THE SCIENTIFIC WORLD OF COPERNICUS

NICOLAI CO-
PERNICI TORINENSIS
DE REVOLVTIONIBVS ORBI-
um cœleſtium, Libri VI.

Habes in hoc opere iam recens nato, & ædito, ſtudioſe lector, Motus ſtellarum, tam fixarum, quàm erraticarum, cum ex ueteribus, tum etiam ex recentibus obſeruationibus reſtitutos: & nouis inſuper ac admirabilibus hypotheſibus ornatos. Habes etiam Tabulas expeditiſsimas, ex quibus coſdem ad quoduis tempus quàm facilli me calculare poteris. Igitur, eme, lege, fruere.

ἀγεωμέτρητος μηδεὶς εἰσίτω.

Norimbergæ apud Ioh. Petreium,
Anno M. D. XLIII.

THE SCIENTIFIC WORLD OF COPERNICUS

On the Occasion of the 500th Anniversary of his Birth
1473–1973

Edited by

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FOREWORD

On February 19, 1973, five centuries have elapsed since the birth of Nicolaus Copernicus – the greatest astronomer of the Renaissance period – who rediscovered for us the heliocentric model of the solar system, and documented it by his life's work in such a manner as to make its concept a permanent property of mankind.

The life of Copernicus, extending from 19 February 1473 to his death on 24 May 1543, was not too rich in adventures or biographical facts. Born in Toruń from a family of Polish burghers, he received his first university training in Cracow between 1491–1494. From Cracow he proceeded to Italy to spend the years between 1496–1503 at the Universities of Bologna, Padua and Ferrara – with occasional visits to Rome – in preparation for an ecclesiastical career. When Bishop Watzenrode – his patron and maternal uncle – could no longer extend his leave, Copernicus returned to Poland in 1503 to enter the service of the church establishment, which soon led to a canonry at the Frombork (Frauenburg) Cathedral in Warmia. And there – in the northern mists not far from the Baltic shores – in a land so different in climate from the sunny Italy of his youth – he was destined to spend the rest of his life.

Copernicus' interest in astronomy was probably awakened already at Cracow by his first outstanding teacher, Wojciech of Brudzewo; though it was not till during his Italian years that he conceived the design which was to blossom out into the finest flower which astronomy contributed to the human culture at the time of the Renaissance. Relatively little is known of Copernicus' life during his Italian years; and after five centuries his trail is difficult to follow from extant records with any assurance. From the early years of his life Copernicus had an inclination to anonymity which grew in him with the years. Only now and then – when contemporary events happened to place him temporarily in a position of prominence – do we recognize his features more clearly; but soon thereafter he lapses back into the shadowy existence which was his second nature. His location, at Frombork, in "the most remote corner of the Earth" – as Copernicus described it – precluded more intimate personal contact with many other scholars of his time; and his ecclesiastical rank (though Copernicus was a canon – and between 1523–1525 chancellor of the Frauenburg chapter – he was never ordained priest) deprived him of a family which he could call his own.

There is, however, no doubt that during his 12 years of University life – both in Poland and abroad – he learned in his youth all that ancient sources had to offer – and these were still the principal sources of human knowledge at that time. It is, therefore, more than probable that, on his return to Poland from Italy in 1503, he brought back with him at least the germ of the idea whose execution was to occupy him for the rest of his life, and to immortalize his name in the annals of our science: namely, a

synthesis of the heliocentric model of the solar system of Aristarchos with the geometrical apparatus of Ptolemaic astronomy.

The idea of the heliocentric model of the solar system was not born at the time of the Renaissance, but goes back much further in the cultural history of mankind. In fact we owe it – like so much else – to the Greeks of the Hellenistic times – times when internal disunity lost them their political power, but when they became the masters of the intellectual world by the sheer weight of their genius. As far as we know, the idea that the Sun – rather than the Earth – is at the centre of our planetary system, and that the Earth revolves around it, was propounded first by Aristarchos of Samos – an outstanding philosopher of the third century B.C. – whom astronomers can rightfully adopt as one of their early patron-saints. Of his life much less is known to us than we know about Copernicus. His date or place of birth is unknown – probably around 310 B.C. – the only fixed date of his lifetime being the year 281 B.C., when he observed (according to Hipparchos) the time of the summer solstice. We know that he was berated for the boldness of his views by the stoic philosopher Kleanthes some time after 264 B.C. We have, however, no idea where Aristarchos lived – whether in Athens or Alexandria – nor where he died; but most part of his life was probably spent in the first half of the 3rd century B.C.

