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No Laughing Matter

These, Gentlemen, are the opinions
upon which I base my facts.

—WINSTON CHURCHILL

Gravity is the mysterious attraction that holds us to the earth and, in general, draws together all things made of matter. Every schoolchild today is brought up with this idea in mind. Yet the notion of gravity as a force is fairly new; it dates back only to the seventeenth century, when Isaac Newton and his contemporaries began to rethink the way the world works. Before that time, gravity was seen in a very different light. It was assumed to be something an object *possessed*, a built-in property of its substance that decided how strong was the object's urge to fall. For almost two thousand years, this belief survived with barely a murmur of protest—an enduring brainchild of the first colossus of gravity.

A Meeting of Minds

Aristotle was born in 384 B.C. in Stagira, a Greek colony and seaport on the Thracian peninsula of Chalcidice, the part of Greece that looks like a three-fingered hand reaching into the northwest Aegean Sea. This is hilly country, tumbling down steeply to the blue salt waters, dense with low-lying fruit trees, bushes, and flowering shrubs, and interspersed here and there with outcrops of bright, bare rock. Aristotle's family was upper class, well connected, and intellectual; they were doctors by profession. His father, Nichomachus, served as court physician to King Amyntas III of Macedonia (the region to the north of Chalcidice), a connection that was instrumental in launching Aristotle's long association with the Macedonian royals, which would lead eventually to his tutoring Amyntas's celebrated grandson, the future Alexander the Great. Not much else is known of Aristotle's childhood. Both his parents died when he was young but probably not before Nichomachus had passed on to his son as much of his expertise as possible, a task he was duty bound to do by the Hippocratic Oath. In this way, Aristotle would have been exposed to some of the most advanced biological knowledge in the classical world, and he likely gained, early on, a deep curiosity about nature.

Although the Chalcidice peninsula is very much a part of modern-day Greece, it was considered rough and barbaric–an intellectual backwater–in those far-off days. All the big thinkers and seats of learning were congregated in a few key city-states, of which Athens, to the northwest, was preeminent. Just outside the city walls of the capital lay the Academy, the Harvard of the ancient world. At the head of the Academy was Plato, the foremost thinker of his age. At the age of eighteen, Aristotle was packed off by his guardian and mentor, Proxenus, to Athens to complete his education under this master of philosophy.

The Academy supposedly took its name from Hekademos, a mythical Attic hero at the time of the Trojan War, who, legend has it, planted twelve olive groves on land he owned about a mile from the center of Athens, using shoots from the sacred tree of Athena, the chief goddess of Greece, on the Acropolis. He then bequeathed the place for use as a public gymnasium (an athletic training ground) and shrine to Athena and other deities. Several hundred years later, in the sixth century B.C., Hippias, a tyrant of Athens, built a wall around the site and put up some statues and temples. Meanwhile, the statesman Kimon went so far as to have the course of the river Cephisus changed so that it would make the dry land of this popular park more fertile. Festivals were held there, as were athletic events in which runners would race between the various altars. Then, in about 387 B.C., Plato inherited a house nearby, together with a garden inside the grounds of the park. Here, within this pleasant, leafy retreat, he founded his Academy.

The Academy has often been described as the first university in the West–a fair enough description in the sense that it became a focus of intellectual energy, a place set aside from the workaday world to which keen minds could come to learn and discuss lofty ideas across a range of disciplines in seminars, informal talks, and meetings. Yet the only university-style lectures in the Academy were in mathematics. Plato is said to have had inscribed "Let no one who is not a geometer enter" above the door.

While that may be myth, given that the first reference to the inscription appears in a document written more than seven hundred years after Plato died, mathematics unquestionably loomed large in Plato's cosmic master plan. He was drawn to the subject because of its idealized abstractions, its transcendent purity, and the fact that it stood aloof from the material world, somehow above and beyond it. Natural philosophy–science, as we now call it–was anathema to him, an inferior and unworthy sort of knowledge. Mathematics in its most unadulterated form, Plato believed, could have nothing to do with the gross and imperfect goings-on in everyday life. Where it interfaced with reality at all, it must be well outside the flawed human realm–working at the most fundamental level, underpinning the very nature of things, and also, on the grandest of scales, encapsulating the structure of the universe as a whole. In such musings there's more than a whiff of intellectual snobbery: the aristocrat of knowledge, from a privileged family–his father's side claimed descent from the sea god Poseidon–waited upon by slaves, not wanting to deal with the sordid reality of commonplace data. But we can also glimpse an early attempt to devise a "theory of everything," a way of accounting for all of the most basic ingredients of nature within a unified mathematical framework.

