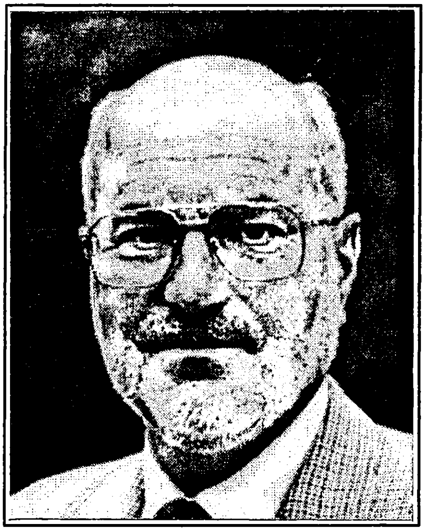

BRAIN DRAIN
NIL NOVE SUB SOLE
A HISTORICAL APPROACH

Guido Vanden Berghe

1. Introduction

"More than one in seven doctorates received by foreigners in the United States is awarded to Europeans. Of these Europeans, about 75 % stay behind. With generous research grants, state-of-the-art facilities, an international environment, and streamlined bureaucracy, America has a lot of going for it".[1] More and more the European decision makers and also the Belgian and Flemish politicians are aware of the problem. Europe has some of the most gifted scientific minds of the planet. After having completed a doctorate at their home university, young Europeans are often advised by their doctoral supervisor or laboratory on what direction to take for a post-doctorate. That often means North America. For many young researchers, the United States is a kind of initial immersion in the world of research, perhaps comparable to the trip to Rome that was the rigueur for the painters of the Renaissance. In Time [2] one can read that "around 400,000 E.U.- born science graduates live in the United States. Thousands more go to study and work each year. But the E.U. needs 700,000 more researchers by 2010. Can Europe bring its best and brightest back home? ". Governments in Europe started up programs to bring top researchers back to their native country with very attractive conditions. In this paper we like to show that such a kind of brain drain is not a phenomenon of the nowadays moment, but it has also been present in other periods of mankind history. Following examples will be discussed:

- The Arabic world in the period 786-900.
- The Renaissance time in the Low Countries.
- Brain drain out of the colonies: India as an example.
- Leo Backeland, a typical Flemish case.
- The escape out of Europe of Jewish scientists during the Nazi-regime.
- Operation paperclip after the Second World War.

2. The Arabic world in the period 786-900 [3]

Many Arabic researchers were associated with the remarkable House of Wisdom that was set up in Baghdad by the Caliph al-Ma'mun. It is worth looking at the events which led up to the founding of this important centre for learning.

Harun al-Rashid became the fifth Caliph of the Abbasid dynasty on 14 September 786, and ruled from his court in the capital city of Baghdad over the Islam Empire which stretched from the Mediterranean to India. He brought culture to his court and tried to establish the intellectual disciplines which at that time were not flourishing in the Arabic world. He encouraged scholarship and the first translations of Greek texts into Arabic, such as Euclid's *Elements* by al-Hajjaj, were made during al-Rashid's reign.

Al-Rashid had two sons, the eldest was al-Amin while the younger was al-Ma'mun. Harun died in 809 and there was an armed conflict between the brothers. Al-Ma'mun won the armed struggle and al-Amin was defeated and killed in 813. Following this, al-Ma'mun became Caliph and ruled the empire from Baghdad. He continued the patronage of learning started by his father and founded an academy called the *House of Wisdom* where Greek philosophical and scientific works were translated. He also built up a library of manuscripts, the first major library to be set up since that at Alexandria, collecting important works from Byzantium. In addition to the House of Wisdom, al-Ma'mun set up observatories in which Muslim astronomers could build on the knowledge acquired by earlier peoples.

This House of Wisdom became an attraction pole for Muslims and non-Muslims. Many mostly unknown researchers of high quality joined that school. They came from all places in the Arabic Empire. We like to stress the attention on two of them. Many others can be cited, but to our view Al-Kindi and Al-Khwarizmi were researchers of top level.

The Iranian philosopher, scientist, and ophthalmologist **Al-Kindi** (the Arabic name is Abu Yousuf Yaqub Ibn Ishaq al-Kindi) was born in Kufa – a town at 170 km in the south of Bagdad - in 800 BCE. His father was an official of Caliph al-Rashid. Al-Kindi was well known for his beautiful calligraphy. In fact, he was even employed as a calligrapher. In the Middle Ages, Al-Kindi was considered to be one of the greatest minds ever, in both Europe and the Arab countries. He was a master of many different areas of thought. He was an expert in music, philosophy, astronomy, medicine, geography, and mathematics, and spent many years in the House of Wisdom in Baghdad dedicated to his studies of these fields.

As a physician, Al-Kindi was the first pharmacologist to determine and apply a correct dosage for most of the drugs available at the time. As an advanced chemist, he was an opponent of alchemy; he debunked the myth that simple, base metals could be transformed into precious metals, such as gold or silver. In mathematics, he wrote a number of books dedicated to the number system, and contributed greatly to the foundation of modern arithmetic. Though Al-Khwarizmi (see hereafter) was the father of the Arabic system of numerals, Al-Kindi made many great developments in the field, as well.

Figure 1 : Al-Kindi

Figure 2: Al-Khwarizmi

Prolific to say the least, Al-Kindi authored at least two hundred and fifty books, contributing heavily to geometry (32 books), medicine and philosophy (22 books each), logic (9 books), and physics (12 books). His influence in the fields of physics, mathematics, medicine, philosophy and music were far-reaching and lasted for several centuries.

In "The Name of the Rose" [4] Al-Kindi is mentioned only in passing. William of Baskerville recognizes some books written in Arabic and translated into Latin. I feel that it was clever of Eco to have William comment on Al-Kindi, who, as mentioned earlier, was an ophthalmologist. Throughout the book, William is constantly talking about the new science that makes it possible for people to wear lenses on the face that magnify what one is looking at. This new discovery was, of course, eyeglasses. William loves the glasses so much that he is constantly putting them on so that everyone can see the new technology that he has, and they do not. Unfortunately, this leads to them being momentarily stolen (by a monk no less).

A second researcher of world importance is Abu Abdullah Mohammad Ibn Musa **al-Khawarizmi**, born at Khawarizm (Kheva), south of Aral Sea, now Uzbekistan around 780 . Very little is known about his early life, except for the fact that his parents had migrated to a place south of Baghdad. It is established that he flourished under Al- Ma'mun at Baghdad through 813-833 and probably died around 840 A.D.

Khawarizmi was a mathematician, astronomer and geographer. He was perhaps one of the greatest mathematicians who ever lived, as, in fact, he was the founder of several branches and basic concepts of mathematics. His work on algebra was outstanding, as he not only initiated the subject in a systematic form but he also developed it to the extent of giving analytical solutions of linear and quadratic equations, which established him as the founder of Algebra. The very name Algebra has been derived from his famous book *Al-Jabr wa-al-Muqabilah*. His arithmetic synthesised Greek and Hindu knowledge and also contained his own contribution of fundamental importance to mathematics and science. Thus, he explained the use of zero, a numeral of fundamental importance developed by the Arabs. Similarly, he developed the decimal system so that the overall system of numerals, 'algorithm' or 'algorizm' is named after him. In addition to introducing the Indian system of numerals (now generally known as Arabic numerals), he developed at length several arithmetical procedures, including operations on fractions. It was through his work that the system of numerals was first introduced to Arabs and later to Europe, through its translations in European languages. He developed in detail trigonometric tables containing the sine functions. He is also reported to have collaborated in the degree measurements ordered by Mamun al-Rashid which were aimed at measuring of volume and circumference of the earth.

The development of astronomical tables by him was a significant contribution to the science of astronomy, on which he also wrote a book. The contribution of Khawarizmi to geography is also outstanding: he revised Ptolemy's views on geography, but also corrected them in detail as well as his map of the world. His other contributions include original work related to clocks, sun-dials and astrolabes.

Several of his books were translated into Latin in the early 12th century. In fact, his book on arithmetic, *Kitab al-Jam'a wal- Tafreeq bil Hisab al-Hindi,* was lost in Arabic but survived in a Latin translation. His book on algebra, *Al-Maqala fi Hisab-al Jabr wa-al- Muqabilah,* was also translated into Latin in the 12th century, and it was this translation which introduced this new science to the West "completely unknown till then". He astronomical tables were also translated into European languages and, later, into Chinese. His geography captioned *Kitab Surat-al-Ard,* together with its maps, was also translated. In addition, he wrote a book on the Jewish calendar *Istikhraj Tarikh al-Yahud,* and two books on the astrolabe.

The influence of Khawarizmi on the growth of science, in general, and mathematics, astronomy and geography in particular, is well established in history. Several of his books were readily translated into a number of other languages, and, in fact, constituted the university text-books till the 16th century. His approach was systematic and logical, and not only did he bring together the then prevailing knowledge on various branches of science, particularly mathematics, but also enriched it through his original contribution. No doubt he has been held in high repute throughout the centuries since then. The House of Wisdom to which many researchers, Muslims, but also Jews, Christians and some people with other faiths have been attracted was the birthplace of many new ideas. Recent research paints a new picture of debt that we owe to the Arabic/Islamic mathematics, studied by these people and their successors. Many ideas which were previously thought to have been brilliant new conceptions due to European mathematicians of the sixteenth, seventeenth and eighteenth centuries find their roots in this particular House.