What is even worse – Aristarchos' views on the structure of the solar systems may have remained unwritten or what he wrote was lost, so that we know about it only from the references to his views made by his contemporaries. The most famous among these is the testimony recorded by the great mathematician Archimedes (287–212 B.C.) in his *Psammites* (Sand Reckoner) – in words which cannot be read without emotion even after the lapse of 22 centuries:

> You (King Gelon II, tyrant of Syracuse, who died before 216 B.C.) are aware that universe (κοσμος) is the name given by most astronomers to the sphere whose centre is the centre of the Earth, and whose radius is equal to the distance between the centre of the Sun and the centre of the Earth. This is the common account as you have heard from astronomers. But Aristarchos of Samos brought out a book consisting of some hypotheses wherein it appears, as a consequence of assumptions made, that the (real) universe is many times greater than the one just mentioned. His hypotheses are that fixed stars and the Sun remain unmoved, that the Earth revolves about the Sun in the circumference of a circle, the Sun lying in the middle of the orbit, and that the sphere of the fixed stars, situated about the same centre as the Sun, is so great that the circle in which he supposes the Earth to revolve bears such a proportion to the distance of the fixed stars as the centre of the sphere bears to its surface ....

To express the meaning of this passage in plainer words, Aristarchos attempted to explain the observed astronomical phenomena by postulating the daily rotation of the Earth about its own axis, as well as the yearly revolution of the Earth around the Sun. A hypothesis of the terrestrial daily rotation was, to be sure, advanced previously by Heracleides; but in postulating the second (annual) motion Aristarchos does not seem to have had any predecessors. Moreover, the existence of such motion would explain in one stroke all retrograde loops exhibited by the outer planets (Mars, Jupiter and Saturn) as a reflex of our own yearly motion around the Sun.

This being said, the reader may ask why the heliocentric planetary system was not adopted readily in antiquity, and had to wait another 17 centuries for Copernicus.

The reason is the fact that the simple model envisaged by Aristarchos failed to represent the observations ("save the phenomena", as the Greeks were wont to say), within the limits of errors of even naked-eye observations; and this could not have been otherwise because of another shortcoming which took many centuries to shake off: namely, the pre-conception that the motions of all celestial bodies must necessarily be circular and uniform.

We do not know who planted this particular false seed in the human mind – probably the Pythagoreans, misled by esthetic rather than physical reasons. But its consequences for the progress of science were singularly disastrous. For we know, of course, and have known since the time of Kepler, that planetary motions in the sky are neither uniform nor circular; and that any attempt to represent the apparent motions of the planets in the sky by pure circles would fail to establish a real agreement between theory and observation regardless of the position of the Sun in the system. This is especially true of our nearest celestial neighbour Mars, which happens to follow a markedly eccentric orbit ($e=0.093$) – and for which, as a result, the differences between the observations and any system – be it geocentric or heliocentric – based on the assumption of uniform circular motion would amount to whole degrees.

Discrepancies of this order of magnitude must have troubled Aristarchos, and been intolerable to Hipparchos living a century later. Therefore, the heliocentric model of the solar system, introduced by Aristarchos in the 3rd century B.C., failed no doubt to gain acceptance because a mere replacement of the Earth by the Sun at its centre – simplify as it did some geometrical aspects of the problem – did nothing to remove the principal obstacle to the practical usefulness of such models: and this was the mistaken concept that all celestial motions must be circular and uniform. There is no indication known to us that Aristarchos would have contemplated any departure from the Pythagorean tradition in this respect; nor did anyone else until the time of Kepler.

In the meantime, the only way which suggested itself to the ancient astronomers for 'saving the phenomena' and reconciling the observed paths of the planets on the celestial sphere with the Pythagorean preconceptions, was to superpose more than one uniform circular motion on top of another. The commencement of this geometrical merry-go-round can be traced to the homothetic spheres of Eudoxos, followed by the geometrical theory of epicycles laid down by Apollonios in the second half of the 3rd century B.C., which was developed further by Ptolemy into a pragmatic geometrical system which survived in astronomy – with many vicissitudes – until the time of Copernicus.

Was Copernicus aware of the fact that the heliocentric system of the planetary family was already proposed in antiquity by Aristarchos? During his Italian years Copernicus no doubt learned all that contemporary astronomy had to offer; and – if nobody else – Mario Novara in Padua would have made him aware of the various shortcomings of the geocentric system. The 'editio princeps' of Archimedes' *Psammites*, with its crucial testimony, quoted above, appeared in Basle in 1544 – one year after Copernicus died. However, that Copernicus was aware of Aristarchos'

work from manuscript sources is attested by his own hand in the manuscript of his book *De Revolutionibus Orbium Celestium*. The respective passage was eventually left out of the printed edition of his work by a stroke of the author's pen; but the manuscript containing it has been preserved to this day.

Copernicus doubtless knew too from his teachers – and, may be, partly from his own observations – that the heliocentric system based upon the Pythagorean preconceptions on the uniformity of motions cannot be made to represent the apparent motions of the planets in the sky even within the limits of accuracy of the observations made with naked eye. This is why, in order to improve agreement, Hipparchos and Ptolemy felt impelled to introduce their complicated systems of epicycles. Copernicus could offer no more adequate mathematical machinery to the same end; but in place of applying it to geocentric orbits of celestial bodies, he set out to graft it on to a heliocentric system. Copernicus was the first one to attempt such a synthesis; and his stature in the history of science rests on this fact. Moreover, the merits of such an accomplishment are scarcely diminished by an admission that Copernicus did not invent the heliocentric model of the solar system, but revived its ancient tradition going back to pre-Ptolemaic days. His main personal contribution was – we repeat – to dress up the heliocentric idea of Aristarchos in the garb of the Ptolemaic geometry. He could scarcely have done otherwise, for kinematically Copernicus was still fully under the spell of the Pythagorean lore; but he was the first to develop such a synthesis into a comprehensive system.