The Fifth Element

At the heart of Plato's cosmological scheme lies the simplest and most perfect of three-dimensional geometric shapes, a point he drives home most emphatically in one of his later and best known dialogues, *Timaeus.* (The bulk of Plato's major writings take the form of contrived two-way conversations, often involving his teacher, the great Socrates.) In *Timaeus*, Plato talks about the five, and only five, possible regular solids–those with equivalent faces and with all lines and angles formed by those faces equal: the four-sided tetrahedron, the six-sided hexahedron or cube, the eight-sided octahedron, the twelve-sided dodecahedron, and the twenty-sided icosahedron. Today we call these shapes the Platonic solids because they first became widely known in medieval Europe through their exposure in *Timaeus.*

But Plato didn't discover them. Almost certainly, he learned of their existence during the ten years or so he spent in Sicily and southern Italy before setting up the Academy, probably from his close friend Archytas, a senior member of the Pythagorean school of thought. In fact, the bulk of Plato's knowledge and philosophy of mathematics was culled directly from the extraordinary Pythagorean sect.

Pythagoras, born in about 570 B.C. on the Ionian island of Samos, and his followers practiced a weird blend of mysticism and mathematics under the rubric "All is number." They lived by a litany of madcap rules, which forbade, for example, looking in a mirror by lamplight, eating beans, and putting one's shoe on the right foot first. They also held some eccentric beliefs (Pythagoras himself thought he was semidivine) as well as a few enlightened ones, including that men and women were equal–something virtually unheard of at the time. Crucially, they were the world's first pure mathematicians. As a good many pure mathematicians and theoretical physicists do today, they started from the premise that thought was a surer guide than the senses and intuition ranked above observation. From the Pythagoreans, Plato inherited his most unshakable conviction–that behind the world we see lies a more fundamental, eternal realm accessible only via the intellect. From them, too, he gained knowledge of the five regular solids. And although "Platonic solids" is a misnomer, Plato was genuinely original in how he interpreted the significance of these shapes. He linked them with the classical elements of earth, water, air, and fire, and, in so doing, formed a bridge between the mathematical and the material. In *Timaeus* he wrote, "To earth, then, let us assign the cubic form, for earth is the most immovable of the four and the most plastic of all bodies, and that which has the most stable bases must of necessity be of such a nature." Noting that the tetrahedron has the smallest volume for its surface area and the icosahedron the largest, Plato saw in these shapes the properties of dryness and wetness, respectively, and hence a correspondence with the elements fire and water. The octahedron, which rotates freely when held by two opposite corners, he regarded as a natural partner for air, the most mobile of the elemental quartet.

But there are *five* regular solids. To Plato, utterly convinced of the truth of his geometric worldview and of the unassailable power of intuition, this discrepancy between theory and observation could mean only one thing: there must be another element in addition to the four already known. There must be, in other words, a *quinta essentia* or *quintessence*, a "fifth essence," not familiar on Earth. Surely, he reasoned, this quintessence was the stuff of the heavens and its form the remaining regular solid–the dodecahedron. In support of his claim he noted that there were twelve sides on the dodecahedron and twelve signs of the zodiac–the constellations that the sun passes through in the course of a year. "God used this solid for the whole universe," he declared, "embroidering figures on it."

A twelve-sided cosmos? Dreamed up long before humanity fathomed the true nature of stars and galaxies and the immensity of space and time? It seems, on the face of it, just another quaint idea, surely long overtaken by events. But in October 2003, Jean-Pierre Luminet and his colleagues at the Paris Observatory published a paper in the journal *Nature* arguing, on the basis of data collected by the orbiting Wilkinson Microwave Anisotropy Probe (WMAP), that the universe does indeed take the shape of a dodecahedron.[19]

WMAP, launched in 2001, is designed to survey very precisely the so-called cosmic microwave background, the much-cooled glow of the vast explosion in which the universe began. The wavelength of this radiation is remarkably pure, but like a musical note, it has harmonics associated with it.