3. The Renaissance time in the Low Countries (1500-1648) [5]

In the beginning of the period we like to discuss here, Emperor Charles V (Charles Quint) was ruling over a large part of Europe, including the Low Countries at the North-Sea

He was emperor of Germany - including Austria, Hungary, Parts of the Balkan, and Italy - as the successor of his grandfather from father's side. He was the owner of the Low-Countries (approximately the Benelux); he was the king of Spain and all the countries (colonies) in America and Asia as the successor of his grandfather from mother's side. In 1555 Charles abdicated from the throne. The Low Countries were attached to Spain and the ruler was Charles' son, Philippe II. Later on in 1598 Philippe's daughter Isabella and her husband Albrecht were ruling the country. It was a time of civil wars in the Low Countries. The people following the protestant religion, especially the Calvinist ones, started a movement of opposition against Philippe II; this scattered over all provinces of the country and soon imparted a revolutionary character. The Low Countries broke into two parts, the Northern part, the Republic of the Netherlands under the leadership of Guillaume or William the Silent, Prince of Orange and later under his sons, Maurice and Frederik Hendrik. In this Northern part the Calvinist religion was state religion. The Southern part became the so-called Spanish Netherlands and remains Catholic.

Figure 3: Desiderius Erasmus

Figure 4 : Gemma Frisius

In this period of one hundred and fifty years one observes two streams of movements of researchers in the Low Countries. Before the religious civil wars the University of Leuven, founded in 1425, was considered as the Mecca of wisdom in this part of Europe. Its academic fame attracted numerous scholars who made valuable contributions to European culture. Allow us to enumerate a few renowned names born in the Northern part of the Low Countries and moved to the South for their studies and scientific activities. The humanist, Desiderius **Erasmus**, lectured in Leuven. Desiderius Erasmus, was born at Rotterdam, apparently on October 28, 1466, as the illegitimate son of a physician's daughter by a man who afterwards turned monk. He studied in many places in Europe, but in 1517 he founded in Leuven the Collegium Trilingue in 1517 for the study of Hebrew, Latin and Greek - the first of its kind. The tutor of the young emperor Charles V, Adriaan Cardinal Florensz of Utrecht, was a professor in Leuven at that College before being elected in 1522 as Pope Adrianus VI.

A typical example of a native of the North who has spent his life time in Leuven is **Gemma Frisius** (1508-1555) [6]. Regnier Gemma Frisius is born in Friesland, a coastal province in northern Netherlands, which explains why he gave himself the name of Frisius. He was born Regnier Gemma and only adopted the name Frisius when he later became a scholar. Like many scholars from his country, he adopted a Latin version of his name. So Regnier Gemma became Gemma Frisius. His parents were very poor people and both died when he was still a young child. Left an orphan and a cripple, he was brought up by his stepmother who on a special feast day, when Gemma was six years old, took him to the shrine of St Boniface in Dokkum. Certainly after this his legs which could not support his weight became stronger and his family believed that he had been cured by a miracle. Certainly given the difficult start he had in life it was indeed a miracle that he was able to achieve so much but, however, he remained a frail person all his life.

Gemma attended school in Groningen then, in 1526, he entered the University of Leuven. Of course his stepmother did not have the means to support him financially through university but he was given a poor student's place in Lily College. He studied for a medical degree but remained at Leuven to study mathematics and astronomy. He went on to become the leading theoretical mathematician in the Low Countries and also to become professor of medicine and mathematics at the University of Leuven. He was also a practicing physician in the same town. Gemma Frisius applied his mathematical expertise to geography, astronomy and map making. In Leuven he cooperated with the engraver and goldsmith Gaspard Van der Heyden (also known as Gaspar à Myrica) in the construction of maps, globes and astronomical instruments. From 1534 Gemma Frisius began to teach his student Gerardus Mercator. Together with Mercator and Van der Heyden, Frisius constructed a terrestrial globe in 1536 and a celestial globe in the following year. Both globes had been protected by copyright by Charles V with Imperial charters. Gemma Frisius made many astronomical observations. In particular he recorded comets in July 1533, January 1538 and 30 April 1539.

In 1533 Frisius published *Libellus de locurum* which described the theory of trigonometric surveying and in particular contains the first proposal to use triangulation as a method of accurately locating places. This provided an accurate means of surveying using relatively few observations. Positions of places were fixed as the point of intersection of two lines and, as Frisius pointed out, only one accurate measurement of actual distance was required to fix the scale. Not only did Frisius propose an efficient theoretical method for surveying which was needed to produce accurate maps, but he also pro-

duced the instruments with which to undertake the surveys and he published accurate maps using the data gathered from such surveys. He can be seen as the father of the modern cartography.
Gerardus Mercator (1512-1594) is a typical example of someone attracted by the scientific knowledge present at Leuven University, but he is also one of the first scientists leaving the Low Countries due to religious reasons [7]. Gerard Mercator's parents were Hubert and Emerentia Kremer. Hubert Kremer worked the land and also was a cobbler, which is a shoemaker. Hubert and Emerentia were people of lowly status but Hubert had a brother Gisbert who had been educated at Leuven University and was a priest in Rupelmonde. It was in the hospice of St Johann in Rupelmonde, where Gisbert was a priest, that Gerard was born. He was the seventh child of Hubert and Emerentia who, a few weeks after the birth, returned to their home town of Gangelt (Germany).
For the first five years of his life Gerard and his parents lived in difficult conditions in Gangelt. The family income was insufficient to provide for more than the basic needs of life and most of their diet consisted of bread for they could afford little else. The family journeyed from Gangelt to Rupelmonde to begin a new life. Gerard began attending school in Rupelmonde shortly after the family came to live there. At school he studied Latin, religion and arithmetic. By the time he was seven years old he was able to speak and to read Latin fluently. Hubert died in 1526 or 1527. His brother Gisbert became Gerard's guardian.
Gisbert wanted the very best education possible for Gerard so in about 1527 he sent him to be educated with the Brethren of the Common Life in 's Hertogenbosch in the Netherlands. While Gerard was there his mother died and he chose a new name for himself. His name 'Kremer' means 'merchant' in German and he was sometimes known as 'Cremer' which is the Dutch equivalent. As a new name he chose Mercator, the Latin for 'merchant' and gave himself the full name of Gerardus Mercator de Rupelmonde.
On 29 August 1530 Mercator matriculated at the University of Leuven, taking the course in the humanities and philosophy. He studied at the Castle, one of four teaching houses of the university which offered two year Arts degrees based almost entirely on the teachings of Aristotle. He graduated from Leuven with a Master's Degree in 1532 and chose not to proceed to a higher degree. Already he felt that he wanted to challenge the views of Aristotle, yet this was as heretical at Leuven at that time as challenging the views of the Catholic Church.

Figure 5: Young Mercator

Figure 6: Gerardus Mercator

This almost certainly explains why he chose to leave the university rather than study for a higher degree, since he had already decided that he did not want to become a philosopher. He travelled to a number of places while going through this personal crisis including Antwerp and Mechelen. His travels did little for his religious worries but gave him a deep interest in geography which he saw at the subject which could best explain the structure of the world which God created.

Mercator returned to Leuven in 1534 where he now studied mathematics under Gemma Frisius. However, not having any background in the subject, Mercator soon found that the mathematics courses beyond him. Realising that Mercator wanted to learn mathematics to apply it to cosmography, Gemma Frisius gave him advice on the best route into learning the mathematics he needed to know, giving him books to study at home. Once put on the right path by Gemma Frisius, Mercator quickly progressed in understanding and enjoyment of mathematics.

In September 1536 Mercator married Barbara Schelleken and they had six children, three daughters and three sons. Mercator was arrested in February 1544 and charged with heresy. This was partly due to his Protestant beliefs, partly due to the fact that he travelled so widely to acquire data for his maps that suspicions were aroused. He spent seven months in prison in Rupelmonde castle. Others that were arrested at the same time admitted that they did not believe that the body of Christ was physically present in the communion host and they did not believe in purgatory. They were burned at the stake or buried alive. Nothing was found to connect Mercator with the others 'heretics' even after they had been tortured. Mercator's house was searched and his belongings confiscated but nothing incriminating was found to show that he was anything other than a good Roman Catholic. He was released from prison in September 1544, mainly due to strong support from the University of Leuven. In 1552 Mercator moved to Duisburg where he opened a cartographic workshop. The fact that a new university was planned for the town meant that he anticipated a ready demand for maps, books, globes and mathematical instruments. In Duisburg Mercator completed his project to produce a new map of Europe by October 1554. It was a large map, 1.6 metres by 1.3 metres. This re-established Mercator as the leading European map maker and, as well as praise for its scholarly value, the map had considerable commercial value.

Mercator was appointed Court Cosmographer to Duke Wilhelm of Cleve, also in 1564. During this period he began to perfect a new map projection for which he is best remembered. The 'Mercator projection' that bears his name was first used by him in 1569 for a wall map of the world on 18 separate sheets. He died in Duisburg in 1594. Mercator is a typical example of the expulsion of intellectuals out of the South part of the Low Countries in that period of religious wars. Other will follow and will give a start to the development of the Golden Era in the Republic of the Netherlands.

