GURPS® Fourth Edition

LOW-TECH™

COMPANION I

PHILOSOPHERS AND KINGS™

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Edited by SEAN PUNCH

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STEVE JACKSON GAMES

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