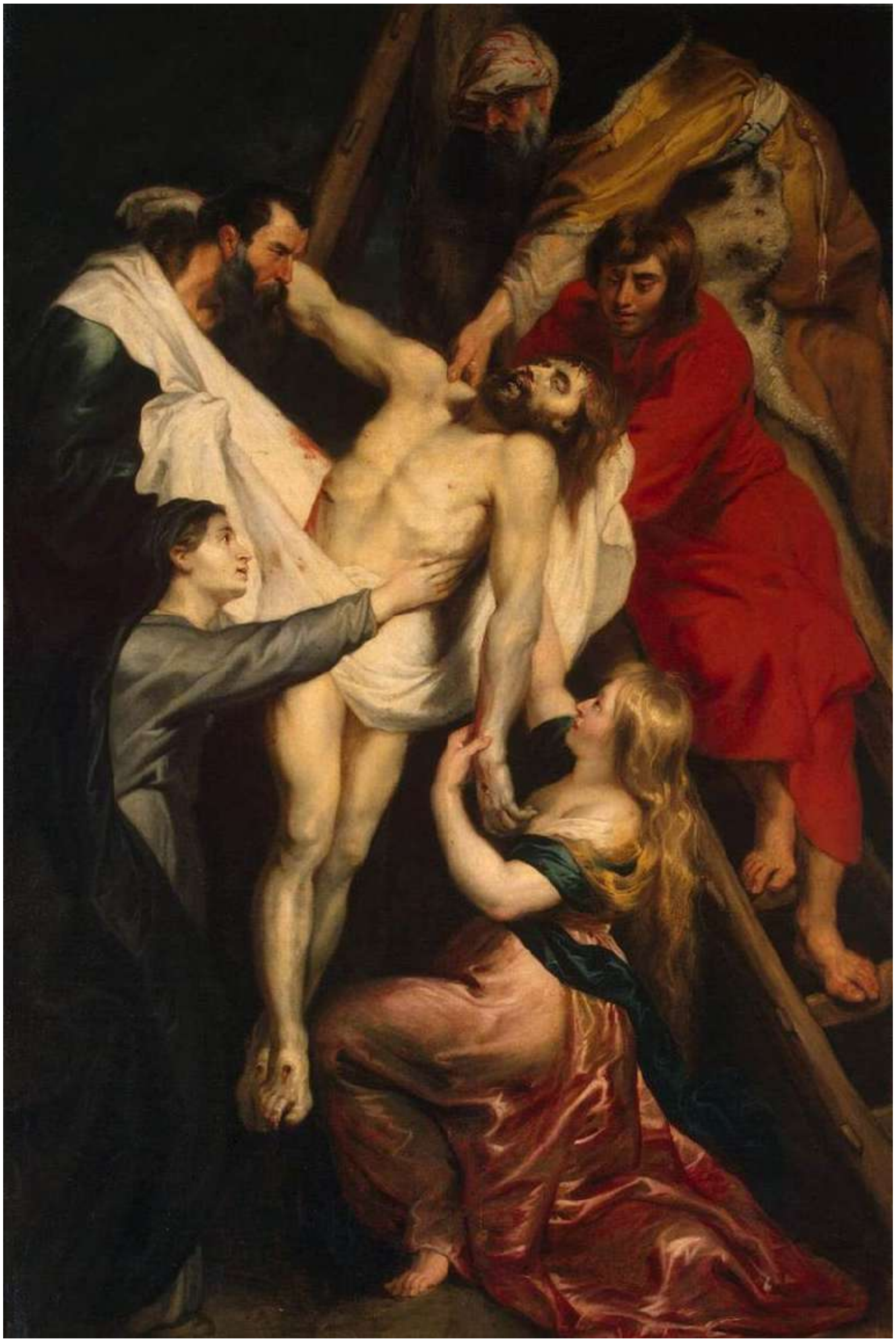

Figure 1.1: ***Descent from the Cross*, 1618, by Peter Paul Rubens, Hermitage Museum.**

Figure 1.2: ***Portrait of Anna of Austria, Queen of France*, c. 1622, by Peter Paul Rubens.**

Figure 1.3: ***Portrait of the Artist*, 1623, by Peter Paul Rubens, Picture Gallery, Buckingham Palace.**

1.2 Vermeer

Artist, art dealer, father and innkeeper in Delft

Johannes Vermeer (1632-1675) was a Dutch painter who lived his entire life in Delft. He is today renowned for his masterly treatment of light and color, and for his portrayal of intimate domestic scenes. He worked very slowly and carefully, and partly for that reason produced very few paintings, only about 66, and of these only 34 survive today. Besides his very slow and careful way of working, the other reason why Vermeer produced so few paintings was that his life was full of many other activities. He was the father of 13 children, of whom 10 survived infancy. He was also an innkeeper and an art dealer.

Vermeer's father, Reijnier Vermeer, was a middle-class dealer in silk and wool, who also owned a large inn. When he died in 1652, his son, Johannes Vermeer took over both businesses. In 1653. he married a Catholic girl, Catherina Bolenes, and converted to Catholicism. His new mother-in-law was much wealthier than he, and as a consequence, the young couple moved into her house.

Vermeer had meanwhile finished his apprenticeship in painting, and had become a highly respected figure within the art world of Delft. His paintings were much sought after by the collectors of the city, who are thought to have supplied him with the very expensive pigments that he used. The fact that all of his paintings were bought by local collectors prevented his reputation from spreading beyond Delft.

The year 1672 was known as the "year of disaster for Holland. In that year, Holland was invaded by the French army of Louis XIV, and as a result there was a severe economic downturn. Vermeer found himself unable to sell not only his own paintings, but also the paintings of others that he had in his collection.

As a result, he became desperate and depressed, and he died in 1675 after a short illness. His wife described his death in the following words: "..during the ruinous war with France he not only was unable to sell any of his art but also, to his great detriment, was left sitting with the paintings of other masters that he was dealing in. As a result and owing to the great burden of his children having no means of his own, he lapsed into such decay and decadence, which he had so taken to heart that, as if he had fallen into a frenzy, in a day and a half he went from being healthy to being dead."

Overlooked for two centuries, then rediscovered

Vermeer's work was overlooked by art historians for two centuries after his death, probably because his high reputation was confined to the city of Delft. He was unknown elsewhere. However, in the 1860's he was rediscovered. Wikipedia writes about this event: **"The Delft master's modern rediscovery began about 1860, when German museum director Gustav Waagen saw The Art of Painting in the Czernin gallery in Vienna and recognized the work as a Vermeer, though it was attributed to Pieter de Hooch at that time."**

Vermeer is now famous throughout the world.

Figure 1.4: ***The Milkmaid*, 1658. by Johannes Vermeer.**

Figure 1.5: ***Girl with a Pearl Earring*, 1665. by Johannes Vermeer.**

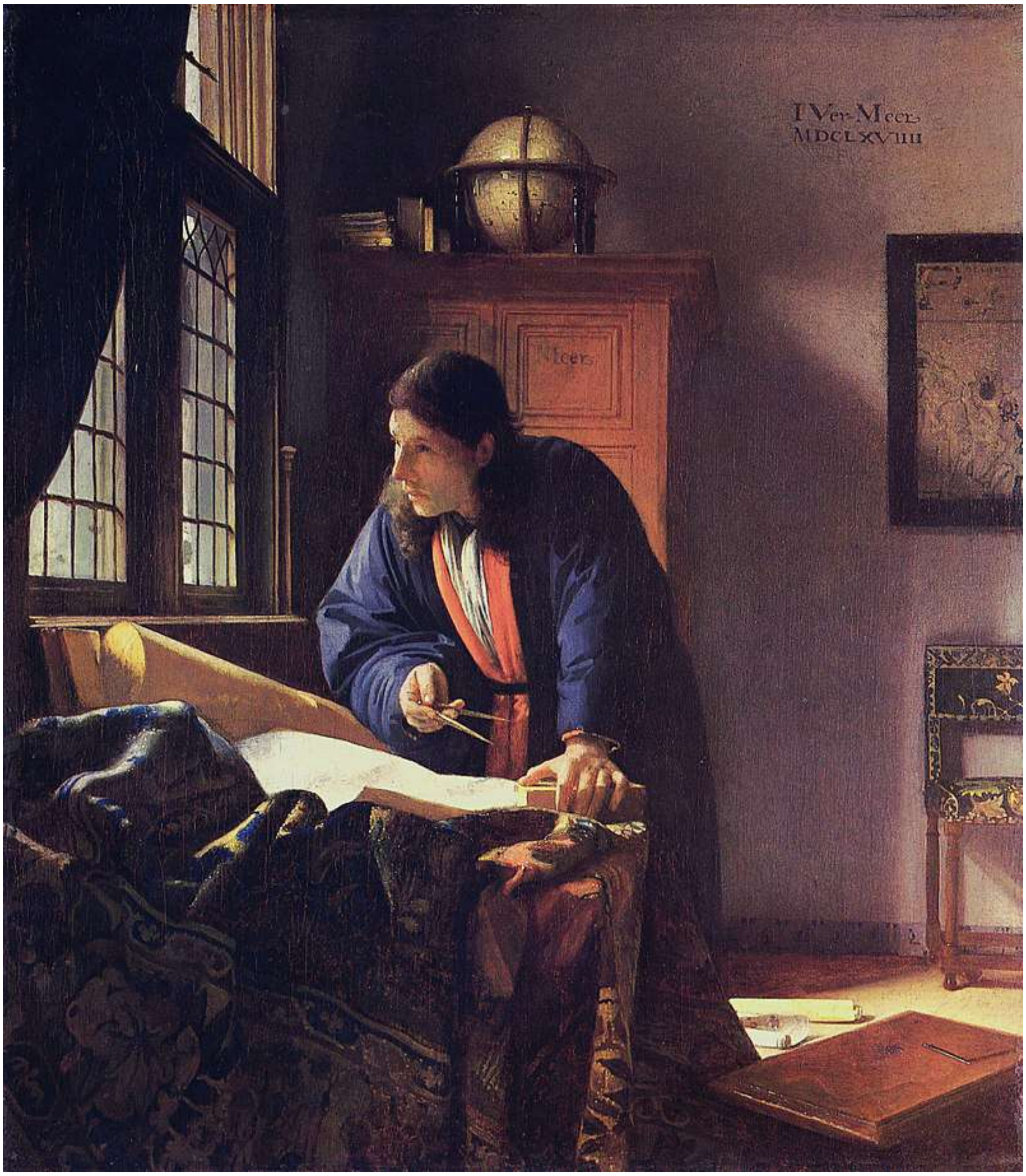

Figure 1.6: ***The Geographer*, 1669, by Johannes Vermeer.**

Figure 1.7: ***Girl with the Red Hat* (c. 1665-1666), National Gallery of Art.**

Figure 1.8: ***Mistress and Maid* (1666-67).**

Figure 1.9: ***Lady Writing a Letter with her Maid*, (c. 1670-71), National Gallery of Ireland in Dublin, Ireland**

1.3 Rembrandt

Early success

Rembrandt Harmenszoon van Rijn (1606-1669) was born in Leiden, in the Dutch Republic. After briefly attending the University of Leiden, he was apprenticed to the Dutch historical painter, Jacob van Swanenburg, and afterwards Pieter Lastman in Amsterdam. He then started his own workshop. In 1631, Rembrandt began to practice as a portrait painter in Amsterdam. He achieved great popularity and his financial success allowed him to marry Saskia van Uylenburgh, whose father had been a lawyer and mayor of the city of Leeuwarden.

Overspending and personal tragedy

In 1639. Rembrandt and Saskia bought a very large house in Amsterdam (now a Rembrandt museum). To make this purchase, Rembrandt borrowed a large amount of money. He could easily have paid off his debt from his earnings, but instead he bought many works by other painters, and he may have made unsuccessful investments.

The family was then struck by tragedy. Three of their children died shortly after birth. Their fourth child, Titus, survived to become an adult, but in 1642, Saskia died, probably from tuberculosis.

In the late 1640's, Rembrandt began a relationship with a much younger woman, Hendrickje Stoffels. She became his long-time partner, and they had a daughter together, but Rembrandt was unable to marry her because of financial conditions related to his inheritance from Saskia.

Rembrandt continued to overspend and became bankrupt. According to the law, he was no longer allowed to deal in art. To get around this regulation a company was set up, "Hendrickje and Titus", with Rembrandt as an employee.

Rembrandt's legacy

Wikipedia says of Rembrandt: "**His reputation as the greatest etcher in the history of the medium was established in his lifetime and never questioned since... Because of his empathy for the human condition, he has been called 'one of the great prophets of civilization'. The French sculptor Auguste Rodin said, 'Compare me with Rembrandt! What sacrilege! With Rembrandt, the colossus of Art! We should prostrate ourselves before Rembrandt and never compare anyone with him!' Vincent van Gogh wrote, 'Rembrandt goes so deep into the mysterious that he says things for which there are no words in any language. It is with justice that they call Rembrandt - magician - that's no easy occupation.'"**

Figure 1.10: ***Self-Portrait*, by Rembrandt van Rijn.**

Figure 1.11: ***The Prodigal Son in a Tavern*, 1635, self-portrait with Saskia, by Rembrandt van Rijn, Gemäldegalerie Alte Meister, Dresden.**

Figure 1.12: ***The Night Watch or The Militia Company of Captain Frans Banning Cocq,*, 1642, by Rembrandt van Rijn, Rijksmuseum, Amsterdam.**

Figure 1.13: ***Rembrandt's Son Titus as a Monk*, 1660, by Rembrandt van Rijn, Rijksmuseum, Amsterdam.**

Figure 1.14: **A typical portrait from 1634, when Rembrandt was enjoying great commercial success.**

Figure 1.15: ***Self Portrait*, 1658, Frick Collection.**

Figure 1.16: **An etching by Rembrandt, c. 1647-1649.**

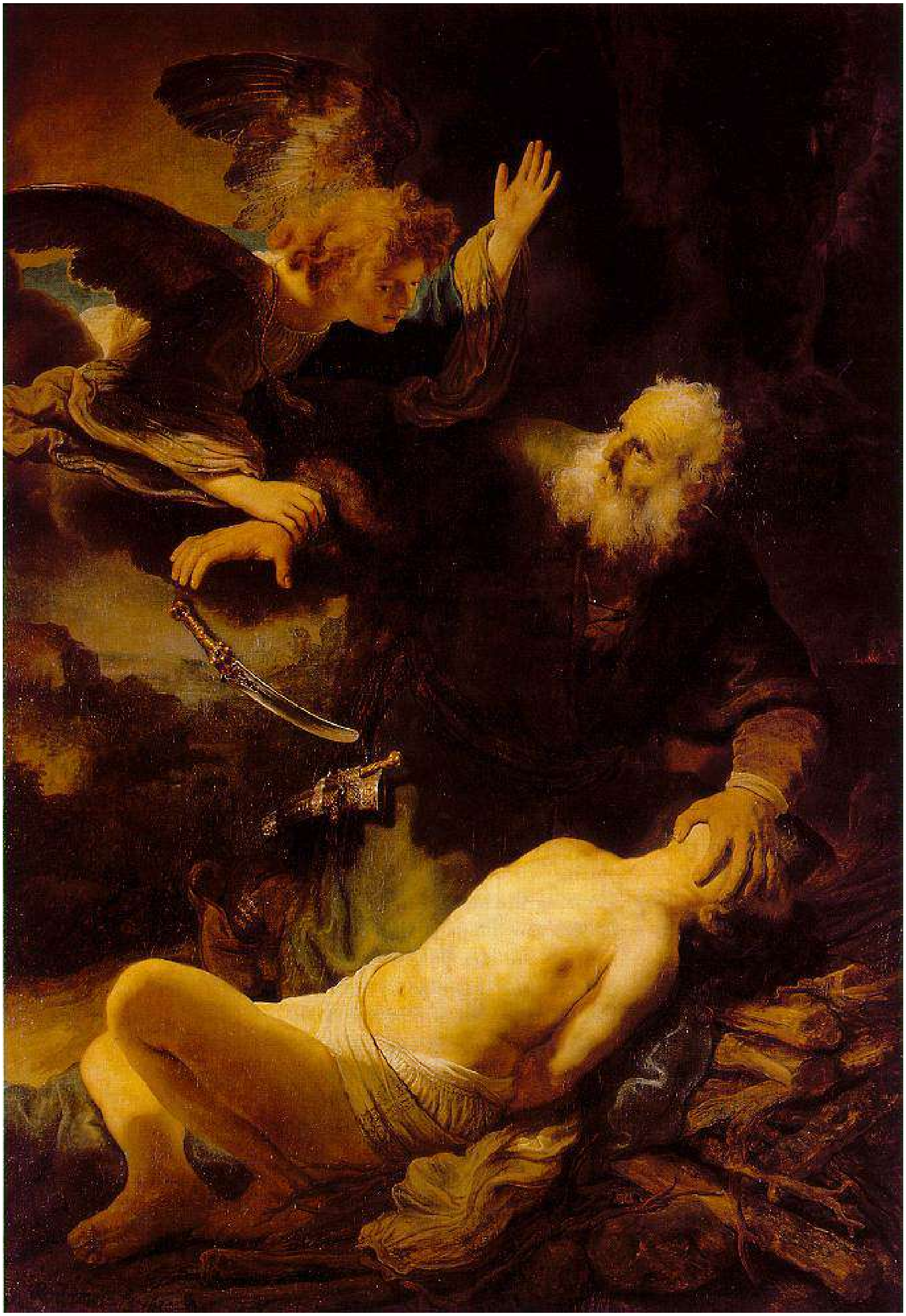

Figure 1.17: ***Sacrifice of Isaac*, 1635.**

Figure 1.18: ***Balthazar's feast*, 1636-1638.**

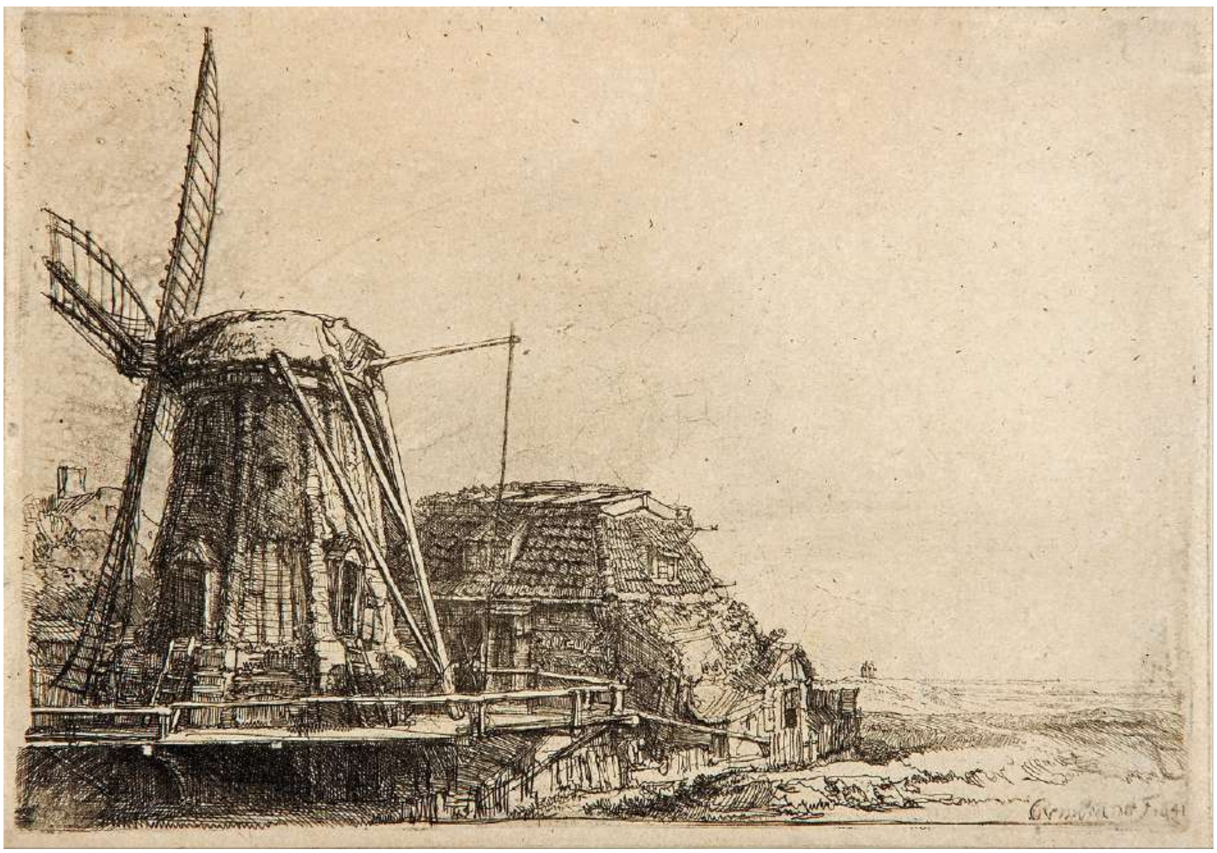

Figure 1.19: ***The Windmill*, 1641, etching.**

1.4 Franz Hals

Franz Hals early life and artistic education

Franz Hals (1582-1666) was born in Antwerp, in the Spanish and Catholic part of southern Holland. However, his parents soon fled with their family to Haarlam in the newly formed Dutch Republic in the north. Franz Hals remained there for the rest of his life. He studied painting under the Flemish émigré artist, Karel van Mande.

Franz Hals first began to earn a living as a restorer of art, paid by the city of Haarlam. All the religious paintings that were judged by the city to be too Catholic were sold to a collector called Cornelis Claesz van Wieringen, on the condition that he should remove them from the city.

Primarily a portrait painter

Franz Hals was primarily a portrait painter, and he is known for his loose style of brushwork. He contributed importantly to the development of 17th century portrait painting.

Wikipedia states that

"Hals's work was in demand through much of his life, but he lived so long that he eventually went out of style as a painter and experienced financial difficulties. In addition to his painting, he worked as a restorer, art dealer, and art tax expert for the city councilors. His creditors took him to court several times, and he sold his belongings to settle his debt with a baker in 1652. The inventory of the property seized mentions only three mattresses and bolsters, an armoire, a table, and five pictures (these were by himself, his sons, van Mander, and Maarten van Heemskerck). Left destitute, he was given an annuity of 200 florins in 1664 by the municipality"

A devoted father

Franz Hals was married twice, and he was a devoted father to his many children.