The University of Leiden [8] was founded in 1575 by Prince William of Orange, leader of the Dutch revolt. The presence within half a century of the date of its foundation of scholars moved from the South to the North in the Low Countries, such as Justus Lipsius, Franciscus Gomarus, Franciscus Heinsius, Simon Stevin, Carolus Clusius and many others, at once raised Leiden University to the highest European fame.

Gomarus was born in Bruges on 30 January 1563 and died in Groningen on 11 January 1641. He was a Reformed theologian; in 1587 he was a minister in Frankfurt, and in 1594 he became a professor in Leiden. In 1604 he initiated a theological dispute about Predestination with his colleague Arminius. In 1609 he resigned his chair in Leiden and became a preacher and lecturer in Middelburg. In 1615 he was appointed professor in Saumur, and in 1618 in Groningen. He contributed to the *Statenvertaling* (States Translation) of the Bible.

Bonaventura Vulcanius was born in Bruges, and died in Leiden in 1614 at the age of 77. He was Leiden's professor of Greek; he had previously been secretary to Marnix van St Aldegonde. Vulcanius left a few writings containing comments against the Catholic Church. During his time in Leiden a handwritten work by Cornelius Aurelius (1460-1531) came into his possession. This Dutch historian was a Latin poet and a friend of Erasmus. Vulcanius adapted the text, crossed out those parts of the original manuscript he considered irrelevant, and sent it off to the printer.
The humanist **Franciscus Nansius** was also a native of Bruges. He moved to Leiden and later taught at the Latin school in Dordrecht. He had a large private library. When his books were sold after his death the University of Leiden bought a number of ninth-century manuscripts, copies of classical authors of the fourth and fifth centuries, the originals of which had long vanished.
Justus Lipsius (the Latinized version of Joest Lips) was born in Overyssche, a village near Brussels and Leuven, in 1547. He studied first with the Jesuits in Cologne and later at the Catholic University of Leuven. After completing his education he visited Rome, in his new position as secretary to Cardinal Granvelle, staying for two years in order to study the ancient monuments and explore the unsurpassed libraries of classical literature. In 1572 Lipsius's property in Belgium was taken by Spanish troops during the civil war while he was away on a trip to Vienna. Without property, Lipsius applied for a position at the Lutheran University of Jena. This was the first of a number of institutional moves that required Lipsius to change his publicly professed faith. His new colleagues at Jena remained sceptical of this radical transformation and Lipsius was eventually forced to leave Jena after only two years in favour of Cologne. While at Cologne he prepared notes on Tacitus that he used in his critical edition of 1574. In 1576 Lispius returned to Catholic Leuven. However after his property was looted by soldiers a second time he fled again in 1579, this time to the Calvinist University of Leiden. He remained at Leiden for thirteen years and it is to this period that his two most famous books – *De Constantia Libri Duo* (1584) and *Politicorum sive Civilis Doctrinae Libri Sex* (1589) – belong. However, Lipsius was by upbringing a Catholic and eventually he sought to return to Leuven, via a brief period in Liège. In 1592 Lipsius accepted the Chair of Latin History and Literature at Leuven. To this final period belong his editorial work on Seneca and his two detailed studies of Stoicism, the *Manuductio ad Stoicam Philosophiam* and *Physiologia Stoicorum*. The two studies were published first in 1604 and the edition of Seneca in 1605. Lipsius died in Leuven in 1606.

Simon Stevin is born in Bruges in 1548 [9]. Simon Stevin's father was Anthuenis (Anton) Stevin who, it is believed, was a cadet son of a mayor of Veurne. His mother was Cathelijne van der Poort who was the daughter of a burgher family of Ypres. Anthuenis and Cathelijne were not married but Simon's mother Cathelijne later married a man who was involved in selling carpets and in the silk trade.


DE

THIENDE.

Leerende door onghehoorde lichticheyt allen rekeningen onder den Menschen noodich vallende, afveerdighen door heele ghetalen sonder ghebrokenen.

Beschreven door SIMON STEVIN van Brugghe.

TOT LEYDEN,

By Christoffel Plantijn.

M. D. LXXXV.

Figure 7: Oil portrait of Stevin Figure 8: The front page of the Thiende

By marriage Cathelijne joined a family who were Calvinists. Nothing is known of Simon's early years or of his education although one assumes he was brought up in the Calvinist tradition. Stevin became a bookkeeper and cashier with a firm in Antwerp. Then in 1577 he took a job as a clerk in the tax office at Bruges. After this he moved to Leiden in 1581 where he first attended the Latin school, then he entered the University of Leiden in 1583 (at the age of 35). While Stevin was at the University of Leiden he met Maurits (Maurice), the Count of Nassau, who was William of Orange's second son. The two became close friends and Stevin became mathematics tutor to the Prince as well as a close advisor. Maurits understood the importance of military strategy, tactics, and engineering in military success. In 1600 he asked Stevin to set up an engineering school within the University of Leiden. It was a good political move to insist that the courses were taught there in the

Dutch language. The author of 13 books, Simon Stevin made significant contributions to trigonometry, mechanics, architecture, musical theory, geography, fortification, and navigation. In 1585 he published *De Thiende*, a twenty-nine page booklet in which he presented an elementary and thorough account of decimal fractions. Although he did not invent decimals (they had been used by the Arabs and the Chinese long before Stevin's time) he did introduce their use in mathematics in Europe. Stevin states that the universal introduction of decimal coinage, measures and weights would only be a matter of time. Robert Norton published an English translation of *De Thiende* in London in 1608. It was titled *Disme, The Arts of Tenths or Decimal Arithmetike* and it was this translation which inspired Thomas Jefferson to propose a decimal currency for the United States (note that one tenth of a dollar is still called a dime). This book features in the famous Philadelphia list *Printing and the Mind of Man*, which highlights books that have had an impact on the evolution of Western Civilisation. Inspired by Archimedes, Stevin wrote important works on mechanics. Mainly dealing with statics, his treatment appears in his book *De Beghinselen der Weegconst* published in 1586. It is famous for containing the theorem of the triangle of forces which gave impetus to statics. In the same year his treatise *De Beghinselen des Waterwichts* on hydrostatics contained notable improvements to the work of Archimedes on this topic. Many consider that he founded the science of hydrostatics with this work by showing that the pressure exerted by a liquid upon a given surface depends on the height of the liquid and the area of the surface. Stevin died in Den Haag in 1620.

Charles de L'Ecluse **or Carolus Clusius** (Arras, February, 1525 - Leiden April, 1609) was a Flemish doctor and pioneering botanist, perhaps the most influential of all 16th century scientific horticulturists. He established the first formal botanical garden of Europe at Leyden, the *Hortus Academicus*, in 1587; he was appointed professor at the University of Leiden in 1594. His detailed planting lists have made it possible to recreate his garden near where it originally lay.

In the history of gardening he is remembered not only for his scholarship but also for his observations on tulips "breaking causing the many different flamed and feathered varieties", which led to the speculative tulipomania of the 1630s. Clusius laid the foundations of Dutch tulip breeding and the bulb industry today. Clusius, as he was known to his contemporaries, published two major original works: his *Rariorum plantarum historia* (1601) is the first record for approximately 100 new species and his *Exoticorum libri decem* (1605) is an important work on exotic flora, both still often consulted. He also published other works, including one of the earliest known books on Spanish flora, *Rariorum aliquot stirpium per Hispanias observatarum historia*. Clusius translated several contemporary works in natural science.

Figure 9: Carolus Clusius

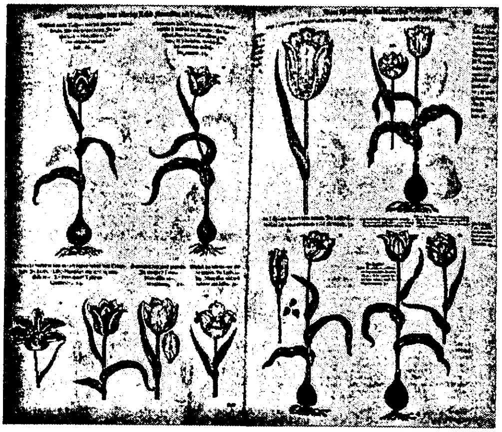

Figure 10: Page with drawings of tulips in one of the works of Clusius.

We have mentioned the names and short bibliographies of some of the scientists, who have left the South in order to help the North to build up a new society. The brain drain from the South to the North in the Low Countries was a disaster for the South, which left as a poor country with only a minority of intellectuals.

4. Brain drain out of the colonies: India as an example

End of the ninetieth, begin of the twentieth century the European countries had a lot of colonies in Africa and Asia. Especially Great Britain has a well developed colonial system in India, where a net of primary and secondary school, as well as universities were established. The best students were drained to the well-known English universities to do specialised research and to obtain a PhD. Many of them did not return to their home land but accepted a teaching and research position in the Western world. As an example we discuss here the lives and work of the mathematician Srinivasa Ramanujan and the astronomer Subramanyan Chandrasekhar.