Before we say a few words on the actual accomplishments of the resulting system, let us describe first some of its salient features. Thus – perhaps contrary to many popular views – the geometrical centre of the Copernican model of the solar system did not coincide with the position of the Sun, but rather with the centre of the circular orbit of the Earth; for it was only in this way that he could account for the phenomena arising (as we now know) from the eccentricity of the terrestrial orbit. Secondly, in order to reconcile his geometrical model of the solar system with the astronomical observations (made mostly by others, to which Copernicus added very few of his own) within 10 minutes of arc – this was the goal of Copernicus' efforts – he had to employ actually a larger number of epicycles to this end than were used in the geocentric models of the same period. The latter, in the hands of George Peurbach (1423–1461) required only 40 epicycles to 'save the phenomena' to a comparable accuracy; while the final system of Copernicus of 1543 required not less than 48 of them; and by abolishing the 'equants' from his theory he had to introduce more 'deferents' in their place.

Under these circumstances, it is only to be expected that the overall picture of the Ptolemaic system of the 16th century was really no more complicated geometrically than that of Copernicus. The latter also did not represent any significant advance in our knowledge of the true size of the solar system. Whereas for Ptolemy (who lived in the 2nd century A.D.), the distance to the Sun was estimated to 610 Earth diameters, Copernicus diminished this distance to 571 Earth diameters (the actual value of the 'astronomical unit' being 11 500 Earth diameters). Moreover, while in the geocentric model the ratios of planetary distances are essentially arbitrary, the heliocentric model

contains a 'built-in' system for a determination of the relative sizes of planetary orbits in terms of that of the Earth (the annual retrograde motion of each planet being merely a reflex of our own motion around the Sun). In this way, Copernicus constructed for the first time the actual model of our solar system; though he still underestimated its scale by a factor close to 20.

It has, however, been traditional in the science of astronomy to measure the value of a new planetary theory by the correctness with which such a theory can predict the positions of the planets in the sky at future times. The planetary tables constructed by Copernicus on the basis of his heliocentric theory (published by Erasmus Reinhold in Wittenberg in 1551, eight years after Copernicus' death, under the title of *Tabulae Prutenicae*) did constitute a significant improvement over the preceding *Alphonsine Tables* from the 13th century, based on the geocentric system. For three quarters of a century the Copernican tables of planetary motion remained the standard source of information – until they were superseded by the *Rudolphine Tables* of Johannes Kepler in 1627; but, by that time, the entire astronomical scenery had undergone a profound change, and the work of Copernicus became a part of history.

Tradition has it that Copernicus received the first copy of his great work *De Revolutionibus Orbium Celestium* (Nürnberg, 1543) on his deathbed, barely aware of its contents. How was the synthesis of the idea of Aristarchos presented in terms of the Ptolemaic geometry received by subsequent generations – in particular, among the clergy – men concerned with philosophical implications of the system? Its thesis was accepted with lukewarm interest on the part of the educated Catholic clergy, and without demur by Pope Paul III to whom Copernicus' book was dedicated. On the other hand, the Lutheran church objected strongly from the beginning to its thesis on grounds of biblical fundamentalism. Martin Luther himself gave out only a few uncouth growls in this connection ("That fool wants to turn the whole art of astronomy upside down") in his native vernacular; while Melanchthon proved the Earth to be at rest in elegant Latin. The real theological storm – in which both Catholics and Protestants began to outbid each other in their denunciations of the heliocentric system – did not break out till the first 3rd of the 17th century, in the wake of the work of Galileo Galilei and Johannes Kepler.

It was, in particular, Kepler – that David armed with mathematics rather than stones in his sling – who was destined to slay that Goliath of Pythagorean preconceptions, and to liberate the planetary theory from the straightjacket of uniform motion in circular trajectories. The dogma of such motions was, however, still held as sacrosanct by Copernicus. For listen to what he had to say on this subject in his *Commentariolus* of 1574:

> Our ancestors assumed a large number of celestial spheres for a special reason: to explain the apparent motions of the planets by the principle of regularity. For they thought it altogether absurd that a heavenly body should not always move with uniform velocity in a perfect circle....

And, as these Pythagorean tenets failed to 'save the phenomena' to the desired accuracy, Copernicus went on ...

Having become aware of these defects, I often considered whether a more reasonable arrangement of circles could perhaps be found ... in which everything would move uniformly about its proper centre, as the rule of absolute motion requires.