Figure 1.20: **Frans Hals. *Gypsy Girl*. 1628-30. Oil on wood, 58 x 52 cm. Musée du Louvre, Paris.**

Figure 1.21: ***Laughing Cavalier*, 1624, canvas, relined, (H) 83 cm x (W) 67 cm, Wallace Collection, London..**

Figure 1.22: ***Malle Babbe*, 1630. Oil on Canvas. Staatliche Museen, Berlin.**

Figure 1.23: ***Catherina Hooft with her Nurse*, 1619-1620.**

1.5 Diego Velázquez

Early life and education

Diego Velázquez (1599-1660) was born in Seville, Spain. He showed an early gift for art, and at the age of the age of twelve he was apprenticed for six years to the painter and teacher, Francisco Pacheco the intellectual development of his students, and taught them the classics as well as painting. Velázquez' early works are kitchen scenes. His painting *Old woman frying eggs*, painted when he was nineteen, shows the unusual skill that he had already achieved. In 1618, Velázquez married Juana Pacheco the daughter of his teacher.

Court painter to Phillip IV, King of Spain and Portugal

The high reputation that Diego Velázquez achieved in Seville eventually led to his being invited to Madrid to become the court painter of Phillip IV, whose previous court painter had just died. On August 30, 1623, Philip IV sat for a portrait by Velázquez. The resulting portrait pleased the king so much that he gave an order that all other portraits of himself should be removed from circulation.

Velázquez' salary as court painter as 20 ducats per month, plus free lodging and payment for any paintings that he might make. He also received 300 ducats from the king to cover the expenses of moving his family to Madrid, and the city became his home for the rest of his life.

First Italian journey

King Philip IV generously sponsored two journeys to Italy for Velázquez, to allow him to see and learn from the Italian style of painting. The first journey took place in 1629. Velázquez visited many Italian cities, and learned from the Italian artistic tradition of historical and mythological painting.

Second Italian journey

In 1649, Velázquez made a second journey to Italy. Ha had been entrusted with the duty of purchasing paintings and sculptures for the royal collection of Philip IV, After landing in Genoa, he proceeded yo Milan and then Venice, buying paintings by Titian, Tintoretto and Veronese. He then travelled to Rome, where he painted a portrait of Pope Innocent X. The pope received Velázquez with much favor, and gave him a medal and a golden chain-However the portrait that Velázquez made of the pope was hardly flattering, since the expression on the pope's face in the portrait is one of extreme ruthlessness. Nevertheless, the pope was pleased with the portrait and he had it hung in his visitor's waiting room.

Figure 1.24: ***Old Woman Frying Eggs*, 1618, National Gallery of Scotland, Edinburgh.**

Figure 1.25: ***Portrait of the Infanta Maria Theresa*, Philip IV's daughter with Elisabeth of France.**

Figure 1.26: ***Portrait of Pope Innocent X*, 1650.**

Figure 1.27: ***The Triumph of Bacchus or The Drunks*, 1629.**

1.6 Sir Anthony van Dyck

Early life and education

Anthony van Dyck (1599-1641) was born in Antwerp, Flanders. His father was a wealthy silk merchant. As a young boy, Anthony van Dyck showed great artistic ability. The self-portrait, which he made between the ages of 14 and 15, shows how mature his painting style was, even at that early age. In 1615, when he was 16 years old, van Dyck set up an independent workshop with his friend Jan Brueghel the Younger. Only a few years later, van Dyck became the chief assistant to the famous Flemish painter, Peter Paul Rubens, who referred to him as "my best student". Undoubtedly van Dyck was influenced by Rubens' style of painting.

Van Dyck's successful career as a portrait painter

In 1620, George Villiers, Marquess of Buckingham invited van Dyck to travel to England. He remained there for four months, working for King James I. In England, van Dyck had a chance to see the paintings of Titian, which greatly inspired him. After returning to Flanders, van Dyck left for Italy, where he spent the next six years, studying the works of Italian masters, and establishing a successful career as a portrait painter. In 1627, he returned to Antwerp, where he remained for five years, successfully continuing his career as a portrait painter.

Court painter of King Charles I

King Charles I of England was a passionate collector of paintings, and he also saw portraiture as a means of promoting his exalted idea of the monarchy. Anthony van Dyck helped the agents if King Charles to collect paintings, and he also vent the king some of his own works. As a consequence, he was invited to England in April 1632 he was invited to Charles' court in London, where he was welcomed with great warmth. By July of that year, he had been knighted, granted a pension of 200 pounds a year, and given the title of "principalle Paynter in ordinary to their majesties". Van Dyck was immediately successful in England. He made an estimated 40 portraits of Charles I, 30 of the queen, and very many others of the royal family and of courtiers.

Portrait of Princess Mary

Figure 1.28: ***Self-portrait*, 1613-1614.**

Figure 1.29: ***Charles I at the Hunt*, c. 1635, Louvre.**

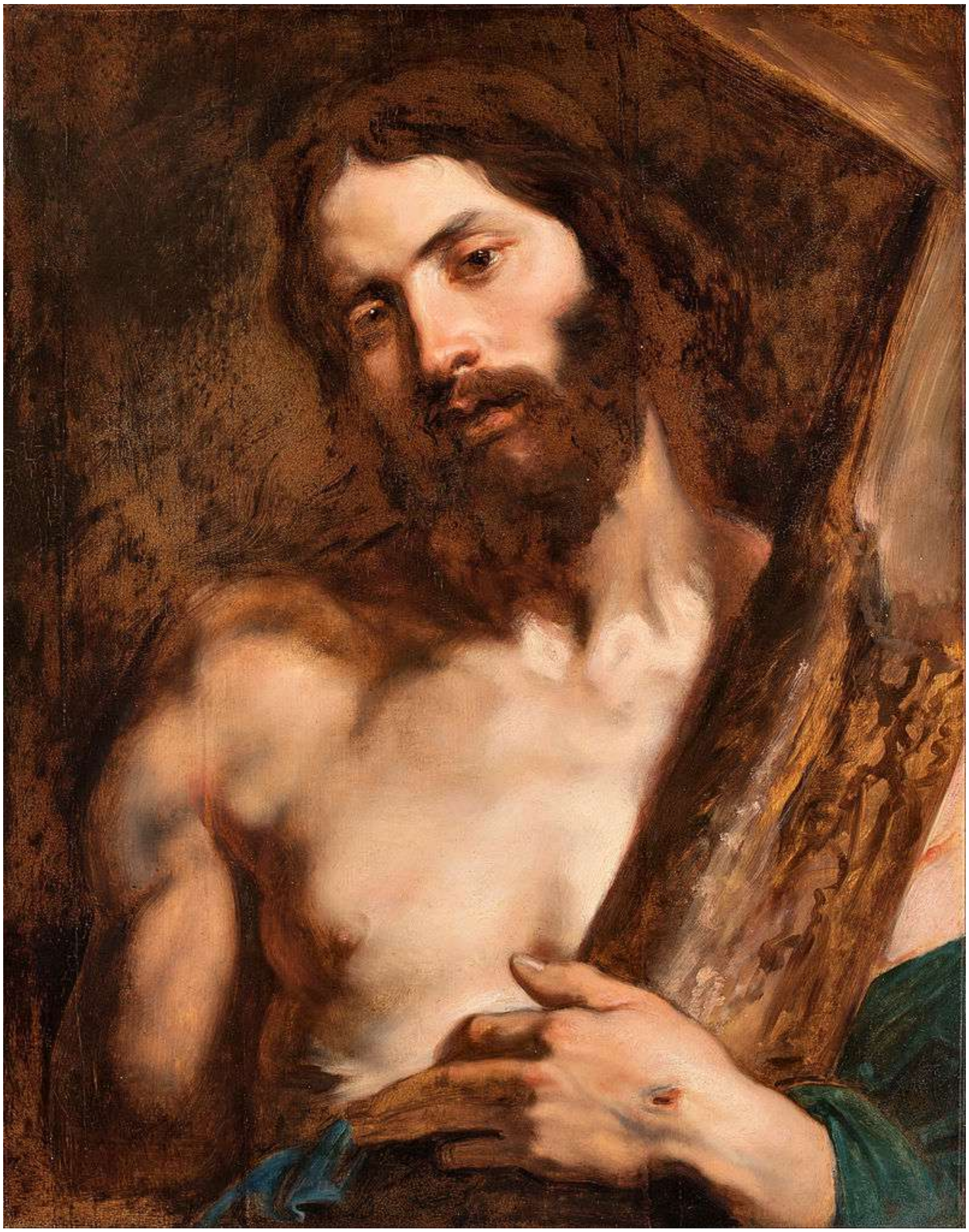

Figure 1.30: ***Christ carrying the Cross.***

Figure 1.31: ***Princess Mary, Daughter of Charles I*, about 1637,**

Suggestions for further reading

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Chapter 2

DESCARTES, NEWTON, LEIBNIZ AND PASCAL

2.1 Uniting geometry and algebra

Until the night of November 10, 1619, algebra and geometry were separate disciplines. On that autumn evening, the troops of the Elector of Bavaria were celebrating the Feast of Saint Martin at the village of Neuberg in Bohemia. With them was a young Frenchman named René Descartes (1596-1659), who had enlisted in the army of the Elector in order to escape from Parisian society. During that night, Descartes had a series of dreams which, as he said later, filled him with enthusiasm, converted him to a life of philosophy, and put him in possession of a wonderful key with which to unlock the secrets of nature.

The program of natural philosophy on which Descartes embarked as a result of his dreams led him to the discovery of analytic geometry, the combination of algebra and geometry. Essentially, Descartes' method amounted to labeling each point in a plane with two numbers, x and y. These numbers represented the distance between the point and two perpendicular fixed lines, (the coordinate axes). Then every algebraic equation relating x and y generated a curve in the plane.

Descartes realized the power of using algebra to generate and study geometrical figures; and he developed his method in an important book, which was among the books that Newton studied at Cambridge. Descartes' pioneering work in analytic geometry paved the way for the invention of differential and integral calculus by Fermat, Newton and Leibniz. (Besides taking some steps towards the invention of calculus, the great French mathematician, Pierre de Fermat (1601-1665), also discovered analytic geometry independently, but he did not publish this work.)

Analytic geometry made it possible to treat with ease the elliptical orbits which Kepler had introduced into astronomy, as well as the parabolic trajectories which Galileo had calculated for projectiles.

Descartes also worked on a theory which explained planetary motion by means of "vortices"; but this theory was by no means so successful as his analytic geometry.

Figure 2.1: **Portrait of René Descartes, after Frans Hals.**

Figure 2.2: **Queen Christina (at the table on the right) in discussion with French philosopher René Descartes. (Romanticized painting by Nils Forsberg (1842-1934), after Pierre Louis Dumesnil.**

Figure 2.3: **Queen Christina of Sweden in a portrait by Sébastien Bourdon.**

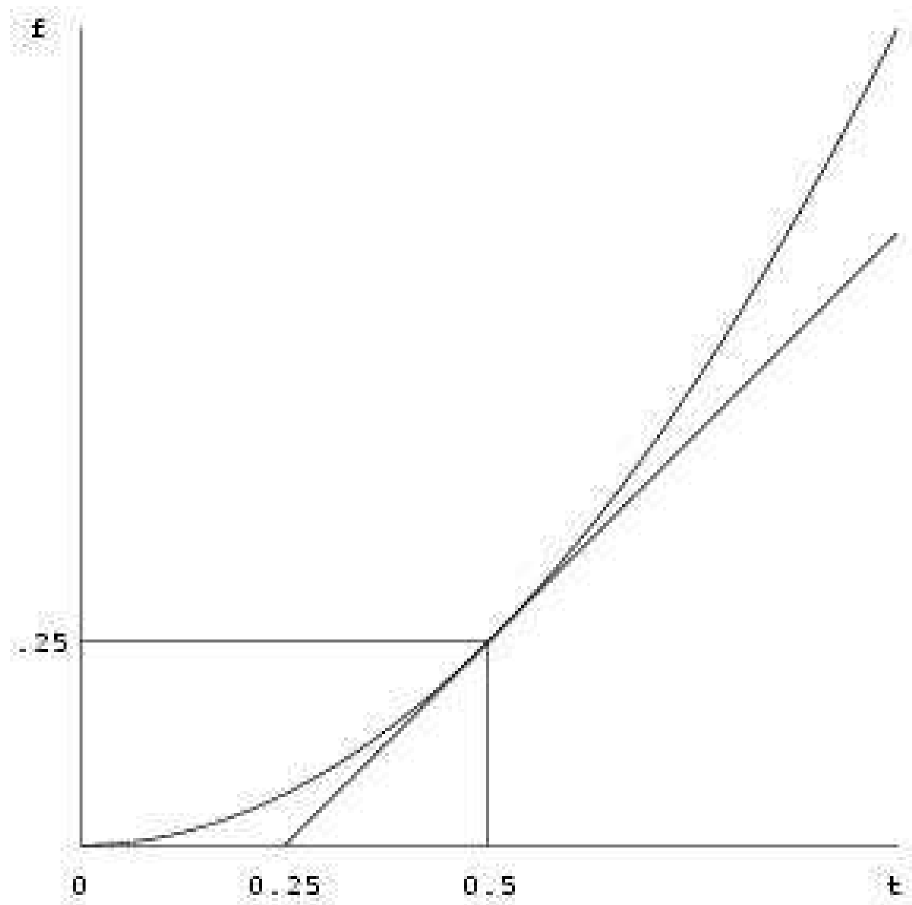

Figure 2.4: **This figure shows the parabola $f = t^2$ plotted using the method of Descartes. Values of f are measured on the vertical axis, while values of t are measured along the horizontal axis. The curve tells us the value of f corresponding to every value of t. For example, when t = 1, f = 1, while when t = 2, f = 4. If we want to know the value of $f = t^2$ corresponding to a particular value of t, we go vertically up to the curve from the horizontal axis, and then horizontally left from the curve to the vertical axis.**

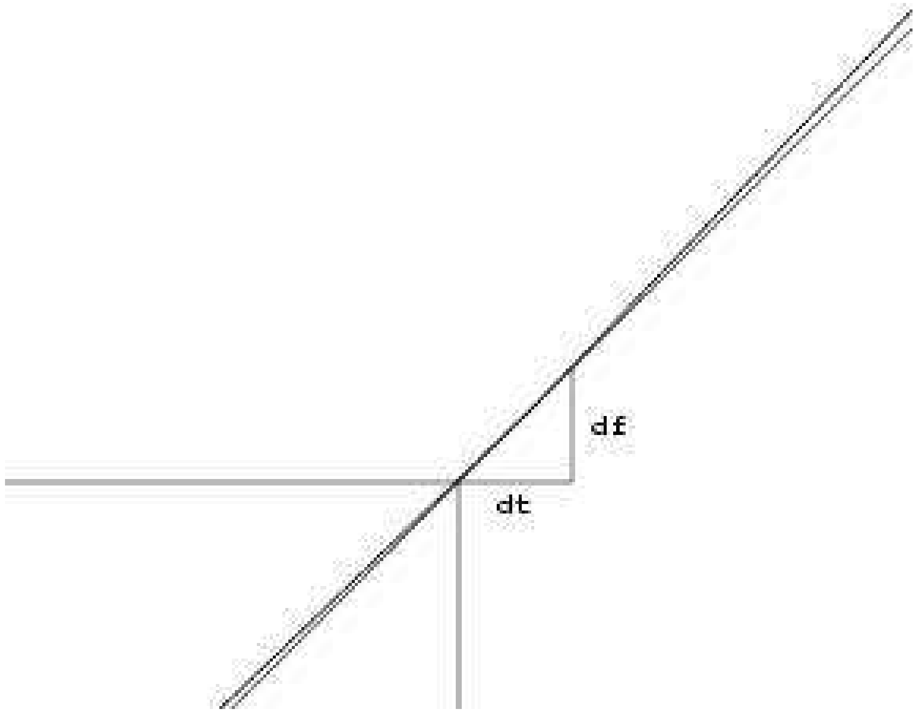

Figure 2.5: **The slope of a curve at a given point t is defined as the limit of the ratio df/dt, when dt becomes infinitesimally small.**

2.2 Descartes' work on Optics, physiology and philosophy

Descartes did important work in optics, physiology and philosophy. In philosophy, he is the author of the famous phrase *"Cogito, ergo sum"*, "I think; therefore I exist", which is the starting point for his theory of knowledge. He resolved to doubt everything which it was possible to doubt; and finally he was reduced to knowledge of his own existence as the only real certainty.

René Descartes died tragically through the combination of two evils which he had always tried to avoid: cold weather and early rising. Even as a student, he spent a large portion of his time in bed. He was able to indulge in this taste for a womblike existence because his father had left him some estates in Brittany. Descartes sold these estates and invested the money, from which he obtained an ample income. He never married, and he succeeded in avoiding responsibilities of every kind.

2.3 Descartes' tragic death

Descartes might have been able to live happily in this way to a ripe old age if only he had been able to resist a flattering invitation sent to him by Queen Christina of Sweden. Christina, the intellectual and strong-willed daughter of King Gustav Adolf, was determined to bring culture to Sweden, much to the disgust of the Swedish noblemen, who considered that money from the royal treasury ought to be spent exclusively on guns and fortifications. Unfortunately for Descartes, he had become so famous that Queen Christina wished to take lessons in philosophy from him; and she sent a warship to fetch him from Holland, where he was staying. Descartes, unable to resist this flattering attention from a royal patron, left his sanctuary in Holland and sailed to the frozen north.

The only time Christina could spare for her lessons was at five o'clock in the morning, three times a week. Poor Descartes was forced to get up in the utter darkness of the bitterly cold Swedish winter nights to give Christina her lessons in a draughty castle library; but his strength was by no means equal to that of the queen, and before the winter was over he had died of pneumonia.

2.4 Newton's early life

On Christmas day in 1642 (the year in which Galileo died), a recently widowed woman named Hannah Newton gave birth to a premature baby at the manor house of Woolsthorpe, a small village in Lincolnshire, England. Her baby was so small that, as she said later, "he could have been put into a quart mug", and he was not expected to live. He did live, however, and lived to achieve a great scientific synthesis, uniting the work of Copernicus, Brahe, Kepler, Galileo and Descartes.

When Isaac Newton was four years old, his mother married again and went to live with her new husband, leaving the boy to be cared for by his grandmother. This may have caused Newton to become more solemn and introverted than he might otherwise have been. One of his childhood friends remembered him as "a sober, silent, thinking lad, scarce known to play with the other boys at their silly amusements".

2.5 Newton becomes a student at Cambridge

As a boy, Newton was fond of making mechanical models, but at first he showed no special brilliance as a scholar. He showed even less interest in running the family farm, however; and a relative (who was a fellow of Trinity College) recommended that he be sent to grammar school to prepare for Cambridge University.

When Newton arrived at Cambridge, he found a substitute father in the famous mathematician Isaac Barrow, who was his tutor. Under Barrow's guidance, and while still a student, Newton showed his mathematical genius by inventing the binomial theorem.

To understand Newton's work on the binomial theorem, we can begin by thinking of what happens when we multiply the quantity a + b by itself. The result is $a^2 + 2ab + b^2$. Now suppose that we continue the process and multiply $a^2 + 2ab + b^2$ by $a + b$. The result of this second multiplication is $a^3 + 3a^2b + 3ab^2 + b^3$, which can also be written as $(a + b)^3$. Continuing in this way we can obtain higher powers of a + b:

$$\begin{aligned} (a+b)^1 &= a+b \\ (a+b)^2 &= a^2+2ab+b^2 \\ (a+b)^3 &= a^3+3a^b+3b^2a+b^3 \\ (a+b)^4 &= a^4+4a^3b+6a^2b^2+4ab^3+b^4 \end{aligned} \tag{2.1}$$

and so on. Newton realized that in general, an integral power of a + b can be expressed in the form:

$$(a+b)^n = a^n + \frac{n}{1!}a^{n-1}b + \frac{n(n-1)}{2!}a^{n-2}b^2 + \frac{n(n-1)(n-2)}{3!}a^{n-3}b^3 + \cdots \tag{2.2}$$

where

$$\begin{aligned} 0! &\equiv 1 \\ 1! &\equiv 1 \\ 2! &\equiv 2\times 1 = 2 \\ 3! &\equiv 3\times 2\times 1 = 6 \\ 4! &\equiv 4\times 3\times 2\times 1 = 24 \\ \vdots & \quad\vdots \qquad\qquad \vdots \end{aligned} \tag{2.3}$$

From the definition of n!, it follows that

$$\begin{aligned} n &= \frac{n!}{(n-1)!} \\ n(n-1) &= \frac{n!}{(n-2)!} \\ n(n-1)(n-3) &= \frac{n!}{(n-3)!} \end{aligned} \tag{2.4}$$

so that we can rewrite the equation for $(a+b)^n$ can be rewritten in the form

$$(a+b)^n = \sum_{j=0}^{n} \frac{n!}{j!(n-j)!)} a^{n-j} b^j \tag{2.5}$$

The large Greek letter $\sum$ indicates a sum. In this case, it is taken over all integral values from 0 up to and including to n.

2.6 Differential calculus

In 1665, Cambridge University was closed because of an outbreak of the plague, and Newton returned for two years to the family farm at Woolsthorpe. He was then twenty-three years old. During the two years of isolation, Newton developed his binomial theorem into the beginnings of differential calculus. He imagined Δt to be an extremely small increase in the value of a variable t. For example, t might represent time, in which case Δt would represent an infinitesimal increase in time - a tiny fraction of a split-second. Newton realized that the series

$$(t+\Delta t)^p = t^p + pt^{p-1}\Delta t + + \frac{p(p-1)}{2!} t^{p-2} (\Delta t)^2 + \cdots \tag{2.6}$$

could then be represented to a very good approximation by its first two terms, and in the limit $\Delta t \to 0$, he obtained the result:

$$\begin{matrix}\text{limit} \\ \Delta t \to 0\end{matrix} \left[\frac{f(t+\Delta t) - f(t)}{\Delta t} \right] = pt^{p-1} \tag{2.7}$$

Thus, in the particular case where $f(t) = t^p$ he found that

$$\frac{df}{dt} \equiv \begin{matrix}\text{limit} \\ \Delta t \to 0\end{matrix} \left[\frac{f(t+\Delta t) - f(t)}{\Delta t} \right] = pt^{p-1} \tag{2.8}$$

$\frac{d}{dt}$ can be thought of as an operator which one can apply to a function f (t). Today we call this operation "differentiation", and df/dt is called the function's "first derivative".