These harmonics reflect the shape of the object in which the waves are produced. In the case of a note, that object is the musical instrument upon which the note is played. In the case of the microwave background, the object is the universe itself. WMAP's measurements revealed that the second and third harmonics of the microwave radiation–the quadrupole and octupole–are weaker than expected. This weakness can be explained, according to the French team, if the universe is assumed to be finite and dodecahedron-shaped. Unfortunately, their model doesn't involve anything quite so simple as a giant Platonic solid. That is because an ordinary dodecahedron has a definite inside and outside and exists in "flat" space–the kind of space we're familiar with in everyday life and to which Euclid's geometry applies. What Luminet and his coworkers proposed is something called *dodecahedral space*, first described by their fellow countryman Henri Poincaré in the nineteenth century. Also known as a Poincaré manifold, this is a strange type of mathematical space that doesn't lend itself to being easily visualized. But the key point is that it has the same kind of symmetry as the dodecahedral cosmos that Plato had in mind.

Plato may have struck lucky on another point, too. It's easy to look at the classical elements–earth, water, air, and fire–and conclude that they have very little in common with the elements known to modern science: hydrogen, helium, carbon, iron, and the rest. But that's not really a fair comparison. It's true that the classical elements don't seem much like the elements of today's periodic table; they *do*, however, correspond very closely with what we now call the states of matter. Read earth for solid, water for liquid, air for gas, and fire for plasma (an ionized gas, often described as the fourth state of matter), and the ancients no longer seem so far off the mark. That leaves Plato's quintessence without a modern-day partner.

Nothing in twentieth-century science seems to correspond to this esoteric, celestial stuff. But then, without any warning, dark matter appears. At least four-fifths of all the mass in the universe, it turns out, consists of this invisible ingredient whose nature remains a subject of intense debate. Even more recently, astronomers have found evidence for another mysterious cosmic component quite unlike anything ever seen on Earth: dark energy. Both dark matter and dark energy have, for the purpose of various theories, been tagged "quintessence" by modern physicists who are mindful of Plato's seminal ideas. Both, as we'll see, have come to figure prominently in the recent story of gravity. But the person who first tackled gravity head-on wasn't Plato himself but his most stellar student, Aristotle.

A Man of Substance

When Aristotle came to the Academy in 367 B.C., Plato had already been at the helm for twenty years. For another two decades they worked alongside each other, first as mentor and pupil, then as colleagues, as Aristotle's stature grew and he took on more of a teaching role. During this time, however, the two men drifted apart philosophically and eventually came to hold radically different views on the nature of the world.

Plato was convinced that ultimate reality lay in ideas and what he called "forms," that is, perfect abstractions of things, which were knowable only through the trained mind. In his opinion, objects we see around us are no more than distortions of the truth–twisted reflections of some Platonic ideal. For example, a particular tree, which might have a branch or two missing, a gnarled trunk, or a carving of lovers' initials, is merely a flawed embodiment of the ideal form of a tree from which its existence derives. Outside of space and time, outside of materiality, is the one pure, transcendent Tree that allows us to identify the imperfect reflections of all particular trees around us. Only reason, guided by the proper use of logic, Plato insisted, makes the perception of such ideal forms possible.

Aristotle had quite a different metaphysical take on the world. For him, the wellspring of reality wasn't some strangely detached realm of intangible forms but what we see right in front of us–physical objects, the nitty-gritty of everyday life, knowable through immediate experience. He had a passion for collecting samples of anything and everything–alive, dead, or inanimate–and then pigeonholing them in what seemed to him a logical way. It's said that both Philip II, son of Amyntas III, with whom Aristotle went to school, and, later, Philip's son, Alexander the Great, showered Aristotle not only with funds for his studies but also with thousands of slaves to scour the land for new specimens. Even if these stories are a bit overblown, there's no denying that Aristotle was a tireless classifier and encyclopedist–the most outstanding accumulator and organizer of natural facts in the ancient world.