Figure 11: The re-constructed Clusius garden in Leiden

Srinivasa Ramanujan [10] (1887-1920) was one of India's greatest mathematical geniuses. He made substantial contributions to the analytical theory of numbers and worked on elliptic functions, continued fractions, and infinite series.
Ramanujan was born in his grandmother's house in Erode, a small village

about 400 km southwest of Madras. When Ramanujan was a year old his mother took him to the town of Kumbakonam, about 160 km nearer Madras. His father worked in Kumbakonam as a clerk in a cloth merchant's shop.

When he was nearly five years old, Ramanujan entered the primary school in Kumbakonam although he would attend several different primary schools before entering the Town High School in Kumbakonam in January 1898. At the Town High School, Ramanujan was to do well in all his school subjects and showed himself an able all round scholar. In 1900 he began to work on his own on mathematics summing geometric and arithmetic series.

Ramanujan was shown how to solve cubic equations in 1902 and he went on to find his own method to solve the quartic. The following year, not knowing that the quintic could not be solved by radicals, he tried (and of course failed) to solve the quintic.

It was in the Town High School that Ramanujan came across a mathematics book by G. S. Carr called *Synopsis of elementary results in pure mathematics*. This book, with its very concise style, allowed Ramanujan to teach himself mathematics, but the style of the book was to have a rather unfortunate effect on the way Ramanujan was written later down mathematics since it provided the only model that he had of written mathematical arguments. The book contained theorems, formulae and short proofs. It also contained an index to papers on pure mathematics which had been published in the European Journals of Learned Societies during the first half of the 19^{th} century. The book, published in 1856, was of course well out of date by the time Ramanujan used it.

Ramanujan, on the strength of his good school work, was given a scholarship to the Government College in Kumbakonam which he entered in 1904. However the following year his scholarship was not renewed because Ramanujan devoted more and more of his time to mathematics and neglected his other subjects. Without money he was soon in difficulties and, without telling his parents, he ran away to the town of Vizagapatnam about 650 km north of Madras. He continued his mathematical work, however, and at this time he worked on hypergeometric series and investigated relations between integrals and series. He was to discover later that he had been studying elliptic functions.

In 1906 Ramanujan went to Madras where he entered Pachaiyappa's College. His aim was to pass the First Arts examination which would allow him to be admitted to the University of Madras. He attended lectures at Pachaiyappa's College but became ill after three months study. He took the First Arts examination after having left the course. He passed in mathematics but failed all his other subjects and therefore failed the examination. This meant that he could not enter the University of Madras. In the following years he worked on mathematics developing his own ideas without any help and without any real idea of the then current research topics other than that provided by Carr's book.

Continuing his mathematical work Ramanujan studied continued fractions and divergent series in 1908. At this stage he became seriously ill again and underwent an operation in April 1909 after which he took him some considerable time to recover. He married on 14 July 1909 when his mother arranged for him to marry a ten year old girl S. Janaki Ammal. Ramanujan did not live with his wife, however, until she was twelve years old.

Ramanujan continued to develop his mathematical ideas and began to pose problems and solve problems in the *Journal of the Indian Mathematical Society*. He developed relations between elliptic modular equations in 1910. After publication of a brilliant research paper on Bernoulli numbers in 1911 in the *Journal of the Indian Mathematical Society* he gained recognition for his work. Despite his lack of a university education, he was becoming well known in the Madras area as a mathematical genius.

In 1911 Ramanujan approached the founder of the Indian Mathematical Society for advice on a job. After this he was appointed to his first job, a temporary post in the Accountant General's Office in Madras. In 1912 Ramanujan applied for the post of clerk in the accounts section of the Madras Port Trust. Ramanujan was appointed to the post of clerk and began his duties on 1 march 1912. Ramanujan was quite lucky to have a number of people working round him with training in mathematics. In January 1913 Ramanujan wrote to G. H. Hardy, professor in Cambridge, having seen a copy of his 1910 book *Orders of infinity*. In Ramanujan's letter to Hardy he introduced himself and his work:

I have had no university education but I have undergone the ordinary school course. After leaving school I have been employing the spare time at my disposal to work at mathematics. I have not trodden through the conventional regular course which is followed in a university course, but I am striking out a new path for myself. I have made a special investigation of divergent series in general and the results I get are termed by the local mathematicians as 'startling'.

Hardy, together with his colleague Littlewood, studied the long list of unproved theorems which Ramanujan enclosed with his letter. On 8 February he replied to Ramanujan, the letter beginning:

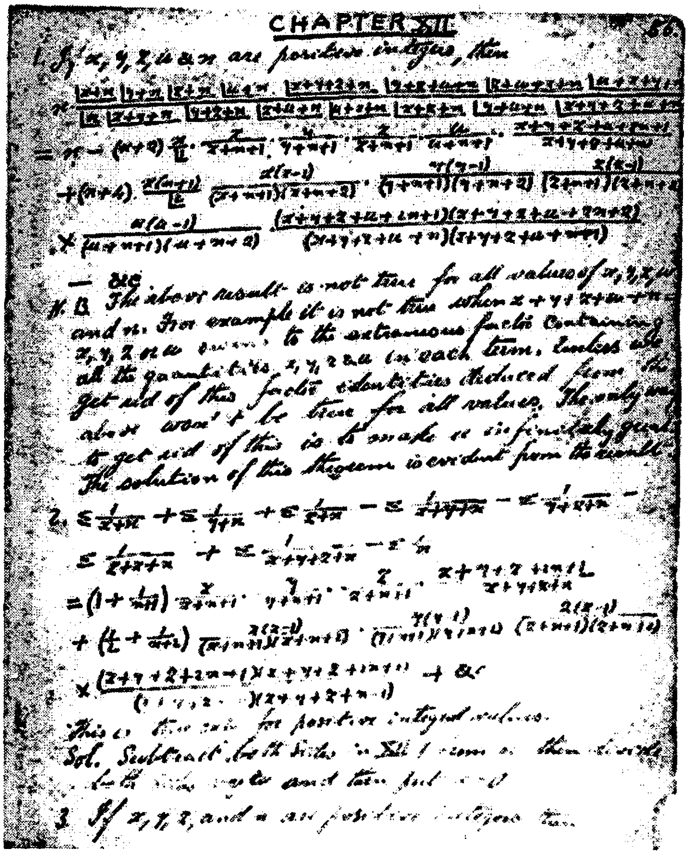

Figure 12: An example of one of the pages of the Notebooks

I was exceedingly interested by your letter and by the theorems which you state. You will however understand that, before I can judge properly of the value of what you have done, it is essential that I should see proofs of some of your assertions. Your results seem to me to fall into roughly three classes:
(1) there are a number of results that are already known, or easily deducible from known theorems;
(2) there are results which, so far as I know, are new and interesting, but interesting rather from their curiosity and apparent difficulty than their im-

portance;
(3) *there are results which appear to be new and important...*
Ramanujan was delighted with Hardy's reply and when he wrote again he said:
I have found a friend in you who views my labours sympathetically. ... I am already a half starving man. To preserve my brains I want food and this is my first consideration. Any sympathetic letter from you will be helpful to me here to get a scholarship either from the university or from the government.
Indeed the University of Madras did give Ramanujan a scholarship in May 1913 for two years and, in 1914, Hardy brought Ramanujan to Trinity College, Cambridge, to begin an extraordinary collaboration. Setting this up was not an easy matter. Ramanujan was an orthodox Brahmin and so was a strict vegetarian. His religion should have prevented him from travelling but this difficulty was overcome, partly by the work of E. H. Neville who was a colleague of Hardy's at Trinity College and who met with Ramanujan while lecturing in India.
Ramanujan sailed from India on 17 March 1914. It was a calm voyage except for three days on which Ramanujan was seasick. He arrived in London on 14 April 1914 and was met by Neville. After four days in London they went to Cambridge and Ramanujan spent a couple of weeks in Neville's home before moving into rooms in Trinity College on 30th April. Right from the beginning, however, he had problems with his diet. The outbreak of World War I made obtaining special items of food harder and it was not long before Ramanujan had health problems.
Right from the start Ramanujan's collaboration with Hardy led to important results. The war soon took Littlewood away on war duty but Hardy remained in Cambridge to work with Ramanujan. Even in his first winter in England, Ramanujan was ill and he wrote in March 1915 that he had been ill due to the winter weather and had not been able to publish anything for five months. What he did publish was the work he did in England, the decision having been made that the results he had obtained while in India, many of which he had communicated to Hardy in his letters, would not be published until the war had ended.

Figure 13: The photograph on the passport of Ramanujan as given on the cover of a popular book.

On 16 March 1916 Ramanujan graduated from Cambridge with a Bachelor of Science by Research (the degree was called a Ph.D. from 1920). He had been allowed to enrol in June 1914 despite not having the proper qualifications. Ramanujan's dissertation was on *Highly composite numbers* and consisted of seven of his papers published in England.
Ramanujan fell seriously ill in 1917 and his doctors feared that he would die. He did improve a little by September but spent most of his time in various nursing homes.
On 18 February 1918 Ramanujan was elected a fellow of the Cambridge Philosophical Society and then three days later, the greatest honour that he would receive: his name appeared on the list for election as a fellow of the

Royal Society of London. His election as a fellow of the Royal Society was confirmed on 2 May 1918, and then on 10 October 1918 he was elected a Fellow of Trinity College Cambridge, the fellowship to run for six years.
The honours which were bestowed on Ramanujan seemed to help his health improve a little and he renewed his efforts at producing mathematics. By the end of November 1918 Ramanujan's health had greatly improved.
Ramanujan sailed to India on 27 February 1919 arriving on 13 March. However his health was very poor and, despite medical treatment, he died there the following year.