The derivative of a function can be interpreted as the slope (at a particular point t) of a curve representing the function. Differential calculus is the branch of mathematics that deals with differentiation, with slopes, with tangents, and with rates of change.

We have used modern notation to go through the reasoning that Newton used to develop his binomial theorem into differential calculus. The quantities that we today call "derivatives", he called "fluxions", i.e. flowing quantities, perhaps because he associated them with a water clock that he had made as a boy - a water-filled jar with a hole in the bottom. If $f(t)$ represents the volume of water in the jar as a function of time, then df/dt represents the rate at which water is flowing out through the hole.

Newton also applied his "method of fluxions" to mechanics. From the three laws of planetary motion discovered by the German astronomer Kepler, Newton had deduced that the force with which the sun attracts a planet must fall off as the square of the distance between the planet and the sun. With great boldness, he guessed that this force is *universal*, and that every object in the universe attracts every other object with a gravitational force that is directly proportional to the product of the two masses, and inversely proportional to the square of the distance between them.

Newton also guessed correctly that in attracting an object outside its surface, the earth acts as though its mass were concentrated at its center. However, he could not construct the proof of this theorem, since it depended on integral calculus, which did not exist in 1666. (Newton himself perfected integral calculus later in his life.)

Referring to the year 1666, Newton wrote later: "I began to think of gravity extending to the orb of the moon; and having found out how to estimate the force with which a globe revolving within a sphere presses the surface of the sphere, from Kepler's rule of the periodical times of the planets being in a sesquialternate proportion of their distances from the centres of their orbs, I deduced that the forces which keep the planets in their orbs must be reciprocally as the squares of the distances from the centres about which they revolve; and thereby compared the force requisite to keep the moon in her orb with the force of gravity at the surface of the earth, and found them to answer pretty nearly."

"All this was in the plague years of 1665 and 1666, for in those days I was in the prime of my age for invention, and minded mathematics and philosophy more than at any time since."

Newton was not satisfied with this incomplete triumph, and he did not show his calculations to anyone. He not only kept his ideas on gravitation to himself, (probably because of the missing proof), but he also refrained for many years from publishing his work on the calculus. By the time Newton published, the calculus had been invented independently by the great German mathematician and philosopher, Gottfried Wilhelm Leibniz (1646-1716); and the result was a bitter quarrel over priority. However, Newton did publish his experiments in optics, and these alone were enough to make him famous.

2.7 Optics

Newton's famous experiments in optics also date from these years. The sensational experiments of Galileo were very much discussed at the time, and Newton began to think about ways to improve the telescope. Writing about his experiments in optics, Newton says:

"In the year 1666 (at which time I applied myself to the grinding of optic glasses of other figures than spherical), I procured me a triangular prism, to try therewith the celebrated phenomena of colours. And in order thereto having darkened my chamber, and made a small hole in the window shuts to let in a convenient quantity of the sun's light, I placed my prism at its entrance, that it might thereby be refracted to the opposite wall."

"It was at first a very pleasing divertisment to view the vivid and intense colours produced thereby; but after a while, applying myself to consider them more circumspectly, I became surprised to see them in an oblong form, which, according to the received laws of refraction I expected should have been circular."

Newton then describes his crucial experiment. In this experiment, the beam of sunlight from the hole in the window shutters was refracted by two prisms in succession. The first prism spread the light into a rainbow-like band of colors. From this spectrum, he selected a beam of a single color, and allowed the beam to pass through a second prism; but when light of a single color passed through the second prism, the color did not change, nor was the image spread out into a band. No matter what Newton did to it, red light always remained red, once it had been completely separated from the other colors; yellow light remained yellow, green remained green, and blue remained blue.

Newton then measured the amounts by which the beams of various colors were bent by the second prism; and he discovered that red light was bent the least. Next in sequence came orange, yellow, green, blue and finally violet, which was deflected the most. Newton recombined the separated colors, and he found that together, they once again produced white light.

Concluding the description of his experiments, Newton wrote:

"...and so the true cause of the length of the image (formed by the first prism) was detected to be no other than that light is not similar or homogenial, but consists of *deform rays, some of which are more refrangible than others*."

"As rays of light differ in their degrees of refrangibility, so they also differ in their disposition to exhibit this or that particular colour... To the same degree of refrangibility ever belongs the same colour, and to the same colour ever belongs the same degree of refrangibility."

"...The species of colour and the degree of refrangibility belonging to any particular sort of rays is not mutable by refraction, nor by reflection from natural bodies, nor by any other cause that I could yet observe. When any one sort of rays hath been well parted from those of other kinds, it hath afterwards obstinately retained its colour, notwithstanding my utmost endeavours to change it."

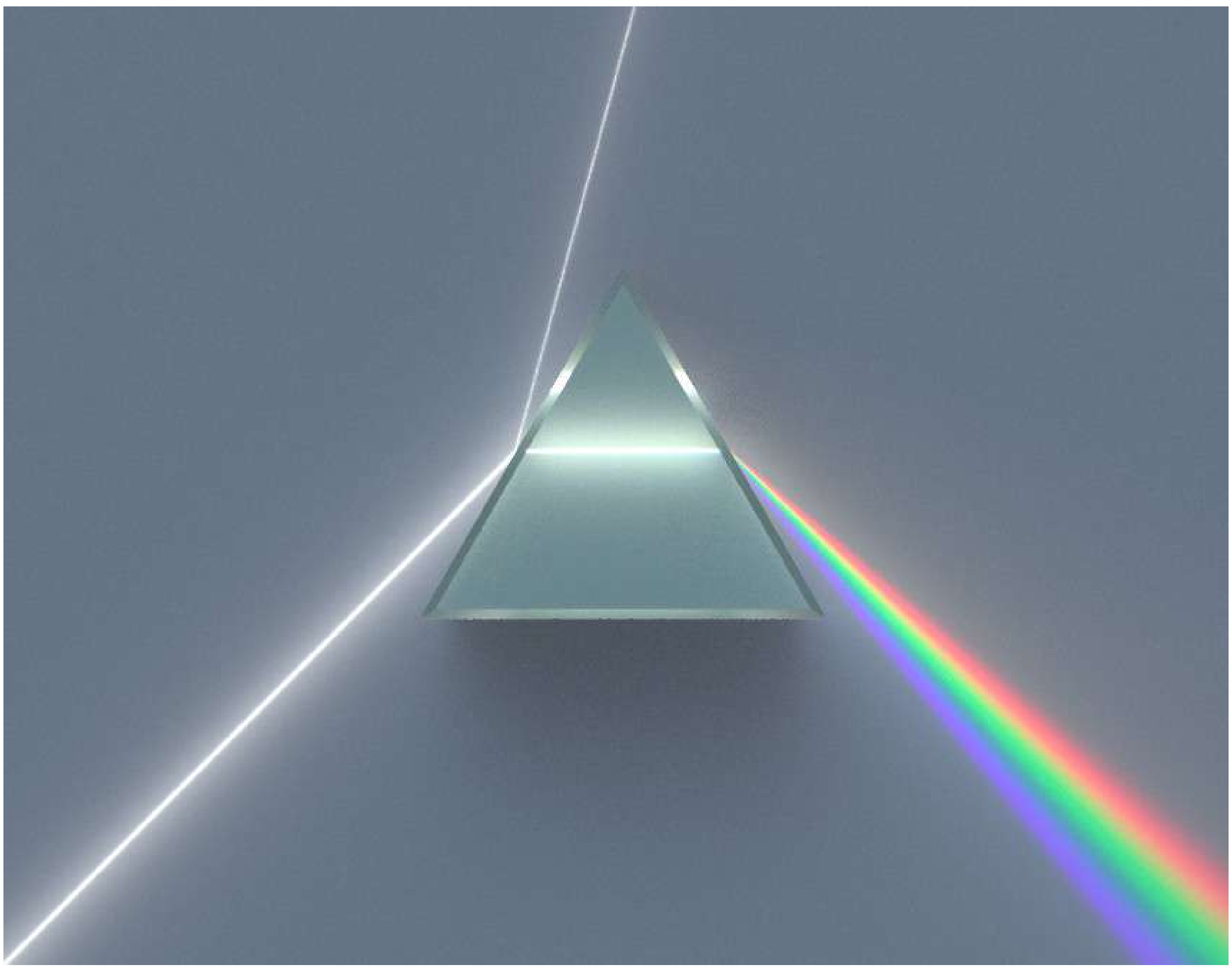

Figure 2.6: **Illustration of a dispersive prism separating white light into the colours of the spectrum, as discovered by Newton.**

Figure 2.7: **Replica of Newton's second reflecting telescope, which he presented to the Royal Society in 1672.**

2.8 Integral calculus

In 1669, Newton's teacher, Isaac Barrow, generously resigned his post as Lucasian Professor of Mathematics so that Newton could have it. Thus, at the age of 27, Newton became the head of the mathematics department at Cambridge. He was required to give eight lectures a year, but the rest of his time was free for research.

Newton worked at this time on developing what he called "the method of inverse fluxions". Today we call his method "integral calculus". What did Newton mean by "inverse fluxions"? By "fluxions" he meant differentials, so we must think of an operation that is the reverse of differentiation.

Suppose that we know from our experience with differentiation that (for example)

$$\text{if and only if } f = t^p + C \text{ then } \frac{df}{dt} = pt^{p-1} \tag{2.9}$$

where C is a constant. Then we also know that

$$\text{if } \frac{df}{dt} = pt^{p-1} \text{ then } f = t^p + C \tag{2.10}$$

2.9 Halley visits Newton

Newton's prism experiments had led him to believe that the only possible way to avoid blurring of colors in the image formed by a telescope was to avoid refraction entirely. Therefore he designed and constructed the first reflecting telescope. In 1672, he presented a reflecting telescope to the newly-formed Royal Society, which then elected him to membership.

Meanwhile, the problems of gravitation and planetary motion were increasingly discussed by the members of the Royal Society. In January, 1684, three members of the Society were gathered in a London coffee house. One of them was Robert Hooke (1635-1703), author of *Micrographia* and Professor of Geometry at Gresham College, a brilliant but irritable man. He had begun his career as Robert Boyle's assistant, and had gone on to do important work in many fields of science. Hooke claimed that he could calculate the motion of the planets by assuming that they were attracted to the sun by a force which diminished as the square of the distance.

Listening to Hooke were Sir Christopher Wren (1632-1723), the designer of St. Paul's Cathedral, and the young astronomer, Edmund Halley (1656-1742). Wren challenged Hooke to produce his calculations; and he offered to present Hooke with a book worth 40 shillings if he could prove his inverse square force law by means of rigorous mathematics. Hooke tried for several months, but he was unable to win Wren's reward.

Meanwhile, in August, 1684, Halley made a journey to Cambridge to talk with Newton, who was rumored to know very much more about the motions of the planets than he had revealed in his published papers. According to an almost-contemporary account, what happened then was the following:

"Without mentioning his own speculations, or those of Hooke and Wren, he (Halley) at once indicated the object of his visit by asking Newton what would be the curve described by the planets on the supposition that gravity diminished as the square of the distance. Newton immediately answered: an Ellipse. Struck with joy and amazement, Halley asked how he knew it? 'Why', replied he, 'I have calculated it'; and being asked for the calculation, he could not find it, but promised to send it to him."

Newton soon reconstructed the calculation and sent it to Halley; and Halley, filled with enthusiasm and admiration, urged Newton to write out in detail all of his work on motion and gravitation. Spurred on by Halley's encouragement and enthusiasm, Newton began to put his research in order. He returned to the problems which had occupied him during the plague years, and now his progress was rapid because he had invented integral calculus. This allowed him to prove rigorously that terrestrial gravitation acts as though all the earth's mass were concentrated at its center. Newton also had available an improved value for the radius of the earth, measured by the French astronomer Jean Picard (1620-1682). This time, when he approached the problem of gravitation, everything fell into place.

By the autumn of 1684, Newton was ready to give a series of lectures on dynamics, and he sent the notes for these lectures to Halley in the form of a small booklet entitled *On the Motion of Bodies*. Halley persuaded Newton to develop these notes into a larger book, and with great tact and patience he struggled to keep a controversy from developing between Newton, who was neurotically sensitive, and Hooke, who was claiming his share of recognition in very loud tones, hinting that Newton was guilty of plagiarism.

Although Newton was undoubtedly one of the greatest physicists of all time, he had his shortcomings as a human being; and he reacted by striking out from his book every single reference to Robert Hooke. The Royal Society at first offered to pay for the publication costs of Newton's book, but because a fight between Newton and Hooke seemed possible, the Society discretely backed out. Halley then generously offered to pay the publication costs himself, and in 1686 Newton's great book was printed. It is entitled *Philosophae Naturalis Principia Mathematica*, (The Mathematical Principles of Natural Philosophy), and it is divided into three sections.

The first book sets down the general principles of mechanics. In it, Newton states his three laws of motion, and he also discusses differential and integral calculus (both invented by himself).

In the second book, Newton applies these methods to systems of particles and to hydrodynamics. For example, he calculates the velocity of sound in air from the compressibility and density of air; and he treats a great variety of other problems, such as the problem of calculating how a body moves when its motion is slowed by a resisting medium, such as air or water.

The third book is entitled *The System of the World*. In this book, Newton sets out to derive the entire behavior of the solar system from his three laws of motion and from his law of universal gravitation. From these, he not only derives all three of Kepler's laws, but he also calculates the periods of the planets and the periods of their moons; and he explains such details as the flattened, non-spherical shape of the earth, and the slow precession of its axis about a fixed axis in space. Newton also calculated the irregular motion of the

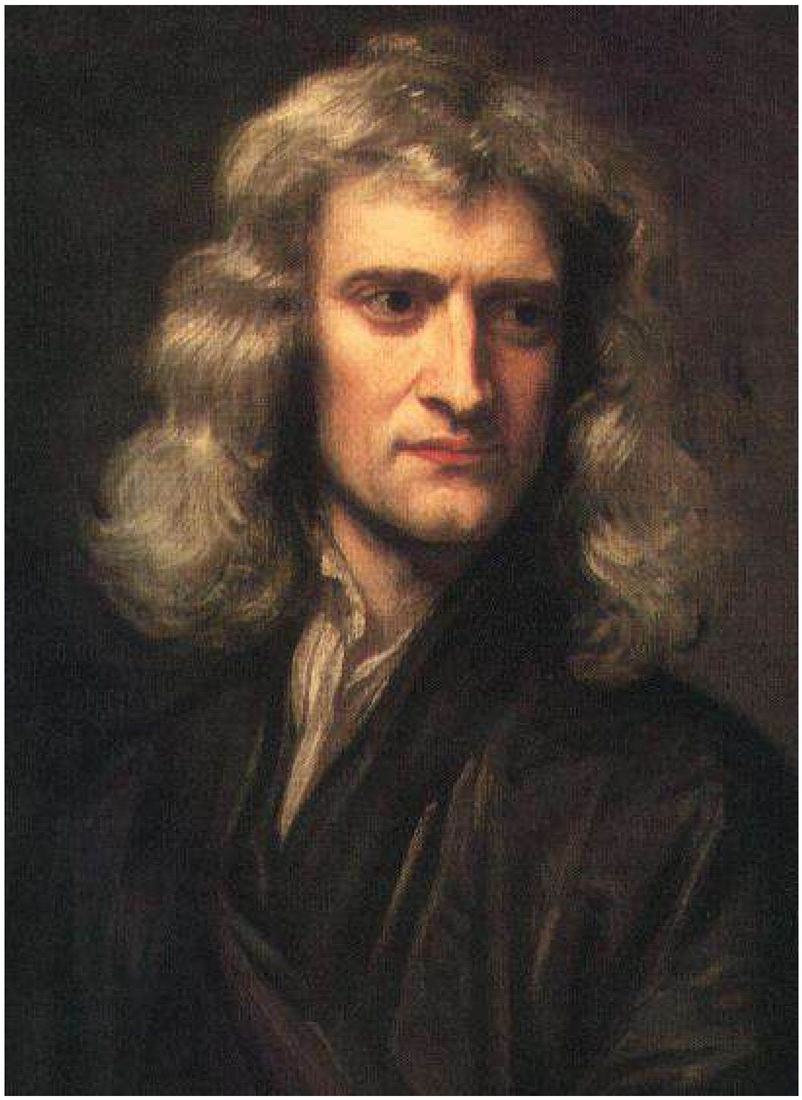

Figure 2.8: **Portrait of Isaac Newton (1642-1727) by Sir Godfrey Kneller.**

moon resulting from the combined attractions of the earth and the sun; and he determined the mass of the moon from the behavior of the tides.

Newton's *Principia* is generally considered to be the greatest scientific work of all time. To present a unified theory explaining such a wide variety of phenomena with so few assumptions was a magnificent and unprecedented achievement; and Newton's contemporaries immediately recognized the importance of what he had done.

The great Dutch physicist, Christian Huygens (1629-1695), inventor of the pendulum clock and the wave theory of light, travelled to England with the express purpose of meeting Newton. Voltaire, who for reasons of personal safety was forced to spend three years in England, used the time to study Newton's *Principia*; and when he returned to France, he persuaded his mistress, Madame du Chatelet, to translate the *Principia* into French; and Alexander Pope, expressing the general opinion of his contemporaries, wrote a famous couplet, which he hoped would be carved on Newton's tombstone:

"Nature and Nature's law lay hid in night.

God said: 'Let Newton be!', and all was light!"

The Newtonian synthesis was the first great achievement of a new epoch in human thought, an epoch which came to be known as the "Age of Reason" or the "Enlightenment". We might ask just what it was in Newton's work that so much impressed the intellectuals of the period. The answer is that in the Newtonian system of the world, the entire evolution of the solar system is determined by the laws of motion and by the positions and velocities of the planets and their moons at a given instant of time. Knowing these, it is possible to predict all of the future and to deduce all of the past.

The Newtonian system of the world is like an enormous clock which has to run on in a predictable way once it is started. In this picture of the world, comets and eclipses are no longer objects of fear and superstition. They too are part of the majestic clockwork of the universe. The Newtonian laws are simple and mathematical in form; they have complete generality; and they are unalterable. In this picture, although there are no miracles or exceptions to natural law, nature itself, in its beautiful works, can be regarded as miraculous.

Newton's contemporaries knew that there were other laws of nature to be discovered besides those of motion and gravitation; but they had no doubt that, given time, all of the laws of nature would be discovered. The climate of intellectual optimism was such that many people thought that these discoveries would be made in a few generations, or at most in a few centuries.

In 1704, Newton published a book entitled *Opticks*, expanded editions of which appeared in 1717 and 1721. Among the many phenomena discussed in this book are the colors produced by thin films. For example, Newton discovered that when he pressed two convex lenses together, the thin film of air trapped between the lenses gave rise to rings of colors ("Newton's rings"). The same phenomenon can be seen in the in the colors of soap bubbles or in films of oil on water.

In order to explain these rings, Newton postulated that "..every ray of light in its passage through any refracting surface is put into a transient constitution or state, which in the progress of the ray returns at equal intervals, and disposes the ray at every return to be easily transmitted through the next refracting surface and between the returns to be easily reflected from it."

Newton's rings were later understood on the basis of the wave theory of light advocated by Huygens and Hooke. Each color has a characteristic wavelength, and is easily reflected when the ratio of the wavelength to the film thickness is such that the wave reflected from the bottom surface of the film interferes constructively with the wave reflected from the top surface. However, although he ascribed periodic "fits of easy reflection" and "fits of easy transmission" to light, and although he suggested that a particular wavelength is associated with each color, Newton rejected the wave theory of light, and believed instead that light consists of corpuscles emitted from lumi Newton believed in his corpuscular theory of light because he could not understand on the basis of Huygens' wave theory how light casts sharp shadows. This is strange, because in his *Opticks* he includes the following passage:

"Grimaldo has inform'd us that if a beam of the sun's light be let into a dark room through a very small hole, the shadows of things in this light will be larger than they ought to be if the rays went on by the bodies in straight lines, and that these shadows have three parallel fringes, bands or ranks of colour'd light adjacent to them. But if the hole be enlarg'd, the fringes grow broad and run into one another, so that they cannot be distinguish'd"

After this mention of the discovery of diffraction by the Italian physicist, Francesco Marea Grimaldi (1618-1663), Newton discusses his own studies of diffraction. Thus, Newton must have been aware of the fact that light from a very small source does not cast completely sharp shadows!

Newton felt that his work on optics was incomplete, and at the end of his book he included a list of "Queries", which he would have liked to have investigated. He hoped that this list would help the research of others. In general, although his contemporaries were extravagant in praising him, Newton's own evaluation of his work was modest. "I do not know how I may appear to the world", he wrote, "but to myself I seem to have been only like a boy playing on the seashore and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."

Figure 2.9: **Newton own evaluation of his work was modest. He wrote "I do not know what I may appear to the world, but to myself I seem to have been only like a boy playing on the seashore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."**

2.10 The conflict over priority between Leibniz and Newton

In this chapter, we have used the modern notation, which is much closer to the notation used by the great German mathematician and universal genius, Gottfried Wilhelm von Leibniz than to that used by Newton.

Newton did not publish his work on differential and integral calculus. Slightly later, Leibniz invented these two branches of mathematics independently. Thus a bitter dispute over priority was precipitated, from which Leibniz suffered when his patron, the Elector of Hanover, left Germany to become King George I of England.

Huygens and Leibniz

On the continent of Europe, mathematics and physics had been developing rapidly, stimulated by the writings of René Descartes. One of the most distinguished followers of Descartes was the Dutch physicist, Christian Huygens (1629-1695).

Huygens was the son of an important official in the Dutch government. After studying mathematics at the University of Leiden, he published the first formal book ever written about probability. However, he soon was diverted from pure mathematics by a growing interest in physics.

In 1655, while working on improvements to the telescope together with his brother

Figure 2.10: **Christian Huygens (1629-1695).**

and the Dutch philosopher Benedict Spinoza, Huygens invented an improved method for grinding lenses. He used his new method to construct a twenty-three foot telescope, and with this instrument he made a number of astronomical discoveries, including a satellite of Saturn, the rings of Saturn, the markings on the surface of Mars and the Orion Nebula.