His philosophy was firmly rooted in the practical, the observable. Whereas Plato argued that individual things acquired their characteristics only by association with the forms that inhabited some ethereal never-never land, Aristotle held that the basis of reality existed in the actual world. First and foremost, there were individual things, living and nonliving, fashioned of what he called primary substance. These individuals made up species composed of a more universal, secondary substance. Species, in turn, fell naturally into different genera consisting of material still more generic than that of species. In contrast to Plato, who was very much a dualist, Aristotle saw matter and form as inseparable aspects of everything that existed. Matter was the raw building material of things–clay, the matter of which bricks were made, bricks, the matter of which walls were made, and so on. Matter was an object's *potential* to become an actual thing. Form was its reality, its shape, and the essence whereby it belonged to a certain class. A block of marble, for instance, had the potential to take on whatever form a sculptor chose, while a seed or embryo had the potential to grow into a particular living animal or plant.

Aristotle questioned, as he did most things, the basic elements of which all matter was composed. In the end, at least as far as our cosmic backyard was concerned, meaning everywhere closer than the moon, he went along with the four-element scheme of earth, water, air, and fire that had first been put forward by Empedocles about a century earlier. Each element, Aristotle argued, had a unique combination of primary qualities–hot or cold and wet or dry. The primary qualities of fire, for example, were hot and dry, while those of earth were cold and dry. As well as these traits, each element had an innate *motive power*, which tended to make it move in a particular direction, toward what Aristotle called its natural place. Two of the elements, earth and water, had the motive power of gravity, which tended to make them fall earthward. The other two elements, air and fire, had a completely different motive power, known as levity, or lightness, which acted in the opposite direction, radially away from Earth.

The important point, in Aristotle's view, was that levity wasn't just a feebler version of gravity. Something that has levity isn't less heavy; it's light in an absolute sense. If gravity is thought of as a tendency to sink, then levity is equivalent to buoyancy. Different elements sort themselves out by changing places, like an air bubble rising in water while the water fills in behind it; each element becomes the motive for the natural tendencies of the other elements to move. Given this way of looking at things, Aristotle was forced to conclude that the idea of empty space was nonsense. After all, a substance located in a void, not surrounded or motivated by any adjoining substance of differing tendencies, wouldn't have any reason to move. "Nature abhors a vacuum," Aristotle insisted, because it would make any kind of motion impossible.

Middle Earth

Along with Plato and most, but not all, other ancient philosophers, Aristotle never doubted that Earth sat at the exact center of a finite, spherical universe–a geocentric, human-focused cosmos that was simple and confined by today's standards. The inner region, which included Earth and all the surrounding space between Earth and the moon–the so-called sublunar domain–was composed of the four elements: earth, water, air, and fire. Because the element of earth possessed the most gravity, its tendency was always to sink to the middle, with water settling into a shell outside it. Air and fire both rose because of their levity, but fire, having the greater levity of the two, naturally drifted up to the outermost region.

Since the earthly sphere was imperfect, its elements didn't usually occur in their pure form but instead were combined into various substances with intermediate properties. Wood, for instance, was a mixture of all four elements, a fact that only became apparent when it burned. Only then did one see the flames of fire set free, the smoke and fumes of air, the water that oozed and bubbled out, and the earthy ash left behind when everything else had escaped and the residue had cooled. In the ideal case, which could never actually be realized, the elements of the sublunar realm would form a set of concentric shells: fire on the outside, followed by air and water, and, finally, at the center, a ball made of pure elemental earth.

The human world, as portrayed in the classical cosmos, was permanently disorganized and in a state of flux, with nothing quite where it was supposed to be. But beyond sublunar space lay the heavens, eternally perfect, composed exclusively of the fifth element, quintessence, or, as Aristotle and the Pythagoreans before him preferred to call it, *ether*. Each of the objects seen in the sky was fixed to its own transparent crystalline sphere: innermost the moon, then the sun, then the planets as far out as Saturn. More distant than Saturn was the heavenly sphere of the fixed stars, and beyond even that, the Deity who had created it all.