Srinivasa Ramanujan left behind Notebooks [11] in which he noted more than 3000 results without proofs, during the period 1904--1912, when he was searching for a benefactor after having failed to pass the First Degree in Arts examinations of the University of Madras (in 1907). These Notebooks were with Ramanujan during his five year sojourn at Trinity College, Cambridge but Ramanujan was so busy with his research work and publications -- twenty-one papers, five in collaboration with Hardy, besides five short notes in Records of proceedings of meetings of the London Mathematical Society, six more in the Journal of the Indian Mathematical Society and several Questions (about twenty-five) to the Journal of the Indian Mathematical Society -- that he did not have the time to publish the contents of his Notebooks.

A few years after Ramanujan's death, Hardy spent three to four months on the two Chapters on hypergeometric series in the Notebook 1 of Ramanujan, and in the introduction to the paper he published [12] on this topic, he wrote:

A systematic verification of the results would be a very heavy undertaking.

Though he discontinued the study of the Notebooks of Ramanujan, after this work, he wrote to the authorities of the University of Madras suggesting that these Notebooks should be edited. In 1931, the University of Madras requested G.N. Watson to edit the Notebooks in a suitable form for publication. Watson undertook the task of editing with B.M. Wilson but the untimely death of Wilson in 1935 put an end to the joint effort. Eventually, in 1957, a facsimile edition of the Notebooks was published by the Tata Institute of Fundamental Research (India). A flurry of research papers followed the publication of the Notebooks, which continue to be a source of inspiration to the mathematicians of the world.

In February 1974, B.C. Berndt sought the Notebooks of Ramanujan in the library of Princeton University, to prove some results using a theorem he had proved earlier. This turned out to be the origin of Berndt's decade's long involvement with editing the Notebooks of Ramanujan, which contained more than 3000 entries, with the objective of researching into the originality of the same and providing proofs wherever they were required [13].

Srinivasa Ramanujan can be seen as a mathematical genius of the twentieth century. Due to the educational system he could not be creative in his own country and has spent the most fruitful years of his young life in Cambridge. Due to his illness he came back to India for passing away. His valuable heritage, the Notebooks, is back in Madras, where they have come into being.

Subrahmanyan Chandrasekhar (1910-1995) was known throughout his life as **Chandra.** His father was C. Subrahmanyan Ayyar and his mother was Sitalaksmi Aiyar. His father, an Indian government auditor whose job was to audit the Northwest Railways, came from a Brahman family which owned some land near Madras, India. Chandra came from a large family, having two older sisters, three younger brothers and four younger sisters. When Chandra was still young his parents moved to Madras and, as he grew up, he was encouraged to seek an education which would see him following his father into government service. However Chandra wanted to be a scientist and his mother encouraged him to follow this route. He had a role model in his paternal uncle Sir Chandrasekhara Venkata Raman who went on to win the Nobel Prize in 1930 for his 1928 discovery of Raman scattering and the Raman Effect, which is a change in the wavelength of light occurring when a beam of light is deflected by molecules. Chandra studied at Presidency College, University of Madras, and he wrote his first research paper while still an undergraduate there. The paper was published in the *Proceedings of the Royal Society*. Also at Presidency College with Chandra was Lalitha Doraiswamy, who was the daughter of a family living close to where Chandra's family lived in Madras. They became engaged to marry at this time. Chandra obtained a scholarship from the Indian government to finance his studies in England, and in 1930 he left India to study at Trinity College, Cambridge, England. From 1933 to 1937 he undertook research at Cambridge, but he returned to India in 1936 to marry Lalitha on 11 September.
They returned to Cambridge in 1936 but in the following year Chandra joined the staff at the University of Chicago where he was to remain for the rest of his life. At first he worked in Yerkes Observatory, part of the Univer-

sity of Chicago in Wisconsin. Later he moved to work on the university campus in the city of Chicago. During World War II he worked in the Ballistic Research Laboratories at the Aberdeen Proving Ground in Maryland. Two reports, written in 1943, show the type of problems he was working on at this time: the first is *On the decay of plane shock waves* while the second is *The normal reflection of a blast wave.* He was honoured with being appointed Morton D. Hull distinguished service professor of the University of Chicago in 1952. Although by that time Chandra had been working in the United States for 15 years, neither he nor his wife had taken out citizenship earlier. However, both became American citizens in the following year and became very much integrated into the life of the country. When Chandra was offered a chair at Cambridge in 1964 he replied by return that he was not interested, so turning down a position which as a young man he would have found the most desirable.

Chandrasekhar published around 400 papers and many books. His research interests were exceptionally broad but we can divide them into topics and rough periods when he was concentrating on these particular topics. First he studied stellar structure, including the theory of white dwarfs, from 1929 to 1939, then stellar dynamics from 1939 to 1943. Next he looked at the theory of radiative transfer and the quantum theory of the negative ion of hydrogen from 1943 to 1950, followed by hydrodynamic and hydro magnetic stability from 1950 to 1961. During most of the 1960s he studied the equilibrium and the stability of ellipsoidal figures of equilibrium but during this period he also began work on topics from general relativity, the radiation reaction process, and the stability of relativistic stars. During the period from 1971 to 1983 he undertook research into the mathematical theory of black holes.

Chandrasekhar received many honours for his outstanding contributions some of which, such as the Nobel Prize for Physics in 1983, the Royal Society's Royal Medal of 1962 and their Copley Medal of 1984. We should also mention, however, that he was honoured with the Bruce medal of the Astronomical Society of the Pacific, the Henry Draper medal of the National Academy of Sciences (United States), and the Gold Medal of the Royal Astronomical Society.

Chandra retired in 1980 but continued to live in Chicago where he was made professor emeritus in 1985. He continued to give thought-provoking lectures such as *Newton and Michelangelo* which he delivered at the 1994 Meeting of Nobel Laureates held in Lindau. He compared Michelangelo's frescoes in the Sistine Chapel and Newton's *Principia* :

... in the larger context of whether there is any similarity in the motivations of scientists and artists in their respective creative quests.

Figure 14: Young Chandra Figure 15: Chandrasekhar as an US citizen

Other lectures in a similar vein include *Shakespeare, Newton and Beethoven or patterns of creativity* and *The perception of beauty and the pursuit of science.*

Chandrasekhar remained active and published a final major book *Newton's Principia for the Common Reader* at 85 years of age in the final months of his life. Shortly after publication of this work he died from heart failure and was buried in Chicago. He was survived by his wife Lalitha. He was an ambassador of India, but his scientific activities all took place outside this country.

5. Leo Baekeland, a typical Flemish case [14]

One of the earliest synthetics that transformed the material basis of modern life was Bakelite, a polymeric plastic made from phenol and formaldehyde. **Leo Hendrik Baekeland** (1863–1944) invented Bakelite in 1907, and his inventive and entrepreneurial genius also propelled him into several other new chemical technological ventures at the turn of the twentieth century.

After completing his doctorate at the University of Ghent in his native Belgium, Baekeland taught for several years. In 1889, when he was twenty-six, he travelled to New York on a fellowship (that had also allowed him to visit universities in England, Scotland, and Germany) to continue his study of chemistry; Professor Charles F. Chandler of Columbia University then persuaded Baekeland to stay in the United States and recommended him for a position at a New York photographic supply house. This experience led him a few years later, when he was working as an independent consultant, to invent Velox, an improved photographic paper that could be developed in gaslight rather than sunlight. In 1898 the Eastman Kodak Company purchased Baekeland's invention for a reputed $750,000, a sum that allowed him to spend the rest of his life in experimentation.

Baekeland next entered the field of electrochemistry. He visited Berlin briefly to update his knowledge of this new area of study, and he equipped his private laboratory on the grounds of his home in Yonkers, New York, with a few electrochemical appliances. At the request of Elon Hooker, Baekeland cooperated with Clinton P. Townsend, the inventor of a new electrolytic cell for producing caustic soda and chlorine from salt, in setting up a pilot plant at the Brooklyn Edison Station. The success of their experiment led Elon Hooker to form Hooker Electrochemical Company in Niagara Falls—now part of the Oxychem subsidiary of Occidental Petroleum.

When friends asked Baekeland how he entered the field of synthetic resins, he answered that he had chosen it deliberately, looking for a way to make money. Chemists had begun to recognize that many of the natural resins and fibbers useful for coatings, adhesives, woven fabrics, and the like were polymers (large molecules made up of repeating structural units), and they had begun to search for combinations of reagents that would react to form *synthetic* polymers. Baekeland began to investigate the reactions of phenol and formaldehyde, and first produced soluble phenol-formaldehyde shellac called "Novolak," which never became a market success. Then he turned to developing a binder for asbestos, which at that time was moulded with hard natural rubber. By carefully controlling the pressure and temperature applied to an intermediate made from the two reagents, he could produce a polymer that, when mixed with fillers, produced a hard mouldable plastic. Bakelite, though relatively expensive, was soon found to have many uses, especially in the rapidly growing automobile and radio industries. Baekeland retired in 1939 to sail his yacht, the *Ion*, among other activities, and sold his successful plastics company to the Union Carbide and Carbon Corporation. Five year later, in 1944, Leo Baekeland died at the age of 80 years.