Huygens was the first person to estimate numerically the distance to a star. By assuming the star Sirius to be exactly as luminous as the sun, he calculated the distance to Sirius, and found it to be 2.5 trillion miles. In fact, Sirius is more luminous than the sun, and its true distance is twenty times Huygens' estimate.

Another of Huygens' important inventions is the pendulum clock. Improving on Galileo's studies, he showed that for a pendulum swinging in a circular arc, the period is not precisely independent of the amplitude of the swing. Huygens then invented a pendulum with a modified arc, not quite circular, for which the swing was exactly isochronous. He used this improved pendulum to regulate the turning of cog wheels, driven by a falling weight; and thus he invented the pendulum clock, almost exactly as we know it today.

In discussing Newton's contributions to optics, we mentioned that Huygens opposed Newton's corpuscular theory of light, and instead advocated a wave theory. Huygens believed that the rapid motion of particles in a hot body, such as a candle flame, produces a wave-like disturbance in the surrounding medium; and he believed that this wavelike disturbance of the "ether" produces the sensation of vision by acting on the nerves at the back of our eyes.

In 1678, while he was working in France under the patronage of Louis XIV, Huygens composed a book entitled *Traité de la Lumiere*, (Treatise on Light), in which he says:

"...It is inconceivable to doubt that light consists of the motion of some sort of matter. For if one considers its production, one sees that here upon the earth it is chiefly engendered by fire and flame, which undoubtedly contain bodies in rapid motion, since they dissolve and melt many other bodies, even the most solid; or if one considers its effects, one sees that when light is collected, as by concave mirrors, it has the property of burning as fire does, that is to say, it disunites the particles of bodies. This is assuredly the mark of motion, at least in the true philosophy in which one conceives the causes of all natural effects in terms of mechanical motions..."

"Further, when one considers the extreme speed with which light spreads on every side, and how, when it comes from different regions, even from those directly opposite, the rays traverse one another without hindrance, one may well understand that when we see a luminous object, it cannot be by any transport of matter coming to us from the object, in the way in which a shot or an arrow traverses the air; for assuredly that would too greatly impugn these two properties of light, especially the second of them. It is in some other way that light spreads; and that which can lead us to comprehend it is the knowledge which we have of the spreading of sound in the air."

Huygens knew the velocity of light rather accurately from the work of the Danish astronomer, Ole Rømer (1644-1710), who observed the moons of Jupiter from the near and far sides of the earth's orbit. By comparing the calculated and observed times for the moons to reach a certain configuration, Rømer was able to calculate the time needed for light to propagate across the diameter of the earth's orbit. In this way, Rømer calculated the velocity of light to be 227,000 kilometers per second. Considering the early date of this first successful measurement of the velocity of light, it is remarkably close to the accepted modern value of 299,792 kilometers per second. Thus Huygens knew that although the speed of light is enormous, it is not infinite.

Huygens considered the propagation of a light wave to be analogous to the spreading of sound, or the widening of the ripple produced when a pebble is thrown into still water. He developed a mathematical principle for calculating the position of a light wave after a short interval of time if the initial surface describing the wave front is known. Huygens considered each point on the initial wave front to be the source of spherical wavelets, moving outward with the speed of light in the medium. The surface marking the boundary between the region outside all of the wavelets and the region inside some of them forms the new wave front.

If one uses Huygens' Principle to calculate the wave fronts and rays for light from a point source propagating past a knife edge, one finds that a part of the wave enters the shadow region. This is, in fact, precisely the effect which was observed by both Grimaldi and Newton, and which was given the name "diffraction" by Grimaldi. In the hands of Thomas Young (1773-1829) and Augustin Jean Fresnel (1788-1827), diffraction effects later became a strong argument in favor of Huygens' wave theory of light.

(You can observe diffraction effects yourself by looking at a point source of light, such as a distant street lamp, through a piece of cloth, or through a small slit or hole. Another type of diffraction can be seen by looking at light reflected at a grazing angle from a phonograph record. The light will appear to be colored. This effect is caused by the fact that each groove is a source of wavelets, in accordance with Huygens' Principle. At certain angles, the wavelets will interfere constructively, the angles for constructive interference being different for each color.)

Interestingly, modern quantum theory (sometimes called wave mechanics) has shown that *both* Huygens' wave theory of light and Newton's corpuscular theory contain aspects of the truth! Light has both wave-like and particle-like properties. Furthermore, quantum theory has shown that small particles of matter, such as electrons, also have wave-like properties! For example, electrons can be diffracted by the atoms of a crystal in a manner exactly analogous to the diffraction of light by the grooves of a phonograph record. Thus the difference of opinion between Huygens and Newton concerning the nature of light is especially interesting, since it foreshadows the wave-particle duality of modern physics.

Among the friends of Christian Huygens was the German philosopher and mathematician Gottfried Wilhelm Leibniz (1646-1716). Leibniz was a man of universal and spectacular ability. In addition to being a mathematician and philosopher, he was also a lawyer, historian and diplomat. He invented the doctrine of balance of power, attempted to unify the Catholic and Protestant churches, founded academies of science in Berlin and St. Petersburg, invented combinatorial analysis, introduced determinants into mathematics, independently invented the calculus, invented a calculating machine which could multiply and divide as well as adding and subtracting, acted as advisor to Peter the Great and originated the theory that "this is the best of all possible worlds" (later mercilessly satirized by Voltaire in *Candide*).

Leibniz learned mathematics from Christian Huygens, whom he met while travelling as an emissary of the Elector of Mainz. Since Huygens too was a man of very wide interests, he found the versatile Leibniz congenial, and gladly agreed to give him lessons. Leibniz continued to correspond with Huygens and to receive encouragement from him until the end of the older man's life.

In 1673, Leibniz visited England, where he was elected to membership by the Royal Society. During the same year, he began his work on calculus, which he completed and published in 1684. Newton's invention of differential and integral calculus had been made much earlier than the independent work of Leibniz, but Newton did not publish his discoveries until 1687. This set the stage for a bitter quarrel over priority between the admirers of Newton and those of Leibniz. The quarrel was unfortunate for everyone concerned, especially for Leibniz himself. He had taken a position in the service of the Elector of Hanover, which he held for forty years. However, in 1714, the Elector was called to the throne of England as George I. Leibniz wanted to accompany the Elector to England, but was left behind, mainly because of the quarrel with the followers of Newton. Leibniz died two years later, neglected and forgotten, with only his secretary attending the funeral.

Figure 2.11: **Portrait of Gottfried Wilhelm Leibniz by J.F. Wentzel.**

2.11 Political philosophy of the Enlightenment

The 16th, 17th and 18th centuries have been called the "Age of Discovery", and the "Age of Reason", but they might equally well be called the "Age of Observation". On every side, new worlds were opening up to the human mind. The great voyages of discovery had revealed new continents, whose peoples demonstrated alternative ways of life. The telescopic exploration of the heavens revealed enormous depths of space, containing myriads of previously unknown stars; and explorations with the microscope revealed a new and marvelously intricate world of the infinitesimally small.

In the science of this period, the emphasis was on careful observation. This same emphasis on observation can be seen in the Dutch and English painters of the period. The great Dutch masters, such as Jan Vermeer (1632-1675), Frans Hals (1580-1666), Pieter de Hooch (1629-1678) and Rembrandt van Rijn (1606-1669), achieved a careful realism in their paintings and drawings which was the artistic counterpart of the observations of the pioneers of microscopy, Anton van Leeuwenhoek and Robert Hooke. These artists were supported by the patronage of the middle class, which had become prominent and powerful both in England and in the Netherlands because of the extensive world trade in which these two nations were engaged.

Members of the commercial middle class needed a clear and realistic view of the world in order to succeed with their enterprises. (An aristocrat of the period, on the other hand, might have been more comfortable with a somewhat romanticized and out-of-focus vision, which would allow him to overlook the suffering and injustice upon which his privileges were based.) The rise of the commercial middle class, with its virtues of industriousness, common sense and realism, went hand in hand with the rise of experimental science, which required the same virtues for its success.

In England, the House of Commons (which reflected the interests of the middle class), had achieved political power, and had demonstrated (in the Puritan Rebellion of 1640 and the Glorious Revolution of 1688) that Parliament could execute or depose any monarch who tried to rule without its consent. In France, however, the situation was very different.

After passing through a period of disorder and civil war, the French tried to achieve order and stability by making their monarchy more absolute. The movement towards absolute monarchy in France culminated in the long reign of Louis XIV, who became king in 1643 and who ruled until he died in 1715.

The historical scene which we have just sketched was the background against which the news of Newton's scientific triumph was received. The news was received by a Europe which was tired of religious wars; and in France, it was received by a middle class which was searching for an ideology in its struggle against the *ancien régime*.

To the intellectuals of the 18th century, the orderly Newtonian cosmos, with its planets circling the sun in obedience to natural law, became an imaginative symbol representing rationality. In their search for a society more in accordance with human nature, 18th century Europeans were greatly encouraged by the triumphs of science. Reason had shown itself to be an adequate guide in natural philosophy. Could not reason and natural law also be made the basis of moral and political philosophy? In attempting to carry out this program, the philosophers of the Enlightenment laid the foundations of psychology, anthropology, social science, political science and economics.

One of the earliest and most influential of these philosophers was John Locke (1632-1705), a contemporary and friend of Newton. In his *Second Treatise on Government*, published in 1690, John Locke's aim was to refute the doctrine that kings rule by divine right, and to replace that doctrine by an alternative theory of government, derived by reason from the laws of nature. According to Locke's theory, men originally lived together without formal government:

"Men living together according to reason," he wrote, "without a common superior on earth with authority to judge between them, is properly the state of nature... A state also of equality, wherein all the power and jurisdiction is reciprocal, no one having more than another; there being nothing more evident than that creatures of the same species, promiscuously born to all the same advantages of nature and the use of the same facilities, should also be equal amongst one another without subordination or subjection..."

"But though this be a state of liberty, yet it is not a state of licence... The state of nature has a law to govern it, which obliges every one; and reason, which is that law, teaches all mankind who will but consult it, that being equal and independent, no one ought to harm another in his life, health, liberty or possessions."

In Locke's view, a government is set up by means of a social contract. The government is given its powers by the consent of the citizens in return for the services which it renders to them, such as the protection of their lives and property. If a government fails to render these services, or if it becomes tyrannical, then the contract has been broken, and the citizens must set up a new government.

Locke's influence on 18th century thought was very great. His influence can be seen, for example, in the wording of the American Declaration of Independence. In England, Locke's political philosophy was accepted by almost everyone. In fact, he was only codifying ideas which were already in wide circulation and justifying a revolution which had already occurred. In France, on the other hand, Locke's writings had a revolutionary impact.

Credit for bringing the ideas of both Newton and Locke to France, and making them fashionable, belongs to Francois Marie Arouet (1694-1778), better known as "Voltaire". Besides persuading his mistress, Madame de Chatelet, to translate Newton's *Principia* into French, Voltaire wrote an extremely readable commentary on the book; and as a result, Newton's ideas became highly fashionable among French intellectuals. Voltaire lived with Madame du Chatelet until she died, producing the books which established him as the leading writer of Europe, a prophet of the Age of Reason, and an enemy of injustice, feudalism and superstition.

The Enlightenment in France is considered to have begun with Voltaire's return from England in 1729; and it reached its high point with the publication of of the *Encyclopedia* between 1751 and 1780. Many authors contributed to the *Encyclopedia*, which was an enormous work, designed to sum up the state of human knowledge.

Turgot and Montesquieu wrote on politics and history; Rousseau wrote on music, and Buffon on natural history; Quesnay contributed articles on agriculture, while the Baron d'Holbach discussed chemistry. Other articles were contributed by Condorcet, Voltaire

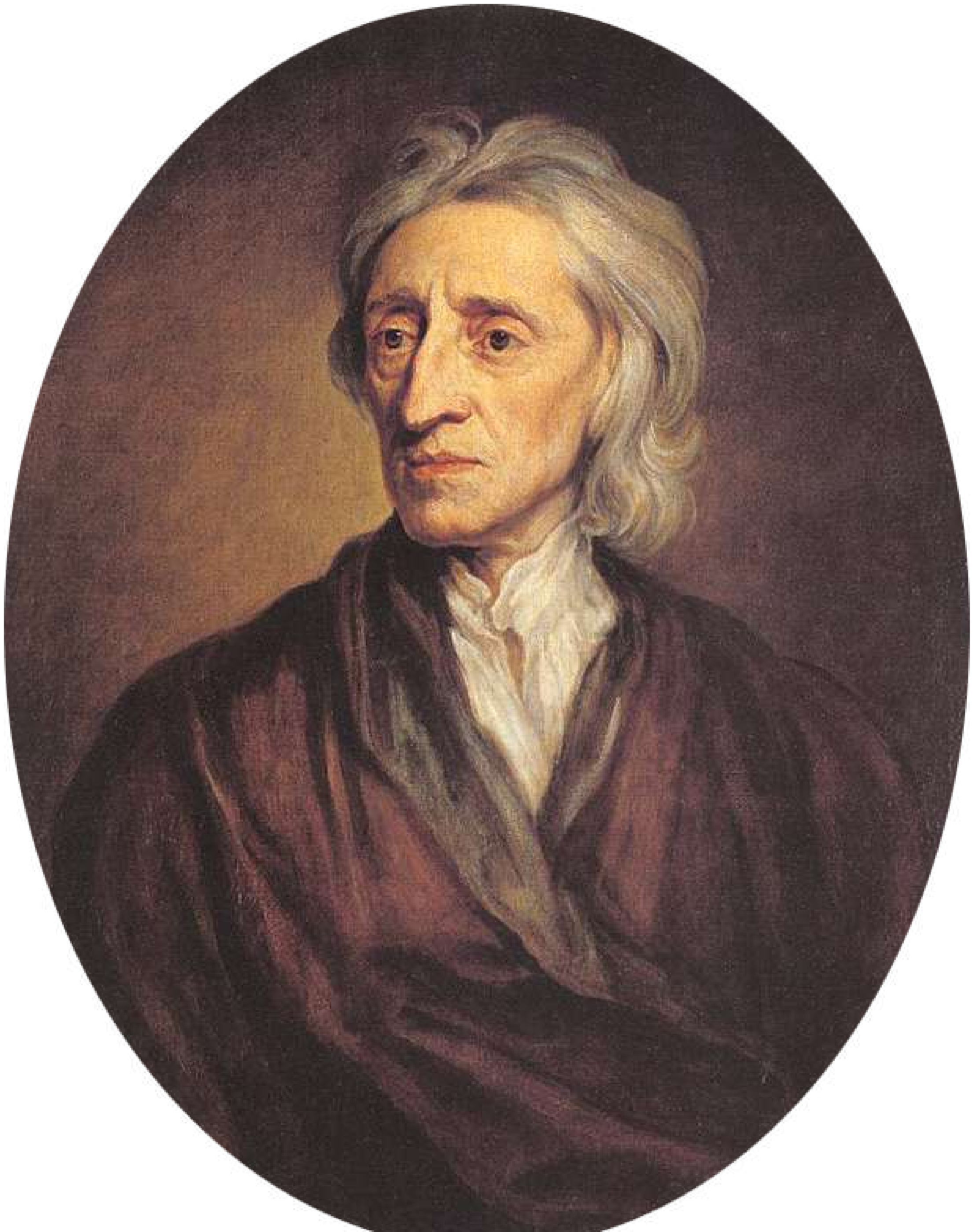

Figure 2.12: **Portrait of John Locke, by Sir Godfrey Kneller.**

and d'Alembert. The whole enterprise was directed and inspired by the passionate faith of Denis Diderot (1713-1784). The men who took part in this movement called themselves *"philosophes"*. Their creed was a faith in reason, and an optimistic belief in the perfectibility of human nature and society by means of education, political reforms, and the scientific method.

The *philosophes* of the Enlightenment visualized history as a long progression towards the discovery of the scientific method. Once discovered, this method could never be lost; and it would lead inevitably (they believed) to both the material and moral improvement of society. The *philosophes* believed that science, reason, and education, together with the principles of political liberty and equality, would inevitably lead humanity forward to a new era of happiness. These ideas were the faith of the Enlightenment; they influenced the French and American revolutions; and they are still the basis of liberal political belief.

2.12 Pascal and Leibniz

If civilization survives, historians in the distant future will undoubtedly regard the invention of computers as one of the most important steps in human cultural evolution - as important as the invention of writing or the invention of printing. The possibilities of artificial intelligence have barely begun to be explored, but already the impact of computers on society is enormous.

The first programmable universal computers were completed in the mid-1940's; but they had their roots in the much earlier ideas of Blaise Pascal (1623-1662), Gottfried Wilhelm Leibniz (1646-1716), Joseph Marie Jacquard (1752-1834) and Charles Babbage (1791-1871).

In 1642, the distinguished French mathematician and philosopher Blaise Pascal completed a working model of a machine for adding and subtracting. According to tradition, the idea for his "calculating box" came to Pascal when, as a young man of 17, he sat thinking of ways to help his father (who was a tax collector). In describing his machine, Pascal wrote: "I submit to the public a small machine of my own invention, by means of which you alone may, without any effort, perform all the operations of arithmetic, and may be relieved of the work which has often times fatigued your spirit when you have worked with the counters or with the pen."

Pascal's machine worked by means of toothed wheels. It was much improved by Leibniz, who constructed a mechanical calculator which, besides adding and subtracting, could also multiply and divide. His first machine was completed in 1671; and Leibniz' description of it, written in Latin, is preserved in the Royal Library at Hanover: "There are two parts of the machine, one designed for addition (and subtraction), and the other designed for multiplication (and division); and they should fit together. The adding (and subtracting) machine coincides completely with the calculating box of Pascal. Something, however, must be added for the sake of multiplication..."

"The wheels which represent the multiplicand are all of the same size, equal to that of the wheels of addition, and are also provided with ten teeth which, however, are movable

Figure 2.13: **Blaise Pascal (1623-1662) was a French mathematician, physicist, writer, inventor and theologian. Pascal, a child prodigy, was educated by his father, who was a tax-collector. He invented his calculating box to make his father's work less tedious.**

Figure 2.14: **The German mathematician, philosopher and universal genius Gottfried Wilhelm von Leibniz (1646-1716) was a contemporary of Isaac Newton. He invented differential and integral calculus independently, just as Newton had done many years earlier. However, Newton had not published his work on calculus, and thus a bitter controversy over priority was precipitated. When his patron, the Elector of Hanover moved to England to become George I, Leibniz was left behind because the Elector feared that the controversy would alienate the English. Leibniz extended Pascal's calculating box so that it could perform multiplication and division. Calculators of his design were still being used in the 1960's.**

so that at one time there should protrude 5, at another 6 teeth, etc., according to whether the multiplicand is to be represented five times or six times, etc."

"For example, the multiplicand 365 consists of three digits, 3, 6, and 5. Hence the same number of wheels is to be used. On these wheels, the multiplicand will be set if from the right wheel there protrude 5 teeth, from the middle wheel 6, and from the left wheel 3."

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Chapter 3

PIONEERS OF MICROSCOPY

3.1 Antonie van Leeuwenhoek, the founder of microbiology

"The father of microbiology"

Antonie Philips van Leeuwenhoek (1632-1723) was a Dutch businessman, who became interested in lenses. He designed and built his own single-lens microscope. Using it, he became the first person to observe microorganisms, such as bacteria. Because of this achievement, he has been called "the father of microbiology".

How van Leeuwenhoek made his best lenses

Antonie van Leeuwenhoek's best lenses were very tiny indeed, and they were not made by grinding. Instead, van Leeuwenhoek drew a melted rod of glass out into two very long and thin fibers. Then he inserted one of these into a flame. The result was that it threw off a tiny sphere of glass, which he used as a lens. With such a lens he could magnify objects about 500 times. However, he did not reveal his methods to the public, and instead encouraged people to believe that he made all his lenses by grinding.