It was a universe divided, split into two completely distinct parts, each with its own makeup and code of behavior. There were the heavens–everything more remote than and including the moon–in which all motion was uniform, never ending, and perfectly circular about the center. Separately, there was Earth and the space immediately around it, in which imperfection and motion of a very different kind were the norm. If the heavens were the playground of astronomy, the sublunar domain was the province of an apparently very different science, physics, and the only place where, according to Aristotle, the twin properties of gravity and levity influenced how objects moved.

All earthly motion, said Aristotle, is either natural or "violent." Natural motion always happens in a dead-straight line along the radius of the universe (in other words, either directly toward or away from Earth's center) and eventually comes to a halt. This idea follows logically from the Aristotelian belief that everything has its natural place. An object made mostly of the element earth will try to get as close to the cosmic middle (exactly to the middle if it's 100 percent earth) as its constitution prescribes, and then it will stop. All natural motion involves things striving to get to where they're supposed to be by virtue of their elemental makeup, the urgency of their movement being dictated by the amount of gravity or levity they contain. From this follows one of Aristotle's key conclusions: the heavier an object (in other words, the more gravity it has), the faster it will fall. Something made of three-quarters earth and one-quarter air, for example, will drop more quickly than something made of half earth and half air. Reality seems to agree–at least at a passing glance. A light and airy thing such as a feather *does* fall more slowly than a heavy, "earthy" object such as a stone, while a levity-rich substance, such as smoke or a flame, actually rises.

Aristotle made another claim about natural motion. He said that how fast an object falls depends inversely on the density of the medium it's falling through; so, for example, the same body will fall twice as fast through a medium that's half as dense. Again, this seems to square pretty well with everyday experience. Drop a stone in air and it will plummet more quickly than the same stone released underwater. In putting forward these ideas, Aristotle became the first to propose *quantitative* rules about how things fall–rules, moreover, that were elegant, easy to grasp, and, superficially at least, credible.

A Symphony of Two Movements

Like the theories of so many scientists and philosophers, those of Aristotle were very much a product of the environment in which they were hatched. Two millennia ago, there were no cars or planes zipping around. There wasn't much in the way of moving machinery at all. What motion an inhabitant of ancient Greece saw around him tended to involve people and animals; it was motion that was *willed*, that had a purpose in taking the creature to someplace it would rather be, and therefore, as Aristotle perceived it, fulfilled the creature's nature. It took no great leap of imagination for him to account for the motion of things obviously *not* alive, such as a pebble dropped from the hand, by extending the concept of the nature of something to inanimate matter. In this way he came to formulate his laws of natural motion of objects in terms of the four elements purposefully seeking their rightful place in the order of things.

Aristotle also had definite ideas about motion that, in his view, was not natural. Throw a stone out into a lake; in Aristotle's opinion, that is an unnatural or what he called a violent movement. Here, he was using the term in its original sense—our word *violent* comes from the Latin *violentus*, which means simply "force." Such movement, he insisted, can happen only as long as there's a continuous pushing: the speed at which something moves (violently) being proportional to the strength of the push. Take away the push, he said, and the unnatural motion stops in an instant. Of course, Aristotle was no fool. He was well aware that projectiles carry on moving for some time after they've been thrown from a hand or shot from a bow or catapult. They don't immediately plunge vertically to Earth.

If Aristotle's idea about unnatural motion was right, there had to be some other kind of push that came into play once an object had been thrown. Two possible explanations suggested themselves. The first was that air, displaced from in front of a thrown object, somehow circulated around the object in a loop and ended up giving it a shove from behind. The second possibility was that the initial impulse, given to the object at the point of release, caused the entire column of air in front of the object to be pushed forward so that the moving shaft of air essentially drew the object forward along with it.

This second theory didn't look very promising, even in Aristotle's time, because in order to account for the continued sideways motion of the projectile, it relied on the continued sideways motion of another object, namely, the air. But this left a question mark over what caused the continued motion of the air and merely swapped one problem for another. On balance, the first explanation—the pushing vortex theory—seemed to Aristotle the better bet.

Intriguingly, in his discussion of these two rival explanations of motion, Aristotle came very near to a major breakthrough. He pointed out that in a void neither of the two theories would work, “so nothing could go on moving unless it were carried.” But then he added, “Nor (if it did move) could a reason be assigned why the projectile should ever stop–for why here more than there? It must therefore either not move at all, or continue its movement without limit, unless some stronger force impedes it.” This truth would be echoed twenty centuries later by another great physicist and be named after him. It is none other than Newton’s first law.