Baekeland was the son of a rather poor shoemaker. Because of his excellent study results he received from the Belgian community a scholarship to study. Being that good he left his country for the US and he is one of the typical examples of the first brain drain in Belgium.

Figure 16: Leo Hendrik Baekeland

6. The escape out of Europe of Jewish scientists during the Nazi-regime

In April 1933 Hitler's first anti-Jewish law was promulgated, stripping all "non-Aryan" academics of their teaching posts. The new law abruptly stripped a quarter of the physicists in Germany, including eleven who had earned or would earn Nobel Prizes, of their positions and their livelihood. Emigration was the only solution.
Some with extreme foresight, saw what the political landscape was to become and made early plans accordingly. Einstein was one of the first to go.
Around 1886 **Albert Einstein** [15] (1879-1955) began his school career in Munich. As well as his violin lessons, which he had from age six to age thirteen, he also had religious education at home where he was taught Judaism. Two years later he entered the Luitpold Gymnasium and after this his religious education was given at school. He studied mathematics, in particular the calculus, beginning around 1891.
In 1894 Einstein's family moved to Milan but Einstein remained in Munich.

In 1895 Einstein failed an examination that would have allowed him to study for a diploma as an electrical engineer at the Eidgenössische Technische Hochschule in Zurich. Einstein renounced German citizenship in 1896 and was to be stateless for a number of years. He did not even apply for Swiss citizenship until 1899, citizenship being granted in 1901.

Following the failing of the entrance exam to the ETH, Einstein attended secondary school at Aarau planning to use this route to enter the ETH in Zurich. Indeed Einstein succeeded with his plan graduating in 1900 as a teacher of mathematics and physics. Einstein worked in the patent office in Bern from 1902 to 1909, holding a temporary post when he was first appointed, but by 1904 the position was made permanent and in 1906 he was promoted to technical expert second class. While in the Bern patent office he completed an astonishing range of theoretical physics publications, written in his spare time without the benefit of close contact with scientific literature or colleagues.

Figure 17: Young Einstein

Figure 18: Einstein in his Princeton's period

Einstein earned a doctorate from the University of Zurich in 1905 for a thesis *On a new determination of molecular dimensions.* In the first of three papers, all written in 1905, Einstein examined the phenomenon discovered by Max Planck, according to which electromagnetic energy seemed to be emitted from radiating objects in discrete quantities. Einstein's second 1905 paper proposed what is today called the special theory of relativity. He based his new theory on a reinterpretation of the classical principle of relativity, namely that the laws of physics had to have the same form in any frame of reference. As a second fundamental hypothesis, Einstein assumed that the speed of light remained constant in all frames of reference, as required by Maxwell's theory. The third of Einstein's papers of 1905 concerned statistical mechanics.

By 1909 Einstein was recognised as a leading scientific thinker and in that year he resigned from the patent office. He was appointed a full professor at the Karl-Ferdinand University in Prague in 1911. He moved from Prague to Zurich in 1912 to take up a chair at the Eidgenössische Technische Hochschule in Zurich. Einstein returned to Germany in 1914 but did not reapply for German citizenship. What he accepted was an impressive offer. It was a research position in the Prussian Academy of Sciences together with a chair (but no teaching duties) at the University of Berlin. He was also offered the directorship of the Kaiser Wilhelm Institute of Physics in Berlin which was about to be established.

In 1920 Einstein's lectures in Berlin were disrupted by demonstrations which, although officially denied, were almost certainly anti-Jewish. During 1921 Einstein made his first visit to the United States. His main reason was to raise funds for the planned Hebrew University of Jerusalem. However he received the Barnard Medal during his visit and lectured several times on relativity. Einstein received the Nobel Prize in 1921 but not for relativity rather for his 1905 work on the photoelectric effect. In fact he was not present in December 1922 to receive the prize being on a voyage to Japan. Around this time he made many international visits, to Paris, Palestine, and South America.

By 1930 he was making international visits again, back to the United States. A third visit to the United States in 1932 was followed by the offer of a post at Princeton. The idea was that Einstein would spend seven months a year in Berlin, five months at Princeton. Einstein accepted and left Germany in December 1932 for the United States. The following month the Nazis came to power in Germany and Einstein was never to return there. During 1933 Einstein travelled in Europe visiting Oxford, Glasgow, Brussels and Zurich. Offers of academic posts which he had found it so hard to get in 1901, were plentiful. He received offers from Jerusalem, Leiden, Oxford, Madrid and Paris.

What was intended only as a visit became a permanent arrangement by 1935 when he applied and was granted permanent residency in the United States. In 1940 Einstein became a citizen of the United States, but chose to retain his Swiss citizenship. He made many contributions to peace during his life. By 1949 Einstein was unwell. A spell in hospital helped him recover but he began to prepare for death by drawing up his will in 1950. He left his scientific papers to the Hebrew University in Jerusalem, One week before his death Einstein signed his last letter. It was a letter to Bertrand Russell in which he agreed that his name should go on a manifesto urging all nations to give up nuclear weapons. It is fitting that one of his last acts was to argue, as he had done all his life, for international peace. Einstein was cremated at Trenton, New Jersey at 4 pm on 18 April 1955 (the day of his death). His ashes were scattered at an undisclosed place.

Several Hungarian Jewish scientists were also leaving Nazi-Europe, we give a short review hereafter and give a small bibliography of a few of them. There were many others.

Theodore von Karman [16] (1881-1963), born in Budapest studied at the Palatine Joseph Polytechnic in Budapest. In 1906 he was awarded a two year fellowship from the Hungarian Academy of Sciences and he left Budapest for Göttingen He was very much interested in aeronautics and he had a real chance to introduce this area as a research topic with the construction of a wind tunnel for the Zeppelin airship company. In 1913 Karman accepted a post as director of the Aeronautical Institute in Aachen. He began theoretical work on aircraft design. Karman visited the USA in 1926, at the invitation of the head of the California institute of Technology, to advise on the design of a wind tunnel. By 1928 he was spending six months each year at Caltech and six months at Aachen, then in 1930 he was asked to be the full-time director of the Aeronautical Laboratory at California Institute of Technology. Despite his love for Aachen, the political events in Germany and in particular the rising anti-Semitism persuaded him to accept. His mother and younger sister went to California with him. In 1933 he founded the U.S. Institute of Aeronautical Sciences continuing his research on fluid mechanics, turbulence theory and supersonic flight. He studied applications of mathematics to engineering, aircraft structures and soil erosion. His work turned towards research on rockets and, when Germany were seen to have developed rockets for military purposes during World War II, the United States Government put large sums of money into rocket research. In November 1944 the funding was used to set up the Jet Propulsion Laboratory at Caltech with Karman as director. This laboratory later made major contributions to the space programme. In 1949 he resigned his two positions of director and became professor emeritus at Caltech. He was still very active in giving advice to the U.S. air force and NATO and played a major role in international conferences on aeronautics. He died in Aachen in 1963.

Figure 19: Von Karman

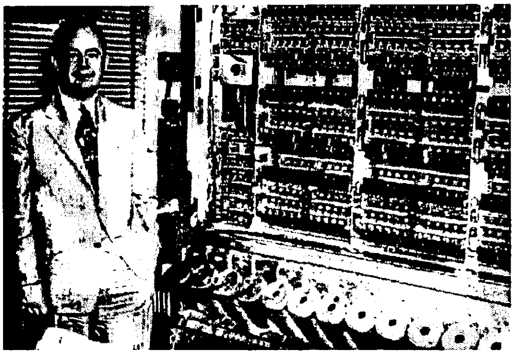

Figure 20: von Neumann and one of the first computers

John von Neumann [17] (1903-1957) was born János von Neumann. His father, Max Neumann, was a top banker and he was brought up in an extended family, living in Budapest. Although the family were Jewish, Max Neumann did not observe the strict practices of that religion and the household seemed to mix Jewish and Christian traditions. In 1911 von Neumann entered the Lutheran Gymnasium. The school had a strong academic tradition which seemed to count for more than the religious affiliation both in the Neumann's eyes and in those of the school. His mathematics teacher quickly recognised von Neumann's genius and special tuition was put on for him. The school had another outstanding mathematician one year ahead of von Neumann, namely Eugene Wigner. In 1921 von Neumann completed his education at the Lutheran Gymnasium. Von Neumann studied chemistry at the University of Berlin until 1923 when he went to Zurich. He achieved outstanding results in the mathematics examinations at the University of Budapest despite not attending any courses. Von Neumann received his diploma in chemical engineering from the Technische Hochschule in Zürich in 1926. Von Neumann lectured at Berlin from 1926 to 1929 and at Hamburg from 1929 to 1930. However he also held a Rockefeller Fellowship to enable him to undertake postdoctoral studies at the University of Göttingen. In 1930 von Neumann became a visiting lecturer at Princeton University, being appointed professor there in 1931. He became one of the mathematics professors in 1933 at the newly founded Institute for Advanced Study in Princeton, a position he kept for the remainder of his life. During the first years that he was in the United States, von Neumann continued to return to Europe during the summers. Until 1933 he still held academic posts in Germany but resigned these when the Nazis came to power. Unlike many others, von Neumann was not a political refugee but rather he went to the United States mainly because he thought that the prospect of academic positions there was better than in Germany. Von Neumann was one of the pioneers of computer science making significant contributions to the development of logical design. He died in Washington D.C. in 1957.