Some of van Leeuwenhoek's observations

Wikipedia states that

"Using single-lensed microscopes of his own design and make, van Leeuwenhoek was the first to observe and to experiment with microbes, which he originally referred to as dierkens, diertgens or diertjes (Dutch for "small animals" [translated into English as animalcules, from Latin animalculum = "tiny animal"]).[8] He was the first to relatively determine their size. Most of the 'animalcules' are now referred to as unicellular organisms, although he observed

Figure 3.1: **Portrait of Antonie van Leeuwenhoek (1632-1723). He has been called "the father of microbiology". As a scientist he was largely self-taught.**

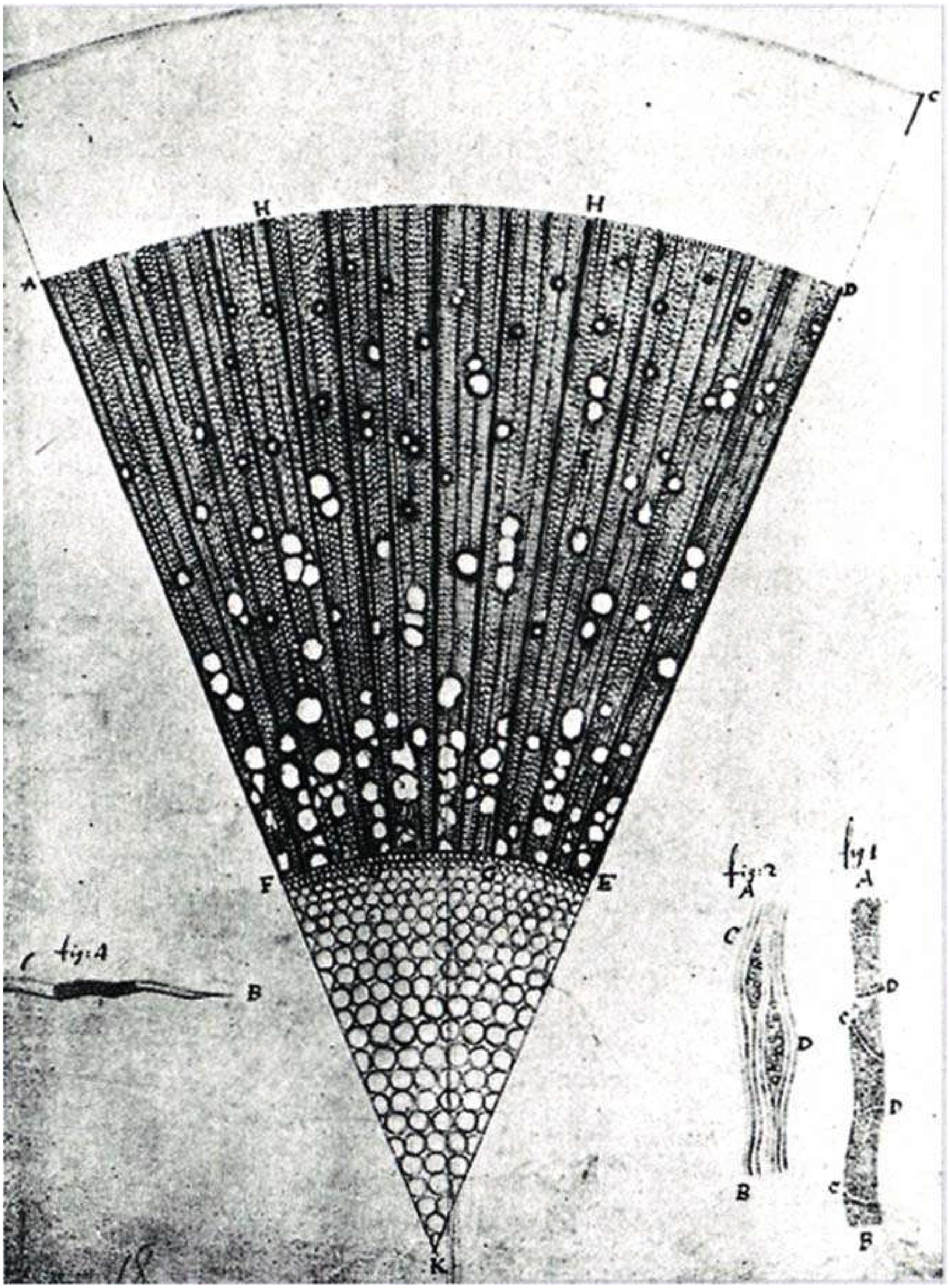

Figure 3.2: **A microscopic section of a one-year-old ash tree microscopic section of a one-year-old ash tree. The drawing was made by Antonie van Leeuwenhoek.**

Figure 3.3: **A replica of a microscope by van Leeuwenhoek. The single-lens microscopes of van Leeuwenhoek were relatively small devices, the largest being about 5 cm long. They are used by placing the lens very close in front of the eye, while looking in the direction of the sun. The other side of the microscope had a pin, where the sample was attached in order to stay close to the lens. There were also three screws to move the pin and the sample along three axes: one axis to change the focus, and the two other axes to navigate through the sample.**

multicellular organisms in pond water. He was also the first to document microscopic observations of muscle fibers, bacteria, spermatozoa, red blood cells, crystals in gouty tophi, and among the first to see blood flow in capillaries. Although van Leeuwenhoek did not write any books, he described his discoveries in letters to the Royal Society, which published many of his letters, and to persons in several European countries"

Letters to England's Royal Society

The Dutch physician, Reinier de Graaf, wrote to Henry Oldenberg, the editor of *Philosophical Transactions of the Royal Society* saying that van Leeuwenhoek's microscopes "far surpassed those which we hitherto have seen". As a result, Oldenberg and van Leeuwenhoek began to exchange letters, which Oldenberg translated and published. Van Leeuwenhoek's discoveries captured the attention of the Royal Society, which elected him to membership in 1680.

Scientific fame

Wikipedia states that

"By the end of the seventeenth century, van Leeuwenhoek had a virtual monopoly on microscopic study and discovery. His contemporary Robert Hooke, an early microscope pioneer, bemoaned that the field had come to rest entirely on one man's shoulders. He was visited over the years by many notable individuals, such as the Russian Tsar Peter the Great. To the disappointment of his guests, van Leeuwenhoek refused to reveal the cutting-edge microscopes he relied on for his discoveries, instead showing visitors a collection of average-quality lenses.

"Van Leeuwenhoek was visited by Leibniz, William III of Orange and his wife, Mary II of England, and the burgemeester (mayor) Johan Huydecoper of Amsterdam, the latter being very interested in collecting and growing plants for the Hortus Botanicus Amsterdam, and all gazed at the tiny creatures. In 1698, van Leeuwenhoek was invited to visit the Tsar Peter the Great on his boat. On this occasion van Leeuwenhoek presented the Tsar with an 'eel-viewer', so Peter could study blood circulation whenever he wanted."

3.2 Robert Hooke's *Micrographia*

Robert Hooke, FRS (1635-1703) was so universally talented that he has been called "England's Leonardo". Although he was initially poor, he soon achieved both wealth and recognition as a surveyor of London after the Great Fire (1666). In this work, he collaborated with Sir Christoper Wren. Hooke's scientific and engineering work included contributions

Figure 3.4: **Microscope manufactured by Christopher White of London for Robert Hooke. Hooke is believed to have used this microscope for the observations that formed the basis of *Micrographia*.**

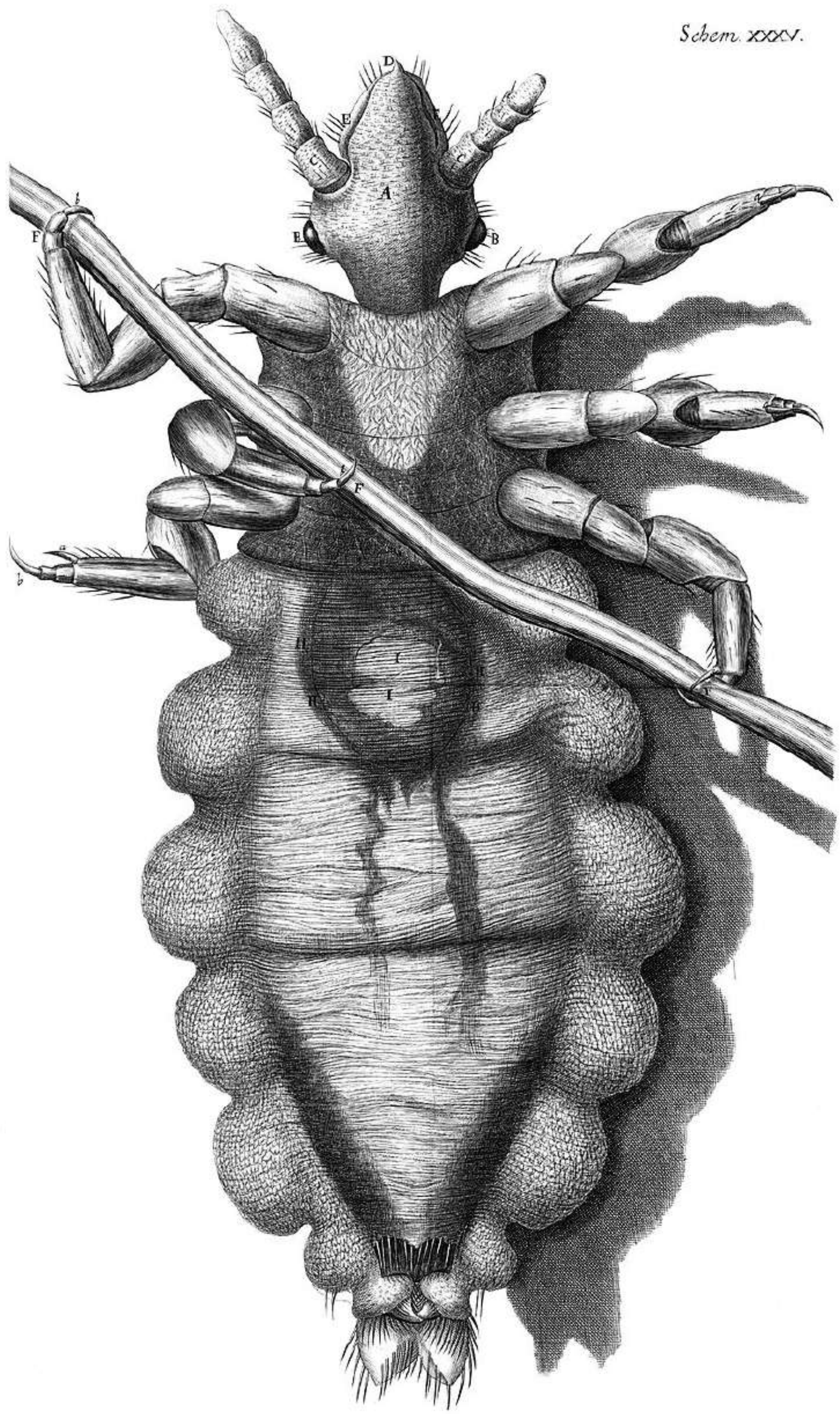

Figure 3.5: **Hooke's drawing of a louse.**

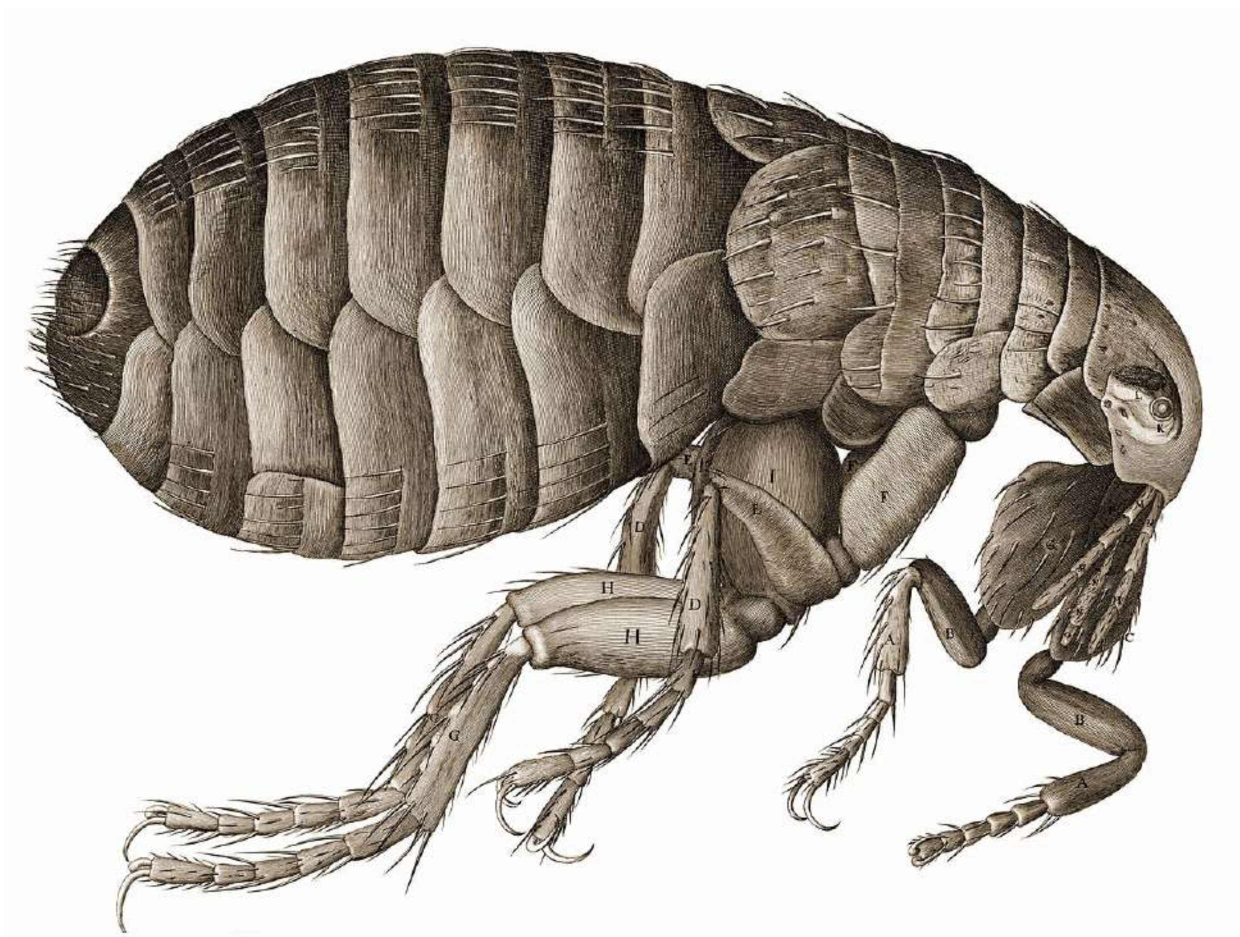

Figure 3.6: **Hooke's drawing of a flea.**

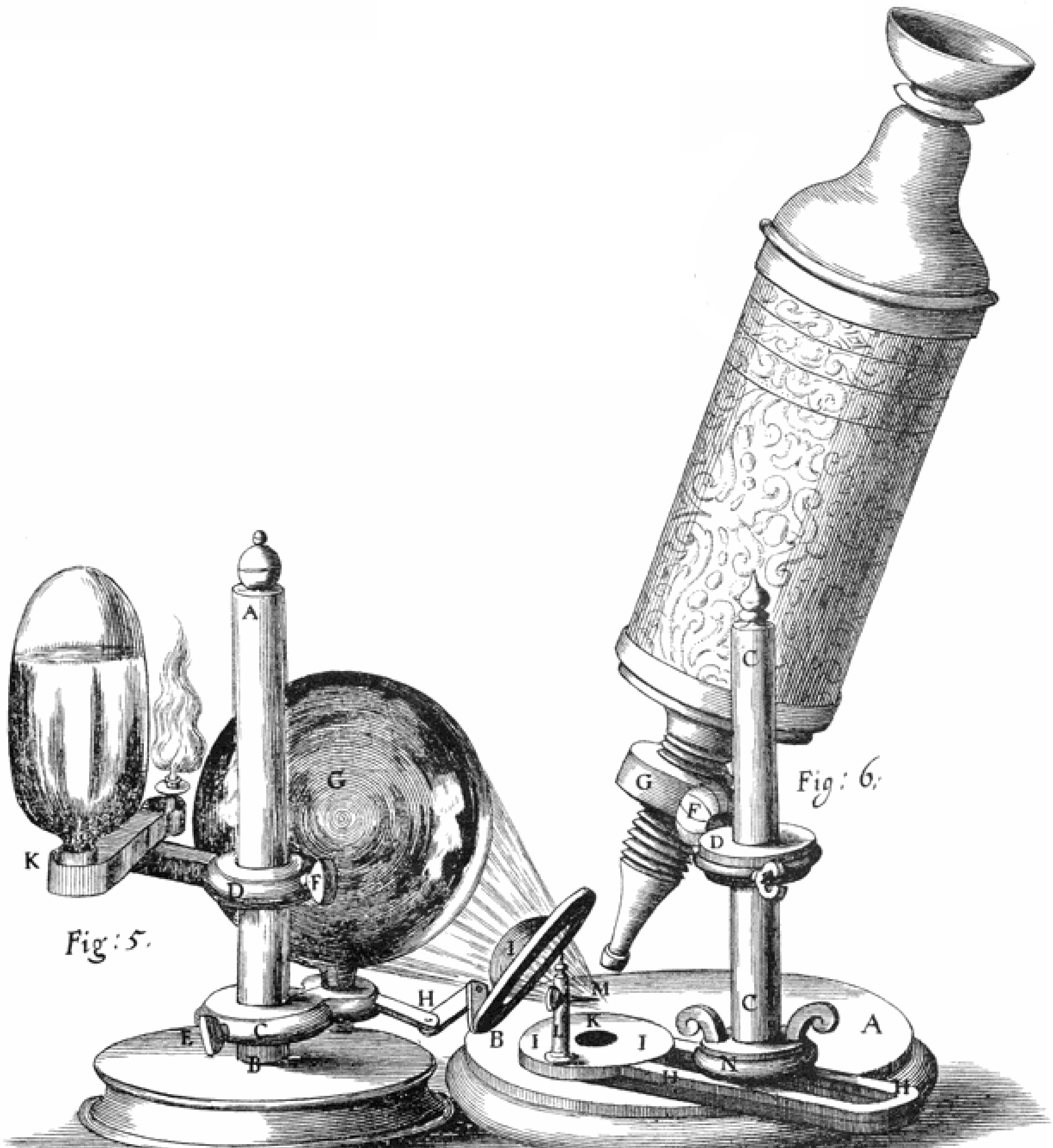

Figure 3.7: **Hooke's microscope.**

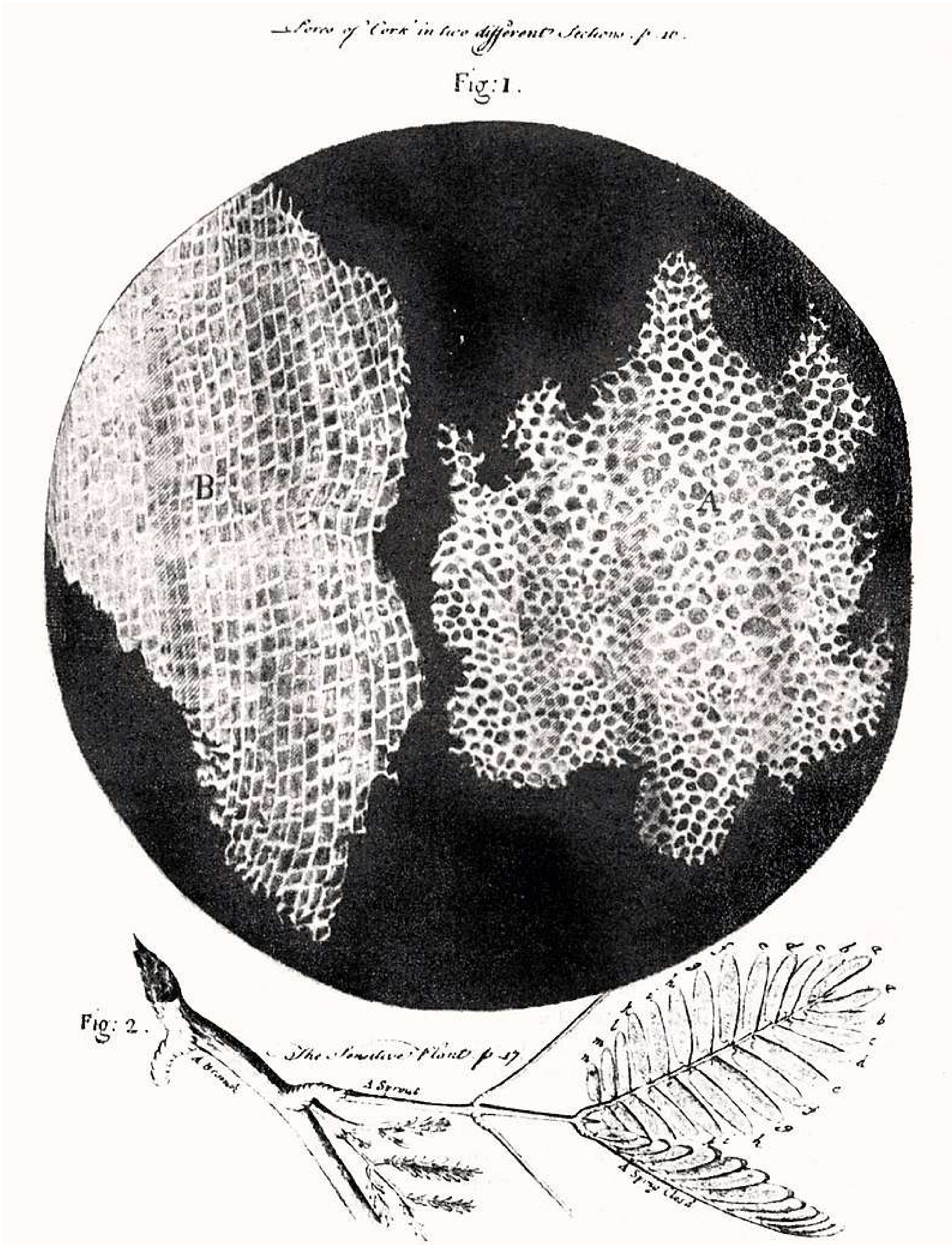

Figure 3.8: **Hooke was the first to apply the word "cell" to biological objects: Cork.**

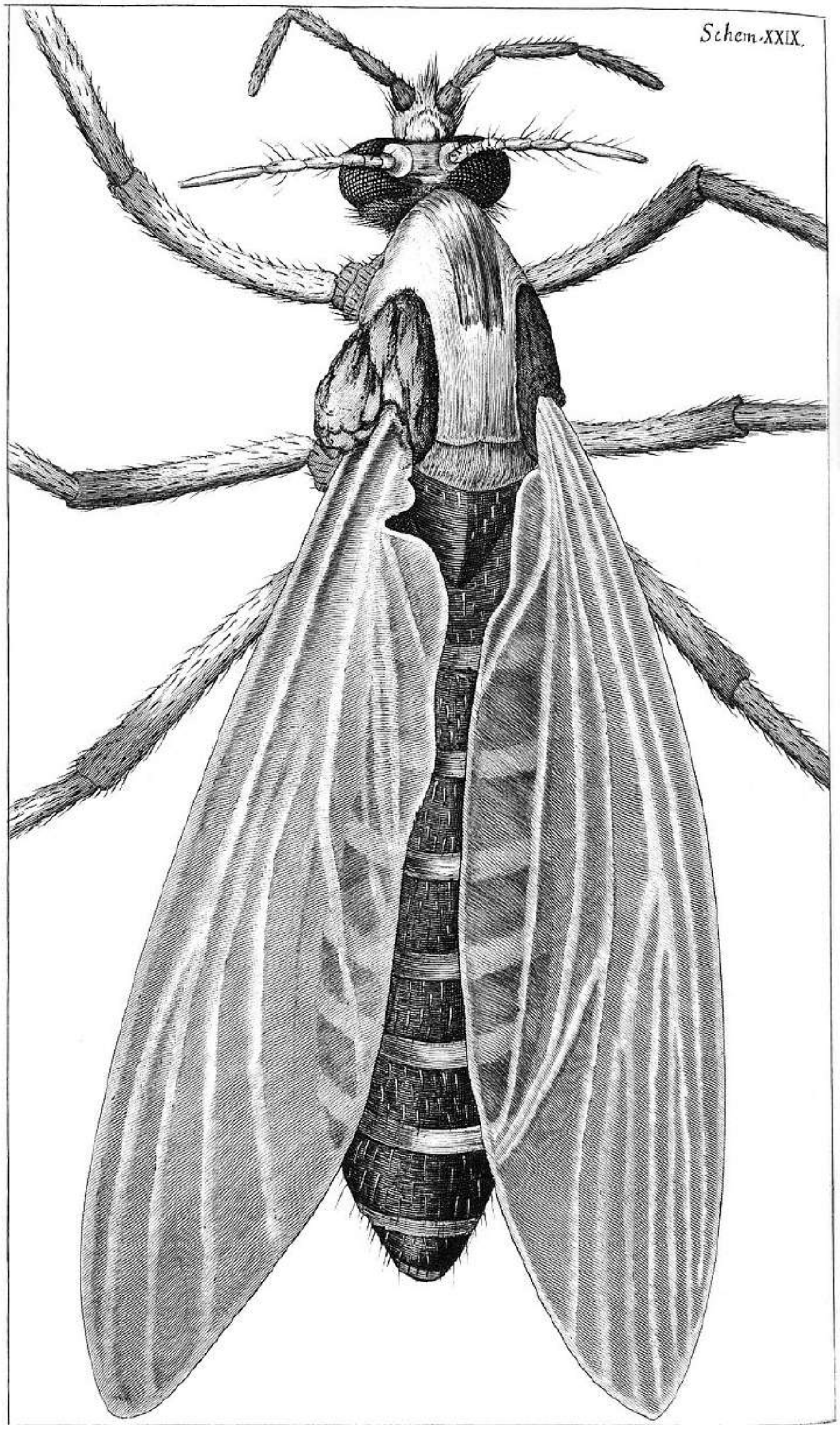

Figure 3.9: **Hooke's drawing of a gnat.**

Figure 3.10: **Hooke's drawing of a blue fly.**

to astronomy and the laws of gravitation, which brought him into conflict with Isaac Newton over questions of priority. Hooke went to Oxford University with Robert Boyle. He assisted Boyle by construction the air pump which Boyle used in his experiments. Hooke also contributed to our knowledge of the laws of elasticity ("Hooke Law). Hooke was one of the founding members of the Royal Society.