As far as the heavens were concerned, Aristotle toed the party line, contending that all celestial motion was circular. Up there, beyond the moon, none of the complicated business of objects seeking their natural place ever occurred. Everything in the heavens was already where it was supposed to be, serenely pursuing the only kind of movement that, in a finite universe, could go on forever without changing–movement that simply cycled around and around.

Problems in Paradise

Providing you don’t ask too many questions or scratch too deeply beneath the surface, the whole Aristotelian scheme can seem quite believable. Certainly, it was good enough for most people and credible enough to survive largely unchallenged for the best part of two thousand years. But a bit of nosing around soon reveals cracks in the theory.

Somewhere between here and the moon, for example, according to Aristotle, there’s a switchover from the types of substance and motion found in the sublunar domain to those that prevail in the heavens. It can’t be a gradual transition between the two realms because perfection and imperfection don't mix: you can't have earthly contamination gumming up the crystalline spheres. There can't even be an empty buffer zone, because Aristotle wouldn't tolerate a vacuum at any price. So there must be a sudden change—a concept that is a bit awkward to say the least.

On top of this, there's a problem with the simple circular motion that the planets were supposed to follow. It didn't exist, as every ancient astronomer who had made careful observations of the night sky knew. There's just no way to explain how the planets move in the sky by assuming that each goes around the Earth on a single round track. If you insist that circular motion is the only game in the heavens, you need wheels within wheels, spheres within spheres, moving this way and that around different axes to pull off the trick of planetary movements, even approximately.

The first person to take on the challenge of devising a workable system of celestial spheres was Eudoxus, the most talented mathematician and astronomer of his day, who built an observatory at Cnidus in the first half of the fourth century B.C. His ingenious arrangement of twenty-seven spheres—one for the fixed stars, three each for the sun and the moon, and four each for the five known planets, Venus, Mercury, Mars, Jupiter, and Saturn—was further elaborated by Callipus and then by Aristotle, who ended up calling upon fifty-six interconnected, gimbaling spheres to bring theory roughly into step with the dance of the heavens.

Aristotle's science of the sky, with some final polishing by Hipparchus and Claudius Ptolemy over the next couple of centuries, survived intact until the 1600s. What's more surprising is that his terrestrial science, including his views on falling objects and projectiles, did the same. Of course, it's always easy to pick holes in the ideas of an earlier age. A modern physicist has no trouble seeing that Aristotle's vortex theory of projectile motion, for instance, is a nonstarter. There's no way a vortex can impart a net positive motive force to an object; at best it can only cut down the drag. Aristotle couldn't have known this. He didn't have access to a wind tunnel or any other means of measuring the air flow around something.

But that's not the point. Aristotle probably wouldn't have used a wind tunnel even if he'd had one available. He just didn't do experiments. Yes, he was a great observer and classifier. As a biologist and, especially, a marine biologist, he was unparalleled: he dissected at least fifty species, including sea urchins and starfish, and his masterful description of the octopus's reproductive system remained unsurpassed until the nineteenth century. But when it came to checking the rules of physics that he'd devised, he just wasn't interested. It seems extraordinary. A heavier object falls faster than a lighter one, he insisted. Fair enough; that isn't a difficult proposition to test. You take two stones of the same material, one twice as heavy as the other. You stand at the top of a tall cliff and release both stones together. If you hear two separate cracks as the stones hit the rocks below at different times, the rule is shown to work (although you might have to do a series of more accurate experiments to check it thoroughly). If you hear a single crack, then something is obviously wrong. Why didn't Aristotle do a test like this, or have his assistants or slaves do it for him? And not just once, but many times, using different objects and locations?

Take another example. If Aristotle is to be believed, a projectile will carry on moving sideways (as well as up or down) as long as it keeps getting a push from the air that supposedly rushes in behind it to avoid the terrible vacuum. But at some point, he argues, while the object is in flight, this pushing will stop. The vortex effect runs out of steam; it gets tired, even exhausted. Then the object, no longer supported in its "violent" motion, does the decent, natural thing and plummets, because of its gravity, vertically to the ground. Again, this isn't a claim you simply have to take for granted. You can watch, sideways on from a distance, as someone throws a stone through the air, fires a rock from a catapult, or shoots an arrow from a bow. You can see with your own eyes if it's true that a projectile ends its flight with a straight-line drop out of the sky. Yet, as far as we know, Aristotle never troubled to put his ideas to such scrutiny.