The father, Antal Wigner, of **Eugene Paul Wigner** [18] (1902-1995) was the director of a leather-tanning factory while his mother, Erzsébet Wigner, looked after the family of three children. Both Antal and Erzsébet were from a Jewish background but they did not practice Judaism. In 1915 Wigner entered the Lutheran High School in Budapest. Here he met John von Neumann who was in the class below him. The school provided a solid education for Wigner in mathematics, literature, classics and religion. It did provide science teaching, but there was less emphasis on this than on other subjects. He was still at the Gymnasium when the communists took control in Hungary in March 1919 and the whole Wigner family fled the country. They lived in Austria until the communists were overthrown in November 1919 when they returned to Budapest and Wigner completed his school education. When he was in his late teens the whole Wigner family became converts to Lutheranism but it did not mean a great deal to Wigner who in later life described himself as "only mildly religious". In 1920 Wigner left school being one of the top students in his class. Already he knew that mathematics and physics were the topics for him. Now Wigner wanted to be a physicist but his father expected him to join the family business and he believed that a degree in chemical engineering would be useful to his son in the family's leather-tanning factory. Wigner followed his father's wishes and took his first degree in chemical engineering spending one year at the Technical Institute in Budapest, then moving to the Technische Hochschule in Berlin. Having completed his doctorate, Wigner returned to Budapest to join his father's tannery firm as planned in 1925. However, things did not go too well and he returned

to Berlin to accept an assistant position. Wigner was invited to Göttingen in 1927 to become Hilbert's assistant. Hilbert, already interested in quantum mechanics, felt that he needed a physicist as an assistant to complement his own expertise. This was an important time for Wigner who produced papers of great depth and significance. Wigner returned to Berlin after the year in Göttingen where he lectured on quantum mechanics, worked on writing his famous text *Group theory and its application to the quantum mechanics of atomic spectra* and continued his research. An offer to spend a term in Princeton saw him travel to the United States at the end of 1930. From 1930 to 1933 Wigner spent part of the year at Princeton, part at Berlin. His Berlin post vanished under the Nazi rules passed in 1933 and from then, except for the years 1936-1938 in Wisconsin, Wigner spent the rest of his career at Princeton. Wigner never really felt at home. Near the end of his life he wrote: *After* 60 *years in the United States I am still more Hungarian than American. ... much of American culture escapes me.*
Wigner received the Nobel Prize for Physics in 1963. He died in Princeton in 1995.

Figure 21: Eugene Wigner

Figure 22: Edward Teller

Edward Teller [19] (1908-2003) is born in Budapest, Hungary, in 1908. He received his university training in Germany and completed his Ph.D. in physics under Werner Heisenberg in 1930 at the University of Leipzig. In 1934, under the auspices of the Jewish Rescue Committee, Teller served as a lecturer at the University of London. He spent two years as a research associate at the University of Göttingen, followed by a year as a Rockefeller fellow with Niels Bohr in Copenhagen. In 1935, Teller and his wife came to the United States, where he held, until 1941, a professorship at George Washington University. The Tellers became U.S. citizens in 1941. In 1946, he became a professor of physics at the University of Chicago but returned to Los Alamos Scientific Laboratory in 1949, where he was also active during the war. From 1954 to 1958, he served as Associate Director at the new Lawrence Livermore Laboratory. He became a consultant to the laboratory in 1952. He was director of the Lawrence Livermore Laboratory from 1958 to 1960, at which time he accepted a joint appointment as a professor of physics at the University of California and as associate director of the laboratory. He held these posts until his retirement in 1975. He continued as a consultant at the Lawrence Livermore National Laboratory. Teller was most widely known for his significant contributions to the first demonstration of thermonuclear energy; in addition he added to the knowledge of quantum theory, molecular physics, and astrophysics. He served as a member of the General Advisory Committee of the U.S. Atomic Energy Commission from 1956 to 1958 and was chairman of the first Nuclear Reaction Safeguard Committee. He died in 2003.

Most of the above cited scientists were involved in the so-called Manhattan project. On 2nd August, 1939, three Jewish scientists Albert Einstein, Leo Szilard and Eugene Wigner, wrote a joint letter to President Franklin D. Roosevelt, about the developments that had been taking place in nuclear physics. They warned Roosevelt that scientists in Nazi Germany were working on the possibility of using uranium to produce nuclear weapons. Roosevelt responded by setting up a scientific advisory committee to investigate the matter. He also had talks with the British government about ways of sabotaging the German efforts to produce nuclear weapons. In 1942 the Manhattan Engineer Project was set up in the United States under the command of Brigadier General Leslie Groves. Scientists recruited to produce an atom bomb included Robert Oppenheimer (USA) and also, Eugene Wigner and Edward Teller, amongst many others. The scientists working on the Manhattan Project were developing atom bombs using uranium and plutonium. The first three completed bombs were successfully tested at Alamogordo, New Mexico on 16th July, 1945. On 6th August 1945, a B29 bomber dropped an atom bomb on Hiroshima. It has been estimated that over the years around 200,000 people have died as a result of this bomb being dropped. Japan did not surrender immediately and a second bomb was dropped on Nagasaki three days later. On 10th August the Japanese surrendered. The Second World War was over. The contribution to this victory of the Jewish scientists was tremendous.

7. Operation paperclip after the Second World War

The *Operation Paperclip* [20] is closely connected to the figure of **Wernher von Braun.** Wernher Von Braun was one of the world's first and foremost rocket engineers and a leading authority on space travel. Wernher von Braun was the second of three sons born to Baron Magnus von Braun and Baroness Emmy von Quistorp. Born March 23,1912 in Wirsitz, Posen, Wernher was always a visionary. After reading Hermann Oberth's *Rocket into Planetary Space*, and the gift of a telescope from his mother, he decided to become a space pioneer and physicist. Later, he enrolled at the Berlin Institute of Technology in 1930. In 1932, at the age of 20, he received his bachelor's degree in mechanical engineering, and was offered a grant to conduct and develop scientific investigations on liquid-fuelled rocket engines. Two years later, Wernher received his PhD in physics from the University of Berlin.
In the early 1930's the German military was searching for a weapon which would not violate the Versailles Treaty of World War I, and at the same time defend Germany. Artillery captain Walter Dornberger was assigned to investigate the feasibility of using rockets. Dornberger went to see the VfR (Verein für Raumschiffahrt) and, being impressed with their enthusiasm, gave them $400 to build a rocket. Wernher von Braun worked through the spring and summer of 1932, only to have the rocket fail when tested in front of the military. However, Dornberger was impressed with von Braun and hired him to lead the military's rocket artillery unit. By 1934 von Braun and Dornberger had a team of 80 engineers building rockets in Kummersdorf, about 60 miles south of Berlin. Von Braun's natural talents as a leader shone, as well as his ability to assimilate great quantities of data while keeping in mind the big picture. With the successful launch of two rockets, Max and Moritz, in 1934, von Braun's proposal to work on a jet-assisted take-off device for heavy bombers and all-rocket fighters was granted. However, Kummersdorf was too small for the task, so a new facility had to be built.
Peenemunde, located on the Baltic coast, was chosen as the new site. Peenemunde was large enough to launch and monitor rockets over ranges up to about 200 miles, with optical and electric observing instruments along the

trajectory, with no risk of harming people and property. By now Hitler had taken over Germany and Herman Goering ruled the Luftwaffe. Dornberger held a public test of the A-2 which was greatly successful. Funding continued to flow to von Braun's team, developing the A-3 and finally the A-4.

In 1943 Hitler decided to use the A-4 as a "vengeance weapon," and the group found themselves developing the A-4 to rain explosives on London. Fourteen months after Hitler ordered it into production, the first combat A-4, now called the V-2, was launched toward Western Europe on September 7, 1944. When the first V-2 hit London von Braun remarked to his colleagues, "The rocket worked perfectly except for landing on the wrong planet."

The SS and the Gestapo arrested von Braun for crimes against the state because he persisted in talking about building rockets which would go into orbit around the Earth and perhaps go to the Moon. His crime was indulging in frivolous dreams when he should have been concentrating on building bigger rocket bombs for the Nazi war machine. Dornberger convinced the SS and the Gestapo to release von Braun because without him there would be no V-2 and Hitler would have them all shot.

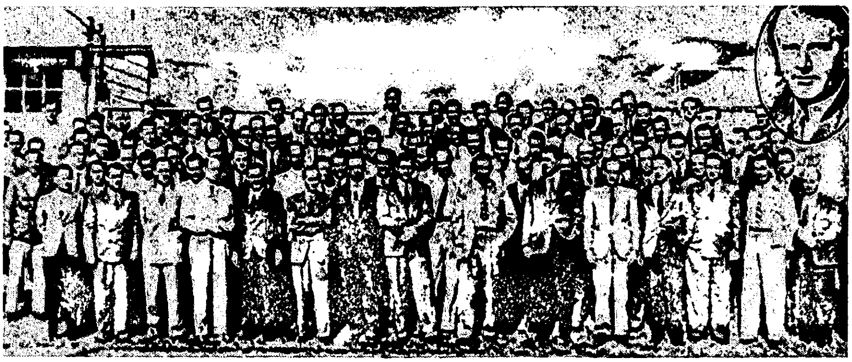

Figure 23: The group of scientists belonging to the operation paperclip

On arriving back at Peenemunde, von Braun immediately assembled his planning staff and asked them to decide how and to whom they should surrender. Most of the scientists were frightened of the Russians, they felt the French would treat them like slaves, and the British did not have enough money to afford a rocket program. That left the Americans. After stealing a train with forged papers, von Braun led 500 people through war-torn Germany to surrender to the Americans. The SS were issued orders to kill the

German engineers, who hid their notes in a mine shaft and evaded their own army while searching for the Americans. Finally, the team found an American private and surrendered to him. Realizing the importance of these engineers, the Americans immediately went to Peenemunde and Nordhausen and captured all of the remaining V-2's and V-2 parts, then destroyed both places with explosives. The Americans brought over 300 train car loads of spare V-2 parts to the United States. Much of von Braun's production team was captured by the Russians.

On June 20, 1945, U.S. Secretary of State Cordell Hull approved the transfer of von Braun's German rocket specialists. This transfer was known as Operation Paperclip because, of the large number of Germans stationed at Army Ordnance, the paperwork of those selected to come to the United States were indicated by paperclips.

They arrived in the United States at New Castle Army Air Base, just south of Wilmington, DE. Afterwards, they were flown to Boston, and then taken by boat to an Army Intelligence Service post at Fort Strong in Boston Harbor. Later, with the exception of von Braun, the men were transferred to Aberdeen Proving Grounds in Maryland to sort out the Peenemunde documents. Those documents would enable the scientists to continue their rocketry experiments where they had left off.

Finally, von Braun and the 126 Peenemunders were transferred to their new home at Fort Bliss, Texas, a large Army installation just north of El Paso, under the command of Major James P. Hamill. They found themselves in a strange situation as they began their new lives in America. Because they could not leave Fort Bliss without a military escort, they sometimes referred to themselves as "PoPs", Prisoners of Peace.

While at Fort Bliss, they were tasked to train military, industrial, and university personnel in the intricacies of rockets and guided missiles and to help refurbish, assemble, and launch a number of V-2's that had been shipped from Germany to the White Sands Proving Grounds in New Mexico. Further, they were to study the future potential of rockets for military and research applications. In 1950, von Braun and his team were transferred to Huntsville, Alabama, his home for the next twenty years. Between 1950 and 1956, von Braun led the Army's development team at Redstone Arsenal, resulting in the Arsenal's namesake: the Redstone rocket.

As Director of the Development Operations Division of the Army Ballistic Missile Agency (ABMA), von Braun's team then developed the Jupiter-C, a modified Redstone rocket. The Jupiter-C successfully launched the western hemisphere's first satellite, Explorer 1, on January 31, 1958. This event sig-

naled the birth of America's space program. NASA was established by law on July 29, 1958. One day later, the 50th Redstone rocket was successfully fired off Johnson Island in the South Pacific as part of Project Hardtack. Two years later NASA opened the new Marshall Space Flight Center in Huntsville, Alabama and transferred von Braun and his development team from the ABMA at Redstone Arsenal to NASA. Dr. von Braun was the center's first Director, from July 1960 to February 1970. The Marshall Center's first major program was development of the Saturn rockets, capable of carrying astronauts to the moon. Von Braun's childhood commitment to "turn the wheel of time," and his later dream to help mankind set foot on the moon became a reality on July 16, 1969 when a Marshall-developed Saturn V rocket launched the crew of Apollo 11. Over the course of the Apollo program, six teams of astronauts explored the surface of our moon. After the Apollo program, the Saturn 1B, also developed at Marshall under von Braun's leadership, lifted the Skylab, the world's first space station, and its crews into orbit. The final use of the Saturn was during the historic Apollo-Soyuz mission in 1975, when an Apollo spacecraft linked up with a Russian Soyuz craft. After the Apollo space program, von Braun felt that his vision for future spaceflight was different than NASA's, and he retired in June 1972. He became the vice-present of Fairchild Industries in Germantown, Maryland, where he was active in establishing and promoting the National Space Institute.
At the peak of his activities, von Braun learned he had cancer. Despite surgery, the cancer progressed, forcing him to retire from Fairchild on December 31, 1976. On June 16, 1977, Wernher von Braun died in Alexandria, Virginia
The brain drain of the German rocket specialists to the US was the start of the space program of that country.

8. Some conclusions

Through history brain drain has always existed. We have demonstrated this phenomenon with the help of some examples situated a long time ago and in the near past. Scientists always have tried to work in the most comfortable surroundings. Their moving to such place is governed sometimes by financial reasons – obtaining a consistent grant, having at one's disposal of an adequate research budget -, but also religious, political and economic reasons are lying at the basis of a displacement of scientists. One can put forward that the present brain drain from the European countries to the US is nothing new under the sun, but should be studied by our politicians and acceptable measures should be taken. In this context we can refer to the recent initiatives of the Flemish Government, where the Odysseus and Methusalem programs have been started up, by which one hopes to bring back to Flanders researchers for the moment active in foreign countries.

Notes

[1] Statement mentioned in "RTD info, Magazine for European Research, special edition, August 2003, p.23".

[2] Time, January 19, 2004, p.35.

3. Most material has been adapted from the information available on the website http://www-groups.dcs.st-and.ac.uk. and in Al-Daffa (Ali Abdullah) - *The Muslim Contribution to Mathematics, Croom Helm - London, Humanities Press, Atlantic Highlands, N.J., 1977.*

[4] Umberto Eco, *The Name of the Rose,* San Diego, Harcourt Brace & Company, 1994.

[5] For this chapter we were inspired in general by *Geschiedenis van de wetenschappen in België van de Oudheid tot 1815*, (Gemeentekrediet, Groep Dexia, 1998), in particular by Chapter 2 (De Wiskunde, by Paul Bockstaele), Chapter 3 (De Kosmologie, Van Gemma Frisius tot Wendelen, by Fernand Hallyn), Chapter 4 (De natuurkunde, by Patricia Radelet-de Grave), Chapter 5 (De cartografie, by Hossam Elkhadem).

[6] G Kish, *Medicina, mensura, mathematica : The Life and Works of Gemma Frisius, 1508-1555* (Minneapolis, 1967).

[7] Nicolas Crane, Mercator, de man die de aarde in kaart bracht, Ambo – Manteau 2002.

[8] Interesting historical facts about the foundation of the University of Leiden and the first period of working can be found in *Libelli introductorii ab Ricardo Vulpitio composite* (anno MCMLXXV), document available at the exhibition on the University of Leiden in the main building at Rapenburg (Leiden).

[9] Jozef T. Devreese en Guido Vanden Berghe, '*Wonder is gheen wonder*', *De*

geniale wereld van Simon Stevin 1548 – 1620, Davidsfonds 2003.

[10] R. Kanigel, R. 1991. *The Man who Knew Infinity: A Life of the Genius Ramanujan*, Charles Scribner's Sons New-York (also Indian edition, Rupa & Co (1994)).

[11] Notebooks of Srinivasa Ramanujan, 1957, Facsimile edition, Tata Institute of Fundamental Research, Bombay, vol 1 and 2.

[12] G. H. Hardy,. 1923. A Chapter from Ramanujan's Notebook, *Proceedings. of the Cambridge Philosophical Society*, **21**, 492--503. See also, G.H. Hardy. 1924. Some Formulae of Ramanujan, Proceedings of the London Mathematical Society, **22**, xii--xiii.

[13] B. C. Berndt, *Ramanujan's Notebooks*, Part I (1985), Part II (1989), Part III (1991), Part IV (1994), Part V (1997), Springer-Verlag New York Inc.

[14] see for example in *Geschiedenis van de wetenschappen in België, 1815-2000,* (Dexia 2001), in particular Chapter 13 (De industriële scheikunde, by Philippe Tomsin).

[15] See for example bibliography in *Dictionary of Scientific Biography* (New-York 1970 – 1990).

[16] S. Goldstein, Theodore von Karman, 1881 – 1963, Biblographical Memoirs of Fellows of the Royal Society of London 12 (1966), 335 – 365.

[17] W Aspray, *John von Neumann and the origins of modern computing* (Cambridge, M., 1990).

[18] See Biography in Encyclopaedia Britannica.

[19] S.A. Blumberg and G. Owens, *Energy and Conflict: The Life and Times of Edward Teller,* (New York: Plenum Press, 1976).

[20] C.G. Lasby, *Project Paperclip: German Scientists and the Cold War*, (Scribner , 1975).