Here we will focus on Hooke's book, *Micrographia*, which became a popular best-seller. It opened up a new world to its readers. Below are quotations from one subsection of the book.

Observ. XLIX. Of an Ant or Pismire.

This was a creature, more troublesome to be drawn, then any of the rest, for I could not, for a good while, think of a way to make it suffer its body to ly quiet in a natural posture; but whil'st it was alive, if its feet were fetter'd in Wax or Glew, it would so twist and wind its body, that I could not any wayes get a good view of it; and if I killed it, its body was so little, that I did often spoil the shape of it, before I could throughly view it: for this is the nature of these minute Bodies, that as soon, almost, as ever their life is destroy'd, their parts immediately shrivel, and lose their beauty; and so is it also with small Plants, as I instanced before, in the description of Moss. And thence also is the reason of the variations in the beards of wild Oats, and in those of Musk-grass seed, that their bodies, being exceeding small, those small variations which are made in the surfaces of all bodies, almost upon every change of Air, especially if the body be porous, do here become sensible, where the whole body is so small, that it is almost nothing but surface; for as in vegetable substances, I see no great reason to think, that the moisture of the Aire (that, sticking to a wreath'd beard, does make it untwist) should evaporate, or exhale away, any faster then the moisture of other bodies, but rather that the avolation from, or access of moisture to, the surfaces of bodies being much the same, those bodies become most sensible of it, which have the least proportion of body to their surface. So is it also with Animal substances; the dead body of an Ant, or such little creature, does almost instantly shrivel and dry, and your object shall be quite another thing, before you can half delineate it, which proceeds not from the extraordinary exhalation, but from the small proportion of body and juices, to the usual drying of bodies in the Air, especially if warm. For which inconvenience, where I could not otherwise remove it, I thought of this expedient.

I took the creature, I had design'd to delineate, and put it into a drop of very well rectified spirit of Wine, this I found would presently dispatch, as it were, the Animal, and being taken out of it, and lay'd on a paper, the spirit of Wine would immediately fly away, and leave the Animal dry, in its natural posture, or at least, in a constitution, that it might easily with a pin be plac'd, in what posture you desired to draw it, and the limbs would so remain, without either moving, or shriveling. And thus I dealt with this Ant, which I have here delineated, which was one of many, of a very large kind, that inhabited under the Roots of a Tree, from whence they would sally out in great parties, and make most grievous havock of the Flowers and Fruits, in the ambient Garden, and return back again very expertly, by the same wayes and paths they went.

It was more then half the bigness of an Earwig, of a dark brown, or reddish colour, with long legs, on the hinder of which it would stand up, and raise its head as high as it could above the ground, that it might stare the further about it, just after the same manner as I have also observ'd a hunting Spider to do: and putting my finger towards them, they have at first all run towards it, till almost at it; and then they would stand round about it, at a certain distance, and smell, as it were, and consider whether they should any of them venture any further, till one more bold then the rest venturing to climb it, all the rest, if I would have suffered them, would have immediately followed: many such other seemingly rational actions I have observ'd in this little Vermine with much pleasure, which would be too long to be here related; those that desire more of them may satisfie their curiosity in Ligons History of the Barbadoes. Having insnar'd several of these into a small Box, I made choice of the tallest grown among them, and separating it from the rest, I gave it a Gill of Brandy, or Spirit of Wine, which after a while e'en knock'd him down dead drunk, so that he became moveless, though at first putting in he struggled for a pretty while very much, till at last, certain bubbles issuing out of its mouth, it ceased to move; this (because I had before found them quickly to recover again, if they were taken out presently) I suffered to lye above an hour in the Spirit; and after I had taken it out, and put its body and legs into a natural posture, remained moveless about an hour; but then, upon a sudden, as if it had been awaken out of a drunken sleep, it suddenly reviv'd and ran away; being caught, and serv'd as before, he for a while continued struggling and striving, till at last there issued several bubbles out of its mouth, and then, tanquam animam expirasset, he remained moveless for a good while; but at length again recovering, it was again redipt, and suffered to lye some hours in the Spirit; notwithstanding which, after it had layen dry some three or four hours, it again recovered life and motion: Which kind of Experiments, if prosecuted, which they highly deserve, seem to me of no inconsiderable use towards the invention of the Latent Scheme, (as the Noble Verulam calls it) or the hidden, unknown Texture of Bodies.

Of what Figure this Creature appear'd through the Microscope, the 32. Scheme (though not so carefully graven as it ought) will represent to the eye, namely, That it had a large head AA, at the upper end of which were two protuberant eyes, pearl'd like those of a Fly, but smaller BB; out of the Nose, or foremost part, issued two horns CC, of a shape sufficiently differing from those of a blew Fly, though indeed they seem to be both the same kind of Organ, and to serve for a kind of smelling; beyond these were two indented jaws DD, which he open'd side-wayes, and was able to gape them asunder very wide; and the ends of them being armed with teeth, which meeting went between each other, it was able to grasp and hold a heavy body, three or four times the bulk and weight of its own body: It had only six legs, shap'd like those of a Fly, which, as I shewed before, is an Argument that it is a winged Insect, and though I could not perceive any sign of them in the middle part of its body (which seem'd to consist of three joints or pieces EFG, out of which sprung two legs), yet 'tis known that there are of them that have long wings, and fly up and down in the air.

The third and last part of its body III was bigger and larger then the other two, unto which it was joyn'd by a very small middle, and had a kind of loose shell, or another distinct part of its body H, which seem'd to be interpos'd, and to keep the thorax and belly from touching.

The whole body was cas'd over with a very strong armour, and the belly III was covered likewise with multitudes of small white shining brisles; the legs, horns, head, and middle parts of its body were bestuck with hairs also, but smaller and darker.

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Chapter 4

ROBERT BOYLE

4.1 Robert Boyle: The last alchemist or the first modern chemist?

"Son of the Earl of Cork and father of chemistry"

Robert Boyle (1627-1691) was born in Ireland, the seventh son and fourteenth child of the immensely rich 1st Earl of Cork. As a very young boy, Boyle was privately tutored in Latin, Greek and French. When he was eight years old, following the death of his mother, he was sent to England to be educated at Eton College.

After three years at Eton, Boyle traveled to continental Europe with a French tutor. Galileo Galilei was still alive at that time, and they visited him in Florence. Undoubtedly, Galileo's insistence on adherence to strictly experimental methods made a strong impression on the youthful Boyle.

In 1644, Robert Boyle, then 17 years old, returned to England with a strong interest in scientific research. With the death of his father, he had inherited sunstancial estates in Ireland, as well as a mansion in Stalbridge, Dorset, England. He lived at Stalbridge between 1644 and 1652, and performed many of his experiments there. He also became a very active member of the "invisible college", which later developed into the Royal Society of London. He visited his Irish estates between 1652 and 1654, but found it difficult to do experimental work in Ireland because of the lack of proper equipment.

In 1654 Robert Boyle moved to Oxford, where he was better able to perform his experiments. He rented a large apartment there, and hired Robert Hooke as his scientific assistant. Together they built an air pump, with which Boyle established the fact that at a constant temperature, the volume of any gas is inversely proportional to the pressure, a relationship that has come to be known as Boyle's Law.

Robert Boyle's last 20 years were spent in the London home of his sister Katherine, with whom he shared all his scientific discussions and ideas. He and his sister worked together on many problems and experiments. Katherine's salon brought Boyle into contact with many important intellectuals of the time, and thus widened his influence.

Although Robert Boyle was an experimentalist, and thus a pioneer of modern chemistry, he was also an alchemist, He believed the transmutation of base metals into silver and gold to be possible. Boyle even helped to achieve the 1689 repeal of a statute forbidding the "multiplication of gold".

Important scientific publications of Robert Boyle

- 1660 - New Experiments Physico-Mechanical: Touching the Spring of the Air and their Effects
- 1661 - The Sceptical Chymist
- 1662 - Whereunto is Added a Defence of the Authors Explication of the Experiments, Against the Obiections of Franciscus Linus and Thomas Hobbes (a book-length addendum to the second edition of New Experiments Physico-Mech anical)
- 1663 - Considerations touching the Usefulness of Experimental Natural Philosophy (followed by a second part in 1671)
- 1664 - Experiments and Considerations Touching Colours, with Observations on a Diamond that Shines in the Dark
- 1665 - New Experiments and Observations upon Cold
- 1666 - Hydrostatical Paradoxes
- 1666 - Origin of Forms and Qualities according to the Corpuscular Philosophy. (A continuation of his work on the spring of air demonstrated that a reduction in ambient pressure could lead to bubble formation in living tissue. This description of a viper in a vacuum was the first recorded description of decompression sickness.)
- 1669 - A Continuation of New Experiments Physico-mechanical, Touching the Spring and Weight of the Air, and Their Effects
- 1670 - Tracts about the Cosmical Qualities of Things, the Temperature of the Subterraneal and Submarine Regions, the Bottom of the Sea, etc. with an Introduction to the History of Particular Qualities
- 1672 - Origin and Virtues of Gems
- 1673 - Essays of the Strange Subtilty, Great Efficacy, Determinate Nature of Effluviums
- 1674 - Two volumes of tracts on the Saltiness of the Sea, Suspicions about the Hidden Realities of the Air, Cold, Celestial Magnets
- 1674 - Animadversions upon Mr. Hobbes's Problemata de Vacuo
- 1676 - Experiments and Notes about the Mechanical Origin or Production of Particular Qualities, including some notes on electricity and magnetism
- 1678 - Observations upon an artificial Substance that Shines without any Preceding Illustration

  1680 - The Aerial Noctiluca
- 1682 - New Experiments and Observations upon the Icy Noctiluca (a further continuation of his work on the air)
- 1684 - Memoirs for the Natural History of the Human Blood
- 1685 - Short Memoirs for the Natural Experimental History of Mineral Waters

- 1686 - A Free Enquiry into the Vulgarly Received Notion of Nature
- 1690 - Medicina Hydrostatica
- 1691 - Experimenta et Observationes Physicae

Figure 4.1: **Robert Boyle (1627-1691).**

Figure 4.2: **Robert Hooke (1635-1703). As a young man, he worked as Robert Boyle's assistant during Boyle's stay at Oxford University, helping Boyle to construct his improved air pump. Hooke later made many important contributions to microscopy, physics and astronomy.**

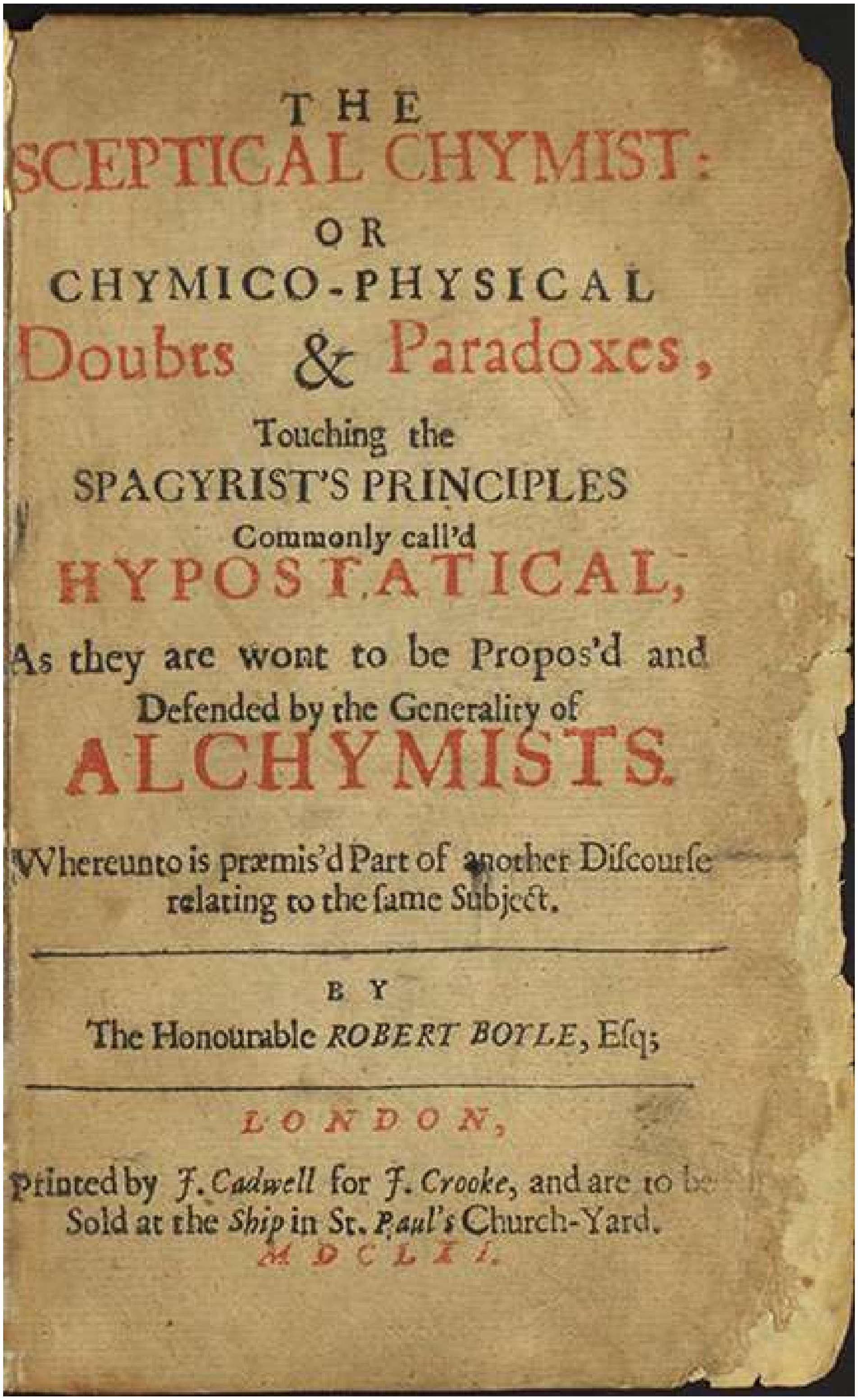

Figure 4.3: **Frontpeice of Boyle's book *The Sceptical Chymist.* Like some of Galileo's books, it is written in the form of a dialogue.**

4.2 Development of the steam engine

The discovery of atmospheric pressure

Early steam engines made use of the pressure of the atmosphere, and in fact it was the discovery of atmospheric pressure that led to the invention of the steam engine. Aristotle had maintained "nature abhors a vacuum", but this doctrine was questioned by the Italian physicist Evangelesta Torricelli (1608-1647), who invented the barometer in 1643.

Pump makers working for the Grand Duke of Tuscany had found that suction pumps were unable to raise water to heights greater than 10 meters (in today's units). Attempting to understand why this should be the case, Torricelli filled an approximately 1-meter-long glass tube with mercury, which is 14 times denser than water. The tube was sealed at one end, and open at the other. He then immersed the open end in a dish of mercury, and raised the sealed end, so that the tube was in a vertical position. Part of the mercury flowed out of the tube into the dish, leaving a 76-centimeter-high column of mercury, and 24 centimeters of empty space at the top. The empty space contained what we now call a Torricellian vacuum.

This experiment enabled Torricelli to understand why the Grand Duke's suction pumps were unable to raise water to a height greater than 10 meters. Torricelli realized that both the 10 meter column of water (the maximum that could be achieved), and the (equally heavy) 76 centimeter column of mercury, were held in place by the weight of the atmosphere, which they exactly balanced. Later experiments soon demonstrated that the height of the column of mercury in Torricelli's barometer depended on the weather, and on height above sea level. Summarizing his experiments, Torricelli wrote: "We live submerged at the bottom of an ocean of elementary air, which is known by incontestable experiments to have weight."

Torricelli's experiments marked the start of period where, throughout Europe, much interest was focused on experiments with gases. In 1650 Otto von Guericke, the Mayor of Magdeburg Germany, invented the first vacuum pump. In a dramatic experiment, performed in 1663 in the presence of Frederick Wilhelm I of Brandenburg, von Guericke's assistants fitted two large copper hemispheres together, after the joining surfaces had been carefully greased to make the junction airtight. Von Guericke's pump was then used to evacuate the volume within the hemispheres. To the amazement of the watching crowd, a team of 24 horses, 12 on each side, strained at the hemispheres but failed to separate them. Von Guericke explained that it was the pressure of the atmosphere that held the hemispheres so tightly together, and he demonstrated that when air was allowed to enter the interior volume, the hemispheres could be separated without effort.

Steam engines using atmospheric pressure

Continuing the vogue for experiments with gases and pumps that was sweeping across Europe, Edward Somerset, the 2nd Marquess of Worcester, designed steam-powered pumps to bring water from wells to fountains. He published the designs for his engines in 1663,

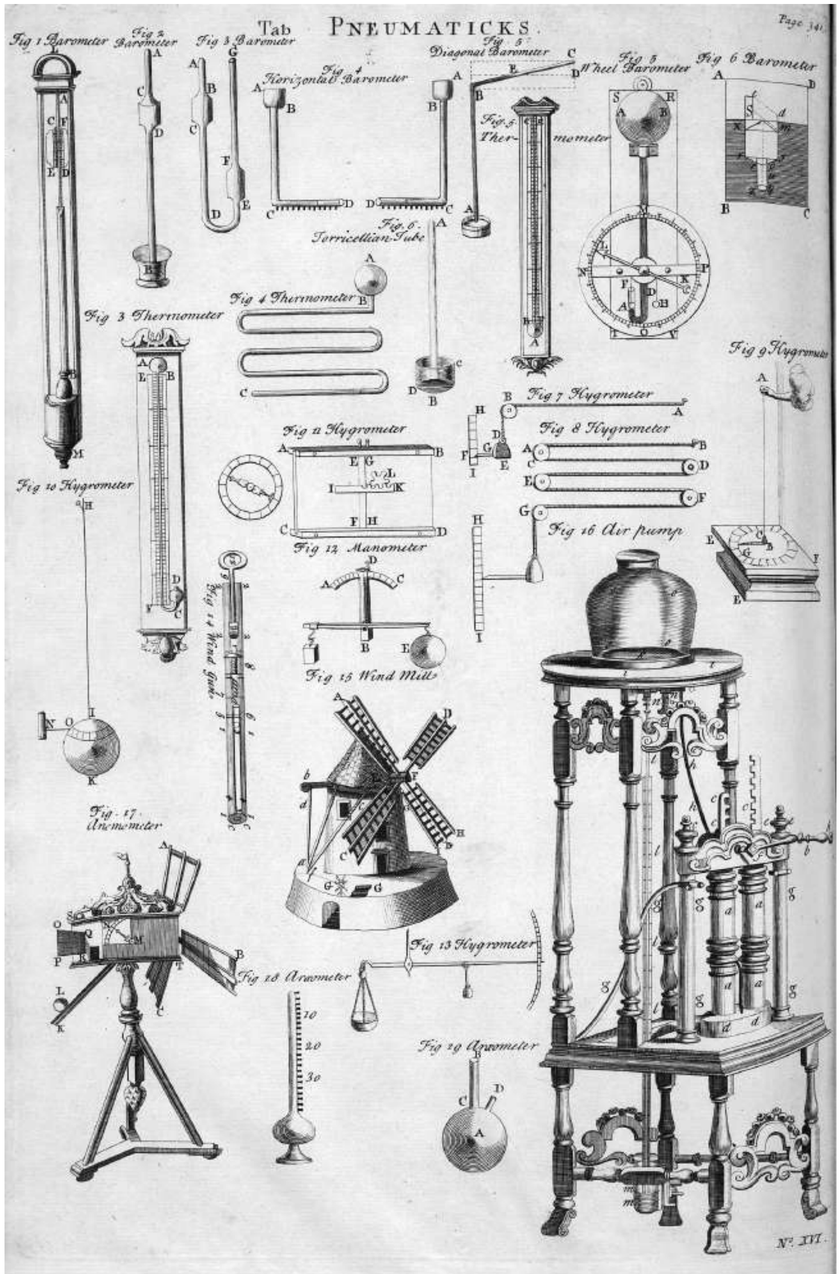

Figure 4.4: **"Table of Pneumaticks" (1728).**

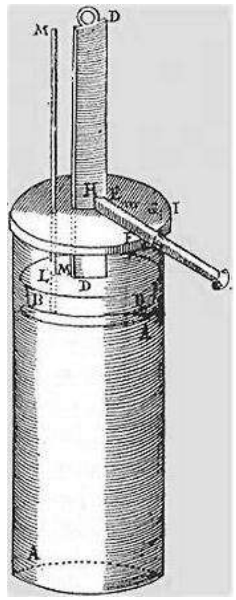

Figure 4.5: **The French physicist Papin's design for a steam engine (1690).**

and he may have installed pumps built according to these designs at Vauxhall House in London. In the 1680's a number of steam-powered pumps were constructed for Louis XIV of France by Sir Samuel Morland (1625-1695), who lived in Vauxhall and may have been influenced by Somerset's ideas.