In comparing Aristotle with Plato, it's easy and fair to conclude that, of the two, Aristotle was closer to being a scientist in the modern sense. That's because, unlike Plato, he did, at least, base his theories on observations of the real world. The trouble is, he didn't subsequently put his theories to the test, and that's a deeply unscientific approach. Aristotle and Plato both relied heavily on reason and logic to build their worldviews. Once they had their mental pictures of the universe in place–their grand scheme of things intellectualized–they weren't about to dirty their hands with experiments to see if reality happened to agree with them. If future observations didn't quite tie in with their prescribed philosophies, well, too bad for the observations.

Aristotle's Legacy

Plato died in 347 B.C., and by every measure of ability and achievement, Aristotle should have succeeded him as head of the Academy. Plato himself referred to him as "the intellect of his school." But Aristotle had fallen out of favor with the other seniors of the institution. It wasn't because he was a bit of a dandy, wearing rings on his fingers and cutting his hair fashionably short. It wasn't even his personality, which, if his enemies were to be believed, tended toward the arrogant and overbearing. Aristotle's political views were, it seems, what got him into trouble. In any event, leadership of the Academy passed to

Plato's nephew Speusippus, and Aristotle left for the court of his friend Hermeas, lord of the state of Atarneus in Mysia (a region in what is now Turkey). There he stayed for three years, marrying Pythias, the king's niece (later he married a second time, a woman named Herpyllis, who bore him a son, Nichomachus), before moving on to Mytilene on the Greek island of Lesbos after Hermeas was deposed by the Persians.

At the invitation of Philip of Macedonia, Aristotle became tutor to Philip's thirteen-year-old son, Alexander, a post he held for the next five years. When Philip died, Alexander succeeded to the throne and Aristotle returned to Athens, which he hadn't visited since the death of Plato. He found the Academy flourishing under a new head, Xenocrates. Platonism had become the dominant philosophy of Athens, but it was also in stagnation. So Aristotle set up his own school at a place called the Lyceum.

For the next thirteen years Aristotle devoted his energies to teaching and to composing his philosophical treatises. He is said to have given two kinds of lectures: more detailed discussions in the morning for an inner circle of advanced students and popular discourses in the evening for the general body of lovers of knowledge.

At the sudden death of Alexander in 323 B.C., the pro-Macedonian government in Athens was overthrown, and there was a general reaction against anything Macedonian. Charged, bogusly, with impiety, Aristotle was forced to flee to Chalcis in Euboea. Not long after, in 322 B.C., he came down with a stomach illness and died.

Aristotle's legacy was huge. He had surveyed the whole of human knowledge as it was known in the Mediterranean world in his time. More than any other thinker, he had determined the direction and content of Western intellectual history. He was the author of a philosophical and scientific system that through the centuries became the support and vehicle for both medieval Christian and Islamic scholastic thought. Until the end of the seventeenth century, Western culture was Aristotelian.

It isn't hard to see why. Aristotle's whole approach to studying nature fitted in neatly with Occidental theology. The idea that every organism was beautifully crafted for a particular function–its "final cause," as Aristotle called it–in the grand scheme of nature pointed to the conclusion that the world had been designed. Also, Aristotle was deeply interested in the concept of *nous*, or eternal intelligence, and this, too, made his work readily acceptable to the Church of the middle ages. Even his chauvinist views weren't out of line with male-dominated orthodox theology. "Full excellence," he insisted, could be realized only by the mature male adult of the upper class, not by women, children, barbarians (non-Greeks), or salaried "mechanics" (manual workers). Some of his other silly ideas, such as that women had fewer teeth than men and that a baby's sex was determined by the wind's direction at the time of its birth, could be safely swept under the philosophical carpet. Backed by the Church, Aristotle's worldview was secure. His laws of motion and his ideas about gravity would stand–as long as no one looked at them too closely.