As the repudiation of such views, held without any foundation for so many centuries, was a *condito sine qua non* for a true renaissance of our science, Copernicus can scarcely be regarded as an actual forerunner of men like Galileo or Kepler, who a century later were to call themselves Copernicans, but whose bold departures from tradition would have horrified their master. No, Copernicus was not one of them. He was, instead, the last of the great ancients – a spiritual companion of Aristarchos, Hipparchos or Ptolemaios from whom he was separated by many centuries of time, but with whom he shared their outlook of the heavens more fully than he would have done with Galileo or Kepler on the other side of the 'great divide' after 1610.

By that time, the work of Copernicus belonged already to the history; and in the history of astronomy his place is forever secure.

Manchester, 1973 ZDENĚK KOPAL

THE COUNTRY AND THE WORLD OF COPERNICUS

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NICOLAUS COPERNICUS, Torunii in Prusia natus, patre Nicolao Copernico, matre vero quae erat germana soror Lucae a Watzelrod Toruniensis, episcopi Varmiensis, praeclare de Republica Polonorum meriti in causa Cruciferorum.*

Copernicus was born in Toruń (Thorn) and quite likely attended school at the neighboring town of Chełmno. Except for five years as student in Cracow and eight in Italy, Copernicus spent the adult years of his life at the bishopric of Lidzbark as canon of the diocese of Warmia (Ermland), at the chapter's administrative center in Olsztyn and, the longest period, at the cathedral of Frombork. It is from here that he traveled to the provincial councils of Prussia and made two trips to the capital of Poland Cracow and perhaps one to Poznań.

His country was the province of ancient Royal Prussia, composed of his native Toruń and Warmia, both components of the Polish state since 1454. In the largest sense, however, one might say that Copernicus was a citizen of the universal republic of scholars, a member of a community that was representative of European culture at the turn of the 16th century.

1. His Country

In the second half of the 15th century, the kingdom of Poland, united by treaty with the Grand Duchy of Lithuania in 1386 and since then ruled by the Jagiellonian dynasty, was the largest country of Europe. Owing to the decline of Mediterranean commerce after the Turks seized Constantinople in 1453, the bulk of European trade was shifted to the Baltic and to the inland territories of Poland and Lithuania which gravitated toward that sea: producers of raw materials themselves, these lands were criss-crossed with land routes over which Russian crude products were carried in transit. The growing populations and industry of Western Europe created a demand for imported grains, fiber crops and forest products. The turning point in the Baltic trade occurred in 1480. West European, and primarily Dutch, merchants broke the monopoly of the Hanseatic towns on the western Baltic coast and established direct trade dealings with the ports on the eastern coast of the Baltic, that is specifically with Gdańsk, Elbląg and Braniewo (Braunsberg), all ports that lay within Polish frontiers. The rising price of grain stimulated production. This was achieved primarily by expansion of large landed estates which were capable of raising surplus crops for export. As lords of large seignories East of the Łaba (Elbe) extended the area of land

* The mottoes placed at the head of each chapter are taken from the first large Polish biography of Copernicus, published by Szymon Starowolski in *Scriptorum Polonicorum Hecatontas*, Venice 1627.

they cultivated, they were able to affect an increase in the price for agricultural products at a rate incomparably faster than the craftsmen. Consequently, the 1520's witnessed a growing disparity in prices, especially as handicrafts organized along traditional lines could not keep pace with the trend toward industrialization. This called for investments which only the merchants with capital and large landowners were capable of making.

The far-flung territories of Poland and Lithuania were a slowly coalescing organism although they remained diversified in geography, nationality and religion. Next to the Poles, who were in the majority, the territories were inhabited by Lithuanians and Orthodox Ruthenians, by small groups of Armenians and Muslim Turks and by Jews and Karaims who professed Judaism. The Germans, largely assimilated by the Poles, formed the upper stratum of the large towns. Inhabitants of small towns were almost entirely Polish.

Distinct in nature within the borders of the Jagiellonian realm were the territories of Prussia that had been conquered by the Teutonic Order in the 13th century. Though partly colonized by Germany, they nevertheless contained a population that was predominantly Slav and Baltic Prussian. Geographically, Prussia occupied what were essentially two areas: the narrow and generally fertile strip of the Baltic littoral and the moraine hummocks of the lake region which still remain largely overgrown with forest. The wide valley of the Vistula (Wisła) and its delta cutting across the moraine ridges formed a distinct region. Because of its rich soil, the valley had been cultivated by man for many centuries, its area increased and protected by methods developed in Holland.

A dense network of strongholds covered the territory of Prussia in the 13th and the 14th century to offer protection against the threat represented by the oppressed native population. There was a total of 120 fortified Teutonic and episcopal castles with cities protected by these fortresses. In the period of insurrection the townsmen of large towns stormed and destroyed Teutonic castles while modernizing town fortifications.

In the 15th century a new conflict broke out between the settlers and the Teutonic Order. In 1454 the knights and townsmen of the territories of Teutonic Prussia rose, regardless of nationality, against the economic repressions and draconic rule imposed by the Teutonic Order. They appealed for help to the Kingdom of Poland with which the territories held by the religious order maintained close economic and cultural ties.