Meanwhile, in France, the physicist Denis Papin (1647-1712) had become interested in the motive force of steam. Together with Gottfried Leibniz he invented the pressure cooker, and he also invented designs for steam engines. Some of Papin's steam engine designs were presented to the Royal Society between 1707 and 1712, without acknowledgment or payment, and this caused Papin to complain bitterly. He died soon afterward.

In 1698, the English inventor Thomas Savery (1650-1715) patented a steam engine for pumping water. It had no piston, but used condensing steam and atmospheric pressure to bring up the water by means of a siphon principle. It was therefore useless for pumping water from very deep mines, although Savery described it as the "Miner's Friend". Savery's design was so similar to Somerset's that it was probably a direct copy.

The ironmonger Thomas Newcomen's "atmospheric-engine" of 1712 proved to be much more practical for pumping water from the deep mines of Cornwall. Newcomen was forced to go into a partnership with Savery because of the latter's patent, and he also used some of Papin's ideas. An important feature of Newcomen's engine was a beam that transmitted power from the working piston to a pump at the base of the mineshaft. In Newcomen's engine, steam entered the cylinder, driving the piston upward. A jet of water was then sprayed into the interior of the cylinder, condensing the steam and allowing atmospheric pressure to drive the piston down. Early models of the engine operated slowly, and the valves were opened and closed by hand. Later, the opening and closing of the valves was performed automatically by means of the "potter cord". According to legend this device is named after a boy, Humphrey Potter, who in 1713 had been given the job of opening and closing the valves. Wishing to play with his friends, he invented the automatic mechanism.

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Chapter 5

17TH CENTURY POETS

5.1 John Milton, 1608-1674

How Soon Hath Time

How soon hath Time, the subtle thief of youth,
Stoln on his wing my three and twentieth year!
My hasting days fly on with full career,
But my late spring no bud or blossom shew'th.
Perhaps my semblance might deceive the truth,
That I to manhood am arrived so near,
And inward ripeness doth much less appear,
That some more timely-happy spirits endu'th.
Yet be it less or more, or soon or slow,
It shall be still in strictest measure even
To that same lot, however mean or high,
Toward which Time leads me, and the will of Heaven;
All is, if I have grace to use it so,
As ever in my great Taskmaster's eye.

On His Blindness

When I consider how my light is spent
Ere half my days in this dark world and wide,
And that one talent which is death to hide
Lodg'd with me useless, though my soul more bent
To serve therewith my Maker, and present
My true account, lest he returning chide,
"Doth God exact day-labour, light denied?"
I fondly ask. But Patience, to prevent

That murmur, soon replies: "God doth not need
Either man's work or his own gifts: who best
Bear his mild yoke, they serve him best. His state
Is kingly; thousands at his bidding speed
And post o'er land and ocean without rest:
They also serve who only stand and wait."

Eve speaks to Adam, from Paradise Lost

With thee conversing I forget all time;
All seasons, and their change, all please alike.
Sweet is the breath of Morn, her rising sweet,
With charm of earliest birds: pleasant the sun,
When first on this delightful land he spreads
His orient beams, on herb, tree, fruit, and flower,
Glistering with dew; fragrant the fertile earth
After soft showers; and sweet the coming on
Of grateful Evening mild; then silent Night
With this her solemn bird and this fair moon,
And these the gems of Heaven, her starry train:
But neither breath of Morn when she ascends
With charm of earliest birds; nor rising sun
On this delightful land, nor herb, fruit, flower,
Glistering with dew; nor fragrance after showers;
Nor grateful Evening mild; nor silent Night
With this her solemn bird; nor walk by moon,
Or glittering star-light without thee is sweet

Figure 5.1: **John Milton is best known for his epic poem, *Paradise Lost*, which is considered to be one of the finest compositions in the English language. He lived at a time of civil war in England and was on the side of the victorious Parliamentarians. As a result, he held governmental offices until the restoration of the monarchy in 1660. By that time, Milton was completely blind, but he continued to write.**

5.2 Abdrew Marvelle, 1621-1678

To his coy mistress

Had we but world enough and time,
This coyness, lady, were no crime.
We would sit down, and think which way
To walk, and pass our long love's day.
Thou by the Indian Ganges' side
Shouldst rubies find; I by the tide
Of Humber would complain. I would
Love you ten years before the flood,
And you should, if you please, refuse
Till the conversion of the Jews.
My vegetable love should grow
Vaster than empires and more slow;
An hundred years should go to praise
Thine eyes, and on thy forehead gaze;
Two hundred to adore each breast,
But thirty thousand to the rest;
An age at least to every part,
And the last age should show your heart.
For, lady, you deserve this state,
Nor would I love at lower rate.
But at my back I always hear
Time's wingÃ¨d chariot hurrying near;
And yonder all before us lie
Deserts of vast eternity.
Thy beauty shall no more be found;
Nor, in thy marble vault, shall sound
My echoing song; then worms shall try
That long-preserved virginity,
And your quaint honour turn to dust,
And into ashes all my lust;
The grave's a fine and private place,
But none, I think, do there embrace.
Now therefore, while the youthful hue
Sits on thy skin like morning dew,
And while thy willing soul transpires
At every pore with instant fires,
Now let us sport us while we may,
And now, like amorous birds of prey,
Rather at once our time devour

Than languish in his slow-chapped power.
Let us roll all our strength and all
Our sweetness up into one ball,
And tear our pleasures with rough strife
Through the iron gates of life:
Thus, though we cannot make our sun
Stand still, yet we will make him run.

Figure 5.2: **Portrait of Andrew Marvelle, attributed to Sir Godfrey Kneller, Trinity College, Cambridge.**

5.3 Juana Inéz de le Cruz, 1648-i695

Juana Inéz de le Cruz was born in San Miguel Nepantla, Tepetlixpa, Mexico. It quickly became apparent that she was a child prodigy. By the age of three, she could read. At six she began to ask permission to cut her hair short so that she could disguise herself as a boy and attend university. At eight, she began to write poetry. At nine, she was learning Latin.

By the time Juana was 16, she was giving lessons in Latin, studying Greek logic, and learning Nahuatl, an Aztec language. She was not only extremely intelligent and entirely self-taught, but also beautiful,

Juana's uncle and aunt, with whom she had been sent to live in Mexico City, presented her to the court of the viceroy, Marquis de Mancera, and in this way she entered the service of his wife.

Because of rumors of Juana's high intelligence, the viceroy decided to test it, and he assembled a panel of scholars to test her knowledge. In the Viceroy's words, Juana sailed through the panel's questions "like a royal galleon defending itself against a few rowing boats".

After four years in the court of the viceroy, Juana entered the Convent of San Jerónimo, where she lived until her death. There she amassed a library of 4,000 books, as well as musical and mathematical instruments. Among her writings was a declaration of the rights of women. She died during an epidemic of the plague, while caring for other members of the convent. Two examples of her many poems are given below.

Love upened a mortal wound

Love opened a mortal wound.
In agony, I worked the blade
to make it deeper. Please,
I begged, let death come quick.

Wild, distracted, sick,
I counted, counted
all the ways love hurt me.
One life, I thought - a thousand deaths.

Blow after blow, my heart
couldn't survive this beating.
Then - how can I explain it?

I came to my senses. I said,
Why do I suffer? What lover
ever had so much pleasure?

Caprice

Who thankless flees me, I with love pursue,
Who loving follows me, I thankless flee;
To him who spurns my love I bend the knee,
His love who seeks me, cold I bid him rue;
I find as diamond him I yearning woo,
Myself a diamond when he yearns for me;
Who slays my love I would victorious see,
While slaying him who wills me blisses true.
To favor this one is to lose desire,
To crave that one, my virgin pride to tame;
On either hand I face a prospect dire,
Whatever path I tread, the goal the same:
To be adored by him of whom I tire,
Or else by him who scorns me brought to shame.

Figure 5.3: **Sor Juana Inés de la Cruz by Miguel Cabrera.**

5.4 John Dryden, 1631-1700

Song: Fair Iris I love and hourly I die

Fair Iris I love and hourly I die,
But not for a lip nor a languishing eye:
She's fickle and false, and there I agree;
For I am as false and as fickle as she:
We neither believe what either can say;
And, neither believing, we neither betray.

'Tis civil to swear and say things, of course;
We mean not the taking for better or worse.
When present we love, when absent agree;
I think not of Iris, nor Iris of me:
The legend of love no couple can find
So easy to part, or so equally join'd.

Marriage a-la-Mode

Why should a foolish marriage vow,
Which long ago was made,
Oblige us to each other now
When passion is decay'd?
We lov'd, and we lov'd, as long as we could,
Till our love was lov'd out in us both:
But our marriage is dead, when the pleasure is fled:
'Twas pleasure first made it an oath.

If I have pleasures for a friend,
And farther love in store,
What wrong has he whose joys did end,
And who could give no more?
'Tis a madness that he should be jealous of me,
Or that I should bar him of another:
For all we can gain is to give our selves pain,
When neither can hinder the other.

Song: Calm was the even, and clear was the sky

Calm was the even, and clear was the sky,
And the new budding flowers did spring,
When all alone went Amyntas and I
To hear the sweet nightingale sing;
I sate, and he laid him down by me;
But scarcely his breath he could draw;
For when with a fear, he began to draw near,
He was dash'd with A ha ha ha ha!

He blush'd to himself, and lay still for a while,
And his modesty curb'd his desire;
But straight I convinc'd all his fear with a smile,
Which added new flames to his fire.
O Silvia, said he, you are cruel,
To keep your poor lover in awe;
Then once more he press'd with his hand to my breast,
But was dash'd with A ha ha ha ha!

I knew 'twas his passion that caus'd all his fear;
And therefore I pitied his case:
I whisper'd him softly, there's nobody near,
And laid my cheek close to his face:
But as he grew bolder and bolder,
A shepherd came by us and saw;
And just as our bliss we began with a kiss,
He laugh'd out with A ha ha ha ha!

Figure 5.4: **Dryden, by John Michael Wright, 1668.**

5.5 Basho, 1644-1694

Autumn Moonlight

Autumn moonlight–
a worm digs silently
into the chestnut.

A Bee

A bee
staggers out
of the peony.

A Snowy Morning

A snowy morning–
by myself,
chewing on dried salmon.

A Monk Sips Morning Tea

A monk sips morning tea,
it's quiet,
the chrysanthemum's flowering.

In Kyoto

In Kyoto,
hearing the cuckoo,
I long for Kyoto.

Figure 5.5: **Portrait of Basho by Hokusai.**

5.6 Tukaram, 1608-1650

Words are the jewels

Words are the jewels
That our homes are filled with
The tools that we strive with
Are but of words
Words are the source
That sustains our life
Wealth of words we give
To one and all
Tuka says behold
Word is the Lord
Let us praise Him
Worship with words

The destitute and the downtrodden

The destitute and the downtrodden
Who considers as his own
He alone is to be recognised as Saint
God is to be experienced only therewith
Tender through and through is butter
So is the heart of the good
Those who are forsaken
He takes them in loving embrace
Mercy meant for own son
He shows to servants and maids too
Tuka says can't praise him enough
He is the Lord incarnate

An Imitation Of Anacreon

Painter in Paphos and Cythera famed
Depict, I pray, the absent Iris' face.
Thou hast not seen the lovely nymph I've named;
The better for thy peace.–Then will I trace
For thy instruction her transcendent grace.
Begin with lily white and blushing rose,
Take then the Loves and Graces... But what good
Words, idle words? for Beauty's Goddess could
By Iris be replaced, nor one suppose

Figure 5.6: **Portrait of Saint Tukaram.**

The secret fraud–their grace so equal shows.
Thou at Cythera couldst, at Paphos too,
Of the same Iris Venus form anew.

5.7 Jean de la Fontaine, 1621-1695

Alice Sick

Sick, Alice grown, and fearing dire event,
Some friend advised a servant should be sent
Her confessor to bring and ease her mind;–
Yes, she replied, to see him I'm inclined;
Let father Andrew instantly be sought:–
By him salvation usually I'm taught.

A messenger was told, without delay,
To take, with rapid steps, the convent way;
He rang the bell–a monk enquired his name,
And asked for what, or whom, the fellow came.
I father Andrew want, the wight replied,
Who's oft to Alice confessor and guide:
With Andrew, cried the other, would you speak?
If that's the case, he's far enough to seek;
Poor man! he's left us for the regions blessed,
And has in Paradise ten years confessed.

Figure 5.7: **Jean de la Fontaine, one of the most widely read French poets of the 17th century. He is known especially for his fables. His image can be found on French paintings, statues, medals, coins and postage stamps.**

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Chapter 6

17TH CENTURY COMPOSERS

6.1 Claudio Monteverdi

Italy during Monteverdi's lifetime

We speak of Claudio Monteverdi as an Italian composer, but it would perhaps be more correct to call him Venetian. During the time when he lived, Italy has no political unity. It was instead a collection of small states which were frequently at war with each other. Among these small states, Venice was the most prosperous and progressive, artistically developed and with freedom of expression for its citizens.

Composer of madrigals

During the course of his life, Claudio Monteverdi composed nine books of madrigals. What are madrigals? They are a form of secular choral music, usually for soprano, alto, tenor and bass, and almost always relating to love, passion, jealousy and so on. During the Renaissance and Baroque periods, singing madrigals was a frequent after-dinner pass-time among well-educated people.

Musical director of St. Mark's Cathedral in Venice

In 1613, Monteverdi became the musical director of the famous St. Mark's Cathedral in Venice (Basilico San Marco). He remained in this position for many years, and was given a generous salery. His duties included not only recruiting and instructing choir members and instrumentalists, but also composing works to celebrate special occasions, such as Holy Cross Day, Christmas Eve. and celebrations of the Doge. Monteverdi introduced works written in a more modern style into the repertoire of San Marcdo. His duties left him with some free time, and he used this to contribute compositions to other churches in Venice.

Pioneer of opera

Wikipedia states that **"The Italian composer Claudio Monteverdi (1567-1643), in addition to a large output of church music and madrigals, wrote prolifically for the stage. His theatrical works were written between 1604 and 1643 and included operas, of which three - *L'Orfeo* (1607), *Il ritorno d'Ulisse in patria* (1640) and *L'incoronazione di Poppea* (1643) - have survived with their music and librettos intact. In the case of the other seven operas, the music has disappeared almost entirely, although some of the librettos exist. The loss of these works, written during a critical period of early opera history, has been much regretted by commentators and musicologists."**

Figure 6.1: **Claudio Monteverdi.**

6.2 Jean-Baptiste Lully

Lully's early life

Jean-Baptiste Lully (1632-1687) was born i Florence, Italy. When he was 14 years old, Lully, dressed as a Harlequin, entertained bystanders at the Mardi Gras celebrations by his violin playing and clowning. In this way he attracted the attention of the chevalier de Guise, son of Charles, Duke of Guise, who was looking for someone to converse in Italian with his niece, Anne Marie Louise d'Orléans, Duchess of Montpensier. Thus, as a boy, Lully was brought to France, where he entered the service of the duchess. He probably honed his musical skills by learning from the court musicians.

Work in the court of Louis XIV of France

Lully spent most of his career working in the court of Louis XIV. By 1653, Lully had attracted the attention of the young Louis XIV, dancing with him in the *Ballet royal de la nuit*. Lully was then appointed as royal composer, and he soon made himself indespensible by composing both vocal and instrumental music for the court's ballets. He later became superintendent of the royal music and music master of the royal family.

Collaboration with Molière

Wikipedia states that **"He [Lully] was a close friend of the playwright Molière, with whom he collaborated on numerous comédie-ballets, including *L'Amour médecin, George Dandin ou le Mari confondu, Monsieur de Pourceaugnac, Psyché* and his best known work, *Le Bourgeois gentilhomme*."**

Lully's strange and tragic death

Jean-Baptiste Lully died in a strange and tragic way. While conducting with a very long and heavy baton, he accidentally struck and wounded his foot. The foot became gangrenous, and doctors recommended that Lully's leg should be amputated. However, Lully refused to have this operation performed, because he so much wished to continue as a dancer. Thus the gangrene spread throughout poor Lully's body, and he died.

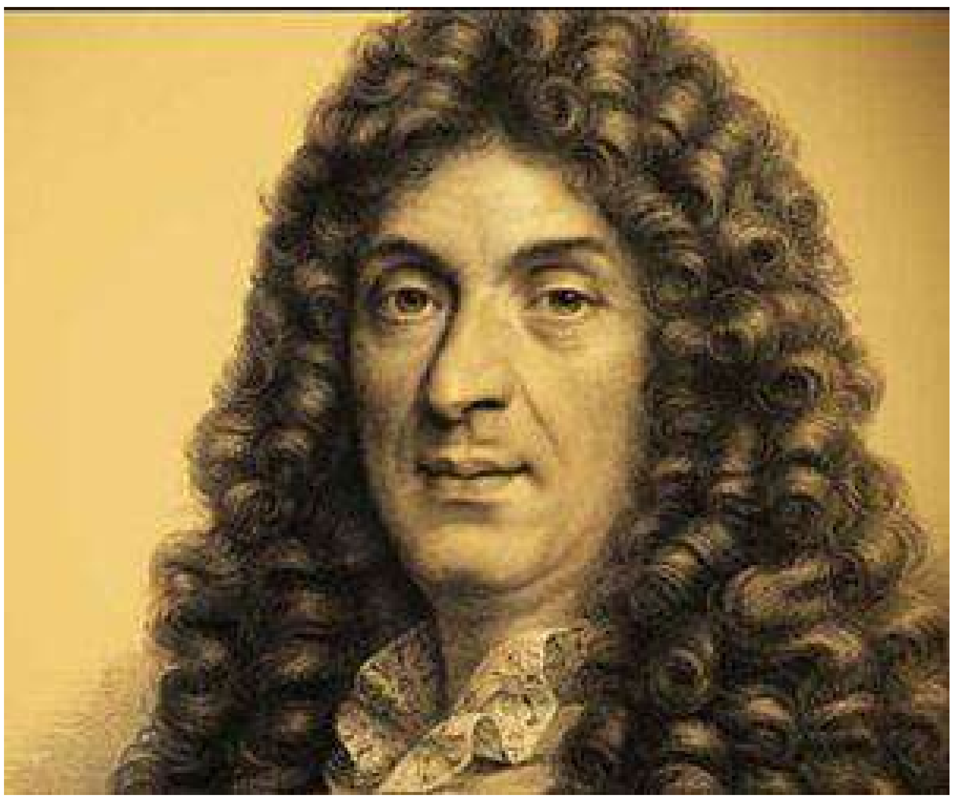

Figure 6.2: **Jean-Baptiste Lully.**

6.3 Johann Paschelbel

Organist and composer

Johann Paschelbel (1653-1706) was born in Nuremberg, Germany to middle-class parents. He was given a musical education, In 1677 he became the court organist in the employ of Johann Georg I, Duke of Saxe-Eisenach.

Friendship with the Bach family

In Eisenach, Paschelbel met, and became a close family friend of, the Bach family, including Johann Ambrosius Bach, the father of Johann Sebastian Bach. Wikipedia states that **"Paschelbel became godfather to Johann Ambrosius' daughter, Johanna Juditha, taught Johann Christoph Bach (1671-1721), Johann Sebastian's eldest brother, and lived in Johann Christian Bach's (1640-1682) house."**

Pachelbel's most famous works

Wikipedia states that **"He composed a large body of sacred and secular music, and his contributions to the development of the chorale prelude and fugue have earned him a place among the most important composers of the middle Baroque era... Today, Paschelbel is best known for the *Canon in D*; other well known works include the *Chaconne in F minor*, the *Toccata in E minor for organ*, and the *Hexachordum Apollinis*, a set of keyboard variations."**

Paschelbel's compositions were immensely popular during his own lifetime, and they are performed and admired today.

Figure 6.3: **Johann Paschelbel.**

6.4 Dieterich Buxtehude

Buxtehude's early life and education

Helsingborg and Helsingør lie on opposites of a narrow sound that separates today's Sweden from Denmark. In the 17th century, both sides were part of Denmark. Dieterich Buxtehude (1637-1707) was born in Helsingborg, which is today part of Sweden. His father, Johannes Buxtehude, was the organist at St. Olaf's Church in Helsingør. Undoubtedly, Dieterich received a musical education from his father.

Organist in Helsingborg, Helsingør and Lübeck

For two years, 1657 and 1658, Dieterich Buxtehude worked as an organist in Helsingborg. Then during the period 166o-1668, he was the organist at St. Mary's Church in Helsingør, a church that still has the original organ on which Buxtehude played. Finally, his last post was in Lïbeck in northern Germany, at the Marienkirche. There, he married the daughter of the previous organist, Franz Tunder. Buxtehude and his wife had seven daughters.

Buxtehude's influence on Johann Sebastian Bach

J.S. Bach, who was then twenty years old, walked 400 kilometers to Lübeck to visit Buxtehude, who was then an old man. Bach stayed for three months to meet the famous organist, to hear him play and as Bach explained, "to comprehend one thing or another about his art". After visiting Buxthude for three months, Bach walked 400 kilometers back again.

Dieterich Buxtehude's legacy

Wikipedia states that

"The bulk of Buxtehude's oeuvre consists of vocal music, which covers a wide variety of styles, and organ works, which concentrate mostly on chorale settings and large-scale sectional forms. Chamber music constitutes a minor part of the surviving output, although the only chamber works Buxtehude published during his lifetime were fourteen chamber sonatas. Unfortunately, many of Buxtehude's compositions have been lost. The librettos for his oratorios, for example, survive; but none of the scores do, which is particularly unfortunate, because his German oratorios seem to be the model for later works by Johann Sebastian Bach and Georg Philipp Telemann. Further evidence of lost works by Buxtehude and his contemporaries can be found in the recently discovered catalogue of a 1695 music-auction in Lübeck"

Today, Buxtehude's compositions are regularly performed as part of the standard musical repertoire of churches.

Figure 6.4: **Dieterich Buxtehude.**

6.5 Archangelo Corelli

Corelli's childhood and musical education

Archangelo Corelli (1653-1713) was born in a northeastern district of Italy known as Romagna. There are many anecdotes about his early life and musical education, but these stories lack firm evidence.

Corelli's parents were prosperous land-owners, but they almost certainly did not belong to the nobility.

According to a friend who knew the composer well, Corelli initially studied music under a priest, before moving to Bologna in 1666. In Bologna, which at the time was a major musical center, Corelli studied the violin under several master violinists. The papal contralto, Matteo Simonelli is said to have taught him to compose in the "Palestrina style".

Professional success

Wikipedia states that

"In 1687 Corelli led the festival performances of music for Queen Christina of Sweden. He was also a favorite of Cardinal Pietro Ottoboni, grandnephew of another Cardinal Pietro Ottoboni, who in 1689 became Pope Alexander VIII. From 1689 to 1690 he was in Modena. The Duke of Modena was generous to him. In 1706 Corelli was elected a member of the Pontificia Accademia degli Arcadi (the Arcadian Academy of Rome). He received the Arcadian name of Arcomelo Erimanteo."

Corelli's influence on other composers

Corelli's compositions greatly influenced other composers. Johan Sebastian Bach studied the works of Corelli, and based an organ fugue on Corelli's Opus 3 of 1689. George Frederic Handel's Opus 6 Concerti Grossi use Corelli's earlier compositions as a model.

Corelli's wealth at the time of his death

At the time of his death, Archangelo Corelli was an extremely wealthy man. Besides possessing a fortune of marks, he also owned a valuable art collection and a collection of fine violins. He was buried in the Pantheon at Rome.

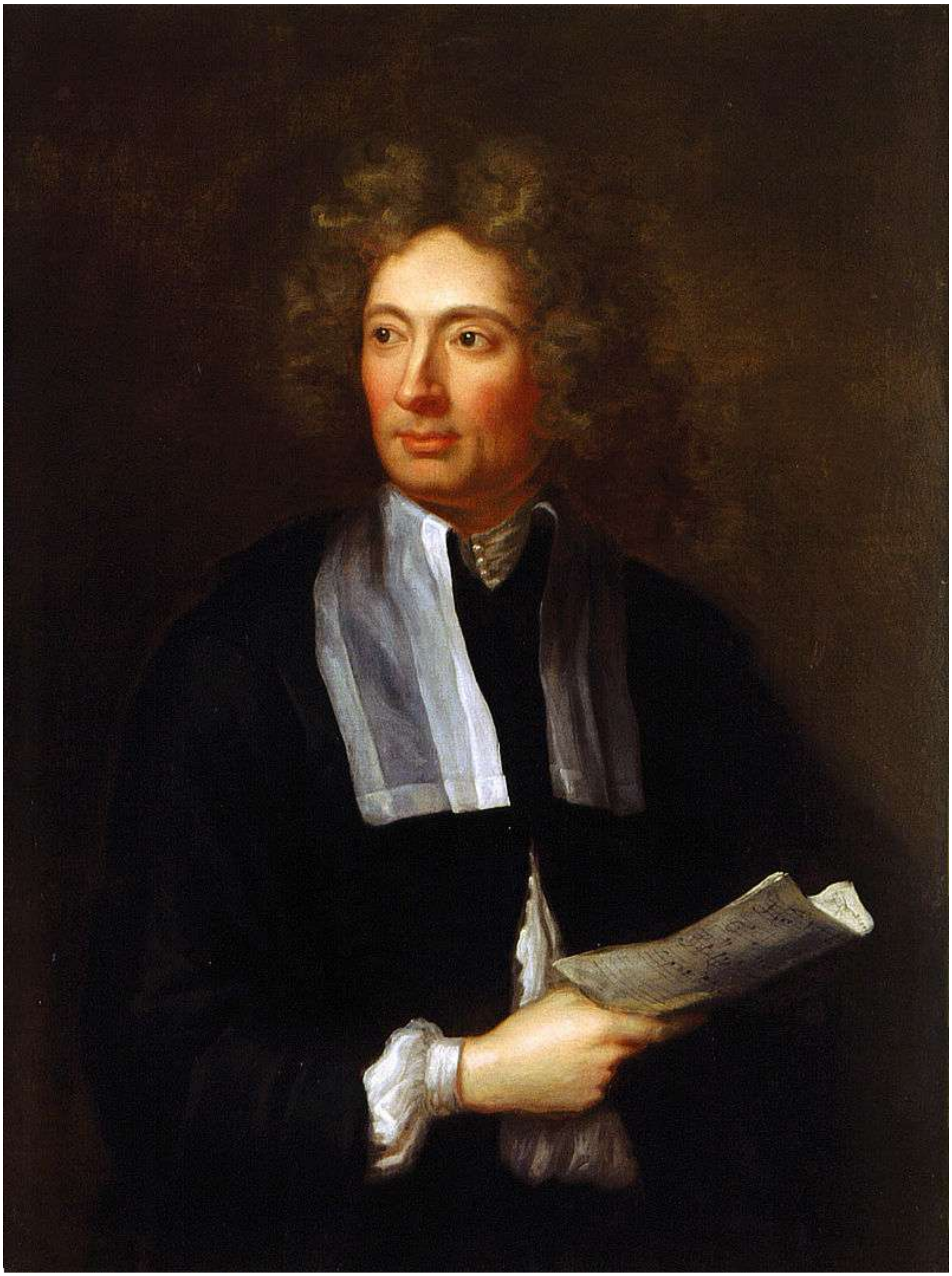

Figure 6.5: **Archangelo Corelli.**

6.6 Henry Purcell

A rebus on the name of Henry Purcell

Here is a poem composed by Purcell's friends, who also set it to music:

The mate of the cock, and corn tall as wheat,
Is the first name of him who in music's complete.
His surname begins with the noise of a cat,
And concludes with the home of a hermit, mark that!
His skill in performance each auditor wins,
But the poet deserves a good kick in the shins.

Purcell's life

Henry Purcell's (1659-1695) was born into a family of musicians. His first compositions were made at the age of nine, but the first presently existing composition that can certainly be attributed to him is his *Ode for the King's Birthday*, written when he was 11.

Wikipedia states that **"Purcell worked in many genres, both in works closely linked to the court, such as symphony song, to the Chapel Royal, such as the symphony anthem, and the theatre. Among Purcell's most notable works are his opera *Dido and Aeneas* (1688), his semi-operas *Diocletian* (1690), *King Arthur* (1691), *The Fairy-Queen* (1692) and *Timon of Athens* (1695), as well as the compositions *Hail! Bright Cecilia* (1692), *Come Ye Sons of Art* (1694) and *Funeral Sentences and Music for the Funeral of Queen Mary* (1695)."**

The greatest English composer until modern times

No native-born English composer approached Henry Purcell's fame, until the 20th century, when Edward Elgar, Ralph Vaughan Williams, Gustav Holst, William Walton and Benjamin Britten approached Purcell's level of recognition.

Purcell's early death, aged 35

Henry Purcell died at the young age of 35. One can only speculate at what he would have achieved if he had lived longer. The cause of his death is uncertain. One theory is that he caught a chill when returning late from the theatre, only to find that his wife had locked him out. Another theory is that he died of tuberculosis.

Figure 6.6: **Henry Purcell.**

6.7 Antonio Vivaldi

The "Red Priest"

Antonio Vivaldi was born in Venice, Italy. On the day of his birth, the city was shaken by an earthquake. His mother, terrified by the earthquake, may have prayed for deliverance and promised that her newborn son should become a priest. In any case. at the age of 15, Antonio Vivaldi began studying for the priesthood. He was nicknamed *il preto roso*, "The Red Priest", because of his hair color, a flaming red.

Virtuoso violinist and teacher

Antonio Vivaldi spent most of his working life as "master of violins" at an orphanage called *Pio Ospedale della Pietà* in Venice. The boys at the orphanage learned a trade and left at the age of 15, nut the girls were given a musical education and remained much longer. Under Vivaldi's direction, the girls' musical performances became renowned. Vivaldi himself, having been given a musical education by his father, became a virtuoso violinist and a prolific and highly influential composer. A German visitor who heard Vivaldi play said "The famous composer and violinist Vivaldi... played a solo accompaniment excellently, and at the conclusion he added a free fantasy [an improvised cadenza] which absolutely astounded me, for it is hardly possible that anyone has ever played, or ever will play, in such a fashion."

Some of Vivaldi's greatest compositions

Vivaldi composed more than 500 concerti and 97 operas, 50 of which survive. He also composed oratorios, motets, and large scale choral works, as well as many sonatas for violins and basso continuo, sonatas for cello, sonatas for flute, sonatas for oboe, sonatas for recorder and bassoon, and trio sonatas for violin and lute.

When we think of Vivaldi today, we immediately think of his set of four violin concerti entitled *The Four Seasons*. This famous and immensely popular composition was probably inspired by the countryside near to Mantra, where Vivaldi was staying when he composed it. In the composition we hear " flowing creeks, singing birds (of different species, each specifically characterized), barking dogs, buzzing mosquitoes, crying shepherds, storms, drunken dancers, silent nights, hunting parties from both the hunters' and the prey's point of view, frozen landscapes, ice-skating children, and warming winter fires."

Admired by the Holy Roman Emperor, Charles VI

Charles VI admired Vivaldi's music so much that he gave the composer the title of knight, a gold medal, and an invitation to Vienna. Vivaldi accepted the invitation, and moved, but Charles VI died, and Vivaldi himself also died soon afterward.

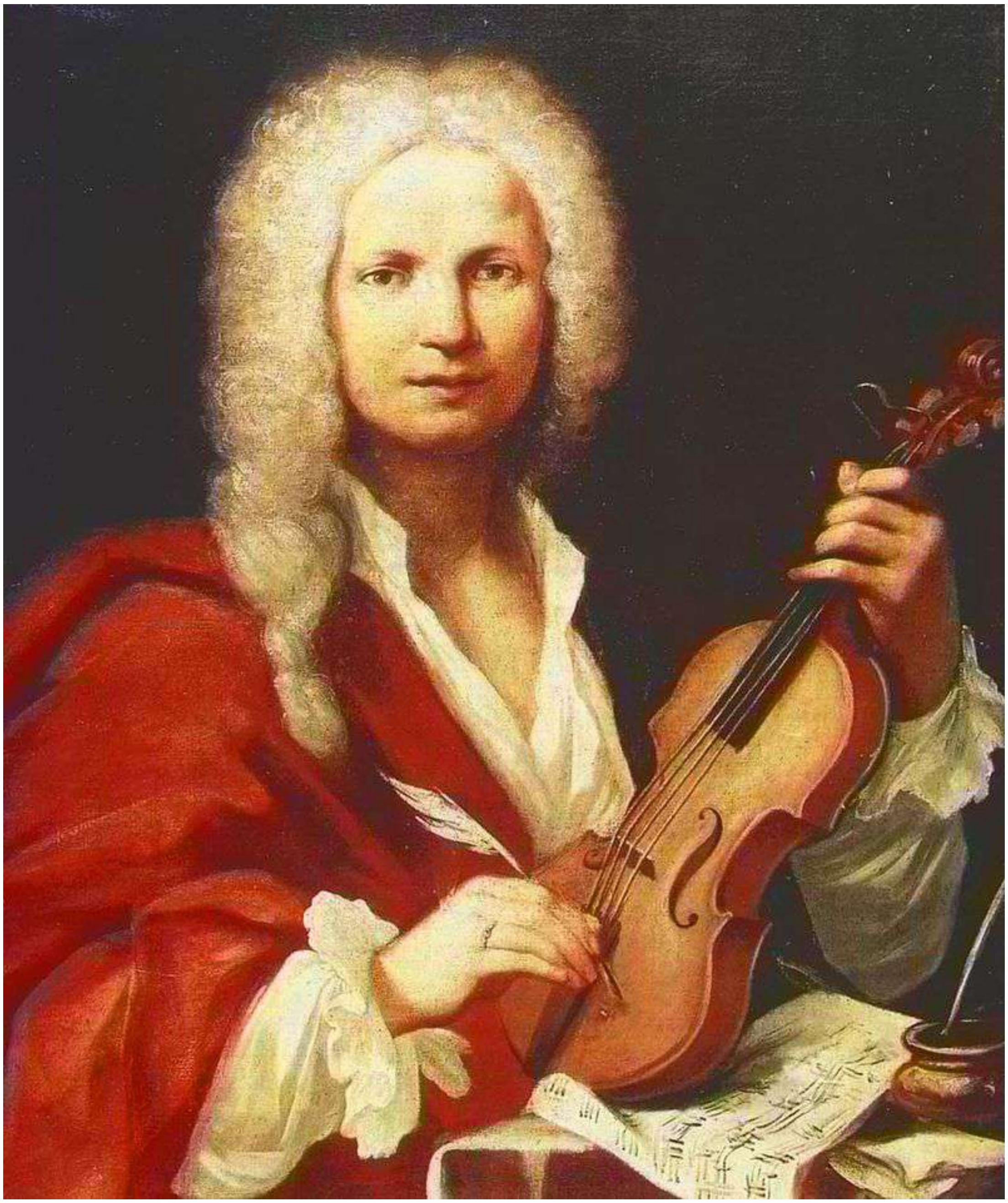

Figure 6.7: **Antonio Vivaldi.**

6.8 Johann Sebastian Bach

Bach's family background

Today, Johann Sebastian Bach is generally regarded as the greatest composer in the history of the western world. He was born into a family of distinguished musicians, and many of his numerous children also had outstanding musical careers.

Influences on Bach, and some of his great compositions

Bach's musical style was influenced by Antonio Vivaldi's works, many of which he transcribed. He was also influenced by the Danish organist and composer, Dieteruch Buxtehude. To visit Buxtehude in the northern city of Lübeck, Bach traveled 450 kilometers, both ways reportedly on foot.

Bach's compositions are very numerous. He composed keyboard music, vocal music, and chamber music, often involving four-part harmony, counterpoint and fugues. Among his many great compositions are The *Well-Tempered Clavier*, the *Tocatta and Fugue in D Minor*, the *Cello Suites*, the *Goldberg Variations*, the *Brandenberg Concertos*, the *St. Matthew Passion*, and the *Mass in B Minor*.

Figure 6.8: **Johann Sebastian Bach.**

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Chapter 7

SHAH JAHAN AND MUGHAL ARCHITECTURE

7.1 The Mughal Empire

The Mughal Empire (1526-1837) was founded by Babur, a warrior chieftain from present-day Uzbekistan. At its height, the Mughal Empire included Afghanistan, Kashmir, Bangladesh, and large portions of India. The empire maintained relative peace in India during the 17th century, and it was a factor in India's economic expansion and the extreme wealth of its rulers. There was a golden age of the arts and architecture, especially under Shah Jahan.

7.2 Shah Jahan's life

Shah Jahan (1592-1666) ruled India from 1628 until 1658. His Reich marked a golden age in India's cultural development. Although he was a very able ruler. Shah Jahan is best remembered for the architectural masterpieces that he commissioned. The best known of these is the Taj Mahal, a memorial that Shah Jahan raised to the memory of his favorite wife, Mumtaz Mahal. Towards the end of his life, Shah Jahan was the victim of a revolt by one of his sons, who overthrew and imprisoned his father.

7.3 Mughal architecture

Examples of Mughal architecture can be seen, nor only within the Mughal empire, but also in other places, such as Pakistan. The Mughal style of architecture employs elements from Islamic, Persian, Turkish and Indian architecture. These include large bulbous domes, slender minarets at the corners, massive halls, large vaulted gateways, and delicate ornamentation.

Figure 7.1: **The Taj Mahal at Agra, India is the most famous example of Mughal Architecture.**

Figure 7.2: **Badshahi Mosque, in Lahore, Pakistan was the largest mosque in the world for 313 years, and is the last of the imperial mosques built by the Mughals.**

Figure 7.3: **The Alamgiri Gate at Lahore Fort, Lahore, Pakistan.**

Figure 7.4: **Bibi Ka Maqbara is a tomb in Aurangabad, Maharashtra, which was built by Aurangzeb in the memory of his wife, Dilras Banu Begum.**

Figure 7.5: **Gardens of Babur in Kabul, Afghanistan.**

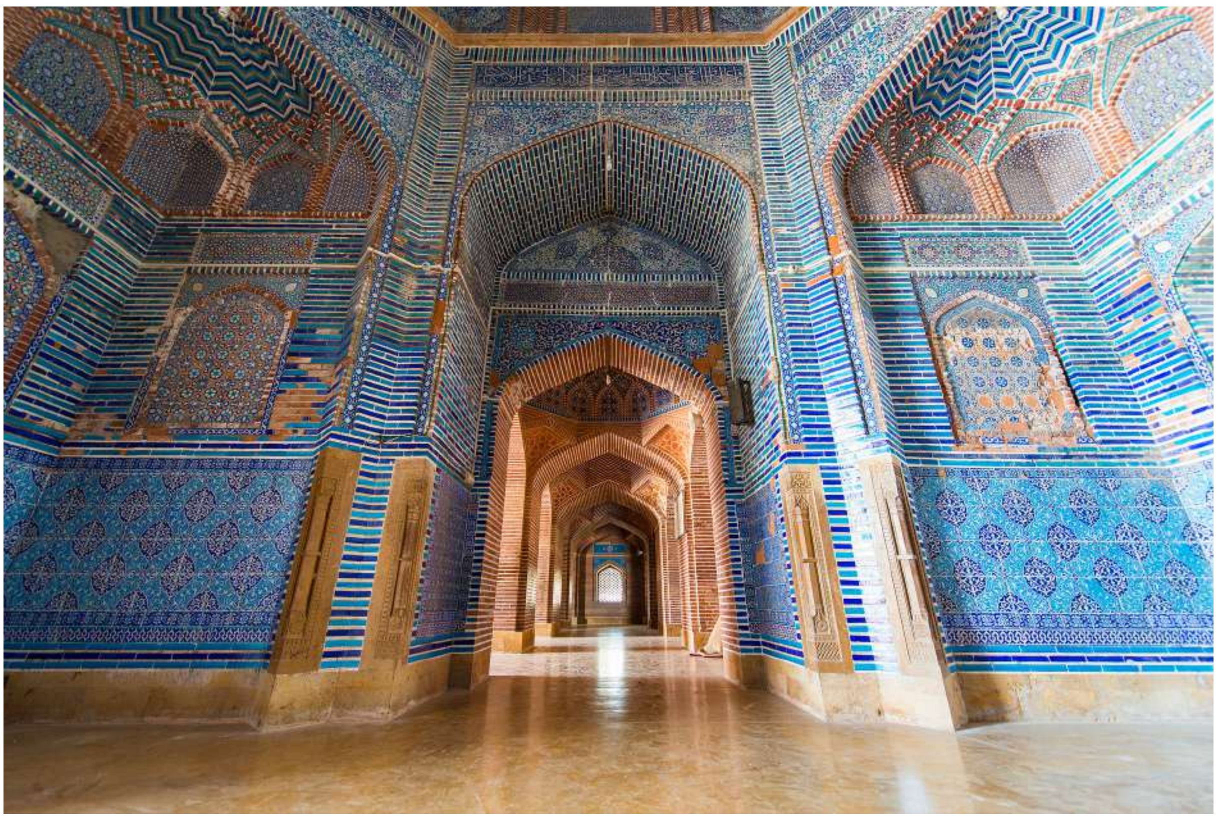

Figure 7.6: **This mosque's tile work exhibits Timurid influences introduced during Shah Jahan's campaigns in Central Asia.**

Figure 7.7: **The Darwaza-i-Rauza (Great Gate) of the Taj Mahal.**

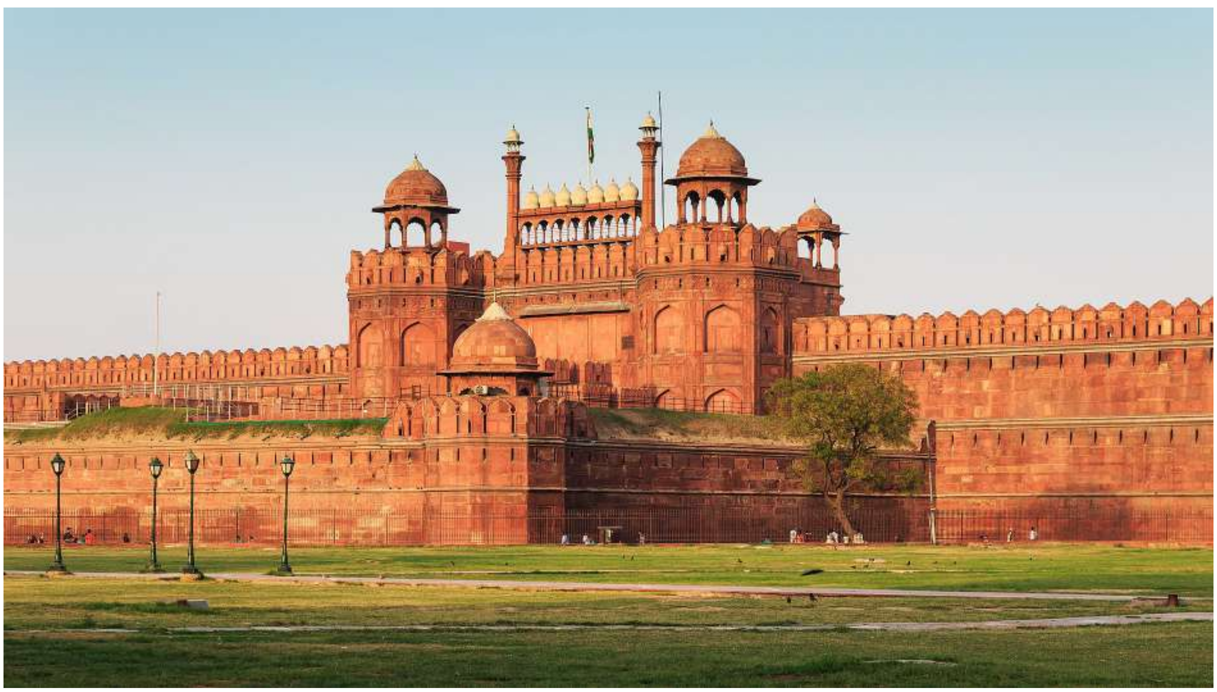

Figure 7.8: **Lahori Gate of the Red Fort, Delhi, India.**

Figure 7.9: **Shah Jahan Mosque in Thatta, Pakistan. The mosque is not built in the Mughal style, but reflects a heavy Persian influence.**

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