In effect the war, fought by mercenary troops and costing Prussian territories and Poland a great amount of money, exercised a significant influence upon world outlook. Traditional ecclesiastic institutions represented by the Teutonic Knights and their state – which lay within the domain of the Holy Roman Empire of the German People – were opposed by demands for the right of subjects to revolt against unjust authority, a concept developed by Polish theologians at the request of Prussian towns. The Kingdom of Poland, together with the territories of Prussia, surmounted the crisis evoked by the anathema deviously obtained from the corrupt and venal Curia Romana by the Order. The peace of 1466, concluded after a war that lasted thirteen years, sealed the doom of the Teutonic Order in Prussia with irrevocable finality. The Grand Master salvaged only a portion of his former domain and became a vassal of the Polish king.

The boundary line between the fief and the territories under the direct jurisdiction

of the king was not drawn along a natural frontier. Consequently, the bishopric of Warmia constituted a virtually separate enclave connected with Royal Prussia only by a thin strip of coastline. The bishopric was almost entirely surrounded by territories that remained in the hands of the Teutonic Order.

The Thirteen Year War of 1454–1466, waged in a small area often with large military forces, brought economic ruin to the country. The population was reduced by more than half. It took over a hundred years to make up this loss. At the same time, however, the excellent economic opportunities, the unification of the territories, formerly under Teutonic rule, with the life-giving inland territories of a large state, the privileges obtained from the Polish king and the broad autonomy enjoyed resulted in quick reconstruction and reform of the structure. The father of Copernicus was swept from Cracow to Toruń on the wave of the 1458 migrations. Through marriage with Barbara Watzenrode, sister of canon Łukasz Watzenrode later bishop of Warmia, he entered the ranks of the Toruń patriciate.

Profits from Poland's transit trade to the Baltic were drawn by four large towns situated on the banks of the Vistula, the main artery by which Polish goods were transported. They were: Toruń, Chełmno and, at the mouth of the Vistula on the Baltic, Gdańsk and Elbląg. The patricians of these towns dominated the economy and the politics of the province, the most densely urbanized part of the monarchy. Due to the autonomy of the territories of Prussia, the economic benefits that accrued from the union with Poland, which provided the sole political defense against the decaying Holy Roman Empire and efforts of the Teutonic Knights to recover the lands they lost, and finally due to the attractions of Polish culture, the union of 1454, consolidated in common military effort, proved as natural as it was lasting.

With the economic stagnation of the territories of Eastern Germany and with the decline of the Hanseatic towns, elements of Netherlands culture appeared here together with the economic contacts. These were principally the *devotio moderna* and congregations of the lay and clerical Brothers of the Common Life who devoted themselves to a form of eduction of the young that became widespread among the wealthy townspeople. The ideals of respectability, simplicity and industry which they embraced complemented the instinct to count profits and to take risks, habits that were strongly entrenched in the merchant mind. The Brothers maintained ties with the world and devoted themselves to writing and teaching and also demonstrated an interest in Latin and classical literature. A school run by the Brothers is known to have existed in Chełmno at the time. By its outward reserve and seriousness of manner it represented a contrast with the exuberant activity of the Dominican and Franciscan Orders whose main interest lay in preaching. The art of the Netherlands found a ready market in Prussia and inspired local artists.

The diocese of Warmia, where with the exception of a few interruptions Copernicus lived for forty years, formed a separate entity within Royal Prussia. Its estates were divided between the episcopacy and the chapter. The one larger mercantile town was Braniewo with a few smaller towns economically subordinated to it. Hence Lidzbark with the bishop's residence, an impressive castle built in a square around an arcaded

courtyard that may still be admired here, and Frombork, a port on the Baltic lagoon sprawling at the foot of a hill which supports a fortress-cathedral. The houses of canons (some of which have been preserved to our time) nestled outside the cathedral walls from which there spread a panoramic view extending beyond the bay rimmed with the dark of a forest and the narrow peninsula that separates the bay from the open sea. In the southern part of the episcopal principality, a full hundred kilometers from the sea, surrounded by lakes and forests and the gravel strewn moraines, the city of Olsztyn rises on a high cliff that overlooks the Łyna River. In the days of Copernicus the castle housing the administrators of the chapter lands dominated the city, today Olsztyn is a busy and fast growing capital of the province.

The agricultural region of Warmia skirting the sea was settled by Germans and Germanized Baltic Prussians while the southern, forested area (together with Olsztyn), was occupied by settlers who arrived from neighboring Poland. Polish settlers were brought in greatest numbers to take possession of villages abandoned after the destructive wars of 1454–1466 and 1520–1521. As administrator of the chapter lands, Copernicus was actively involved in bringing the Poles to Warmia. He visited the villages and kept a careful register of the peasants who settled here. Surrounded by Polish villages, the urban population of southern Warmia was swiftly Polonized. While the lands settled by Poles at an earlier time contained a fairly large number of wealthy and petty nobles and prosperous peasants, Warmia, being a poor and recolonized country, contained a negligable number of estates owned by the gentry and knights and a large group of less prosperous peasants.

2. The World of Copernicus

Left an orphan at a tender age, Nicolaus Copernicus spent his early childhood in Toruń, one of the principal towns of the Prussian territories. The town flourished and prospered after the Thirteen Year War. In the second half of the 15th century, however, Toruń allowed Gdańsk to take the lead.

Founded in 1231 by the Teutonic Knights on the banks of the Vistula in the Polish Province of Chełmno that directly bordered with Prussian territories, Toruń thrived principally on trade. It expanded in size when New Toruń, inhabited by tradesmen and artisans, was established nearby in 1280. In the 14th century the town waxed rich on commerce with Poland. The trade came abruptly to a halt in the early 15th century with the outbreak of war between the Teutonic Knights and Poland. The modern visitor may still be impressed by Toruń's splendid brick churches, the Old Town Hall, the town fortifications and the magnificent statuary and paintings.

The years of peace after 1466 mark a new phase in the development of Gothic art. The vertical accents of early Gothic architecture were now superseded by plain surfaces divided by horizontal lines. The parochial church of St. John the Baptist is perhaps the finest example of this style. The large edifice, expanded and enlarged in 1468–1472, rises above the city to this day. This is where we find the bronze baptismal font at which in the year 1474 a son of the Old Toruń merchant Copernicus was

baptized and given the name of Nicolaus, the patron saint of merchants. Taking advantage of the support he received from his enterprising uncle, canon and from 1489 bishop of Warmia, the gifted boy was not enroled in the school ordinarily attended by merchants' sons. However, he received at his family home a working familiarity with arithmetic, the habit of using an astronomical calendar and a knowledge of money. The people of his time were excited by astronomical phenomena and internal urban affairs. Confined by restricted international horizons, they fully realized the value of thrift and combined an innate habit of taking risks with a respect for industry.

Destined for a church career and a higher education, Copernicus was quite probably sent to Chełmno where the *studium particulare* was established on a higher academic standard than the parochial school of Toruń.

Chełmno was located a day's journey down the Vistula from Toruń. Although it was one of the major Prussian towns, it sank into economic stagnation after the war. However, the old school tradition (steps had been taken in the 14th century to set up a Prussian university here) still remained alive. The Brothers of Common Life offered the students other stimuli and moral concepts than the idea of getting rich at all cost which was the moving spirit of Copernicus' native town.

In the autumn of 1491, Copernicus then eighteen years of age, entered the University of Cracow instead of one of the Baltic universities at Rostock or Greifswald. His decision was motivated by family tradition and the reputation the Polish academy enjoyed. It was considered one of the finest universities of Central Europe at the time.

Cracow was not only the capital of a large power but also a commercial metropolis, a market town of an agricultural region and administrative center of a mining district. Its population, larger than that of any town in Prussian territories, was multinational in character. Next to the German patricians, quickly assimilated by the predominantly Polish population, came the Italians who also made their home here. In some ways the magnates dominated the townsmen.

The political horizons were circumscribed by the territories over which the block of four countries ruled by the Jagiellonians, extended. The boundaries of the block, composed of Poland, Lithuania, Bohemia and Hungary, extended in the south to the Adriatic and the Black Sea. The Baltic issue receded into the background as the Turkish danger grew ominous. With the loss of the Black Sea ports to the Turks (Kaffa-Feodosiya in the Crimea in 1475 and Chilia and Belgorod Dnestrovski (Alba Iulia) in 1484), the countries began to mount the disastrous retaliatory expedition of 1497 to the mouth of the Danube.

Cracow with its white stone structures in no way resembled the red brick towns of the Prussian territories. Gothic was entering upon a new phase of development when Copernicus arrived there. The new style incorporated window tracery, flamboyant fan vaults that came to central Europe by way of Saxony, Silesia and Upper Hungary (Slovakia).

The new form of architecture was preceded by great works of painting and altar sculptures. The young man from Toruń and Chełmno was awed by the magnificence

of group compositions of the late Gothic and by the remarkable miniatures he saw. (Toruń was not to received the great 'Descent from the Cross' until 1495).

Church interiors were furnished with pictures, tapestries, sculptures, decorative gold leaf ornamentation designed generally with figural though also with floral and geometric patterns. As historical sense in the modern meaning of the term was alien to the genius of that age, biblical scenes were placed in contemporary settings and ancient figures mingled with living persons and saints popular at the time. The trend fostered by the new intellectual attitude that took hold of the country, that is by interest in the discovery of the world and man, provides a fairly good picture of 15th century man, of his appearance, the manner in which he dressed and the kinds of work he performed as seen in the various social, anthropological and emotional aspects. The limited range of symbolic colors and the hieratic figures were now more diversified, the shades of light and the very shape of life were depicted with greater veracity. All these developments served to stimulate public imagination.

While custom and technical difficulties weighed heavily on the monumental, poster-like altar paintings, there were fewer obstacles to innovation in the elite art of the miniature which flourished in Cracow in the 16th century. Many fine illuminated volumes of liturgy and private prayer books were brought out at the time. Private and individual experiences of men of breeding and taste began to play a larger role in the illuminations as did the surrounding secular world, with its fascinating sweep of landscapes and touching detail. The most remarkable, and this a secular, work produced at the time was the *Codex picturatus*, commissioned by the town clerk of records Baltazar Behem. The book is a collection of the statutes of the Cracow guilds illustrated with 28 miniatures. They form a series of pictorial sonnets depicting artisans at their various occupations. Workshop interiors, landscapes, symbolizing and rhapsodizing snowy winter and hot summer, form a unique encyclopedia of urban life inscribed in luminous gold and subtle shadings of color, ranging from black and white to lemon yellow and blue. We see the same range of color in the pictures painted by Vermeer 150 years later.

Painting and sculpture, with the glints of gold, the glowing purity of color, the drama of narrative and the sacred nature of the subjects presented, had a powerful and lasting effect upon human emotion and gave impetus to intellectual development.

The finest expression of the art of Cracow were the large painted and carved triptychs and polyptychs enclosed within the sculptured frames of Gothic architecture. The triptych, with its side panels thrown open during the service, was intended to dazzle the people with its opulence. Since the triptych was subordinated to the liturgical rites performed in front of the altar, consequently, the style tended to be conservative and hieratic in form. The backgrounds for the figures and scenes from the bible and from the lives of saints were invariably in gold. The less luxurious exteriors of the side panels (visible when the triptych was closed) were executed by young and very often highly inventive artists. The scenes were free of the lavish use of gold and represented the ordinary world. The first large Cracow triptych, found in the Dominican Church (1477), marks the beginning of realism and the wider use of a rich pro-

fusion of flora and fauna in the landscapes that were clearly reminiscent in hue of the countryside of Cracow. Events that took place in distant lands and in remote ages were symbolically depicted as occuring now and here in the country lanes and in the presence of neighbors, shepherds and their herds, artisans and merchants. Birds sing in the trees, a mole can be glimpsed through the flowers and grass as it burrows in the fresh plowed earth and an angel, resembling a large insect, shoots across the star-studded firmament like a falling star.

The greatest masterpiece of the European art produced in that century, one whose completion was witnessed by Copernicus, was the polyptych that took the German sculptor Wit Stosz (Veit Stoss) a full twelve years to carve, gild and paint. More gold was used in the adornment of the altar, founded with contributions made by the townsmen of Cracow – most of whom were Poles, than in any other altar of that day in Europe. But it also must have provided the strongest emotional experience.

The center panel represents the 'Last Sleep of the Virgin Mary'. As the Apostles cluster around her in great agitation, her body sinks gently to the ground. The agitation is expressed by concern and indignation painted on their faces, by the wringing of hands, the gnarled legs and the heavy gilt robes billowing in the wind. Each disciple reacts differently to the death of the Virgin (or is it a reaction to the death of an age and order in which the artist lived?). The scenes on the side panel done in polychrome low relief relate not only the story of the life of the Virgin Mary and the Passion of Her Son – a tale dear to the heart of the people – but also recount the epic, or rather make an encyclopedic enumeration of people and objects, of the sins and virtues of the dying middle ages.

The triumph Stoss celebrated with the altar he made for the townsmen of Cracow opened to him the portals of the royal cathedral at Wawel. Stoss produced another masterpiece here. This time it was a mausoleum for Casimir Jagiellończyk who died in 1492. The movingly realistic death mask, the king's figure in red veined marble twisting in the agony of death lies on a tomb engraved with figures of traditional mourners which contrast with the sumptuous canopy of intersecting late Gothic arches that represent the firmament.

In Cracow the great sculptor spent the happiest and most productive years of his life (1477–1496). From his tragic Nuremberg period comes the bronze plaque of Philip Kallimachos (born Filipo Buonoccorsi), Italian historian, humanist and political advisor to the Jagiellonians, owner of a townhouse that stood next to the home of the Copernicus family in the Old Town Market Square of Toruń. The bronze plaque was cast in Nuremberg for Poland by Peter Vischer.

When Stoss departed from Cracow, he left behind him pupils and imitators who were active in a large area that stretched from Slovakia as far as Warmia. The many remarkable works they produced gave a true picture of Poland and Poles of the early 16th century. Fine paintings continued to be produced in Cracow. Notable among these was Marcin Czarny's 'Last Sleep of the Virgin Mary' depicted on one of the panels of the Bodzentyn triptych of 1508 which also contains a full length portrait of its founder, the Cracow bishop, Jan Konarski.

The democratic, black and white art of printing developed with the support of the University. The faculty of liberal arts at the Cracow University where Copernicus spent four years as a student had a fine tradition which dated back to the first half of the 15th century. Students, these chiefly from Central Europe, continued to flock to this still very vigorous academic community. Lively contacts were maintained with Italian humanism through a course in the masterpieces of literature. We might mention the fact that in 1492 ten lectures were given on the subject of classical literature, namely the works of Cicero, Ovid and Virgil (his *Bucolics*, the *Aeneid* and the *Georgics*). Jean Buridan's interpretation of Aristotelian physics was expounded in the natural sciences, hence principally the theory of momentum which represented an approach to the motion of bodies that laid the foundations for the development of modern physics and astronomy. Buridan also formulated the proposition regarding direct observations of natural phenomena. Mathematics and astronomy attained a high level of development at the university of Cracow. It seems quite likely that the nephew of the bishop and politician Watzenrode did have some connection with the extramural 'second circle' of intellectual culture where itinerant humanists occasionally mixed with bishops, politicians and diplomats.

Although Copernicus did not obtain a degree at Cracow, there is no doubt that he did acquire an education there. His knowledge of mathematics and first observations made clear to him the contradictions inherent in the theory of the geocentric system of the universe. He left for Italy in 1496 bearing with him this rankling problem and a thorough grounding for further studies.

He arrived after the 1495–1496 revolution in military technology. This was a time when in the service of their countries scholars and artists were feverishly bent on discovering new technological solutions which would counteract the destructive force of artillery and the strong defenses of fortifications. They looked for new uses to which the mobility of artillery could be put in battles waged in the field. Spanish and French commanders developed new infantry tactics that were later put to the test in the battlefields of Italy. We do not know what impression the ancient monuments and the discovery of perspective represented in masterpieces painted by contemporary artists that he saw in Bologna, Ferrara, Padua and the Rome of Alexander VI made on the student from the kingdom of Poland who, outside the regular course of study of medicine and law (the official purpose of his journey to Italy), devoted himself assiduously to the computation and the ever more scrupulous checking of data gathered from the observation of 'the heavenly spheres'.

Having obtained a doctorate in canon law, Copernicus hastily returned to Warmia where he was to remain to the end of his days. Until his uncle's death in 1512, he lived at the castle of Lidzbark and accompanied the bishop to Cracow on two occasions and most likely once to Poznań. In Cracow he must have surely observed the changes in the architectural panorama, the new Gothic fan vaults of the Collegium Maius completed in 1497 and the first works of the king's Italian architects representing the Tuscan renaissance style in its purest form. He must have also seen the latest works of Veit Stoss and the sculptures produced in abundance by his pupils as well as the

first renaissance works of Florentine artists. Moreover, he could observe the technical and economic progress of the country and of its capital and renew old friendships, principally perhaps with Bernard Wapowski, a remarkable cartographer and historian; Copernicus corresponded with him in later years. Moreover, nowhere but in Cracow could Copernicus publish his first book, the humanistic *Letters* of Theophilactos Simocatta he translated into Latin from the Greek.

He was in Cracow too early to meet the illustrious humanists born about the year 1500 (except perhaps for Stanislaus Hosius, canon of Warmia from 1538 and later cardinal). However, he must have heard of issues relating to the internal policies of the Jagiellonian states, principally of the movement of the wealthier gentry who as they grew rich threw off the supremacy of the magnates and sought economic privileges. However, Copernicus remained most vitally interested in Prussian affairs.

He accompanied his uncle frequently to the provincial diets of Prussia and continued to attend them even after 1512 (the year of his uncle's death) as delegate of the Warmia chapter. Hence, he traveled occasionally to Gdańsk, Toruń, Grudziądz, Elbląg. Most often, however, he journeyed to the former Teutonic capital of Malbork. Its castle, at one time the residence of the Grand Master, was one of the finest buildings in Europe. Its massive bulk still looms over the wide currents of the Nogat River.

Oriented in the arcana of politics and economy, Copernicus commanded due respect of the magnates and members of the gentry and clergy he encountered at the provincial diets and other meetings as well as of the representatives of large and small towns. For this was an age when even the ideology of knighthood proclaimed that the two pillars without which the world would be reduced to chaos are 'chevalerie et science, qui moult bien conviennent ensemble'. The title of doctor was accorded the same privileges as the knights enjoyed.

His immediate homeland, Royal Prussia, changed its aspect in its own peculiar fashion, although the light and shadow effects of the fan vaults and the softer contours of the renaissance also made their appearance in Warmia. The pointed arches of red brick became rounded under the influence of Netherlands architects who arrived by way of the Baltic and of the Saxon artists who came by overland routes that led from the Central European commercial metropolis of Leipzig. The cares and concerns of the Prussian gentry, whose spokesman was the Italian educated Fabian of Losainen (1512-1523), successor of Bishop Łukasz Watzenrode, impressed the minds of the intellectuals congregated in the Frombork chapter. The interests of the powerful Gdańsk patricians were represented by the next bishop, the authoritarian and ruthless Maurycy Ferber (1523–1532), while the grand design of the royal policies of Cracow were personified by Jan Dantyszek, poet and courtier, for many years envoy to the court of Charles V at Valladolid, later correspondent and patron of Erasmus of Rotterdam. Jan Dantyszek was bishop of Warmia in 1537–1548.

The chapter, to which Copernicus was appointed in 1495, differed from other corporations of this type by the fact that it was composed almost exclusively of townsmen. The remarkable majority of the canons had a higher education, although only few of them were ordained to the higher priesthood. Among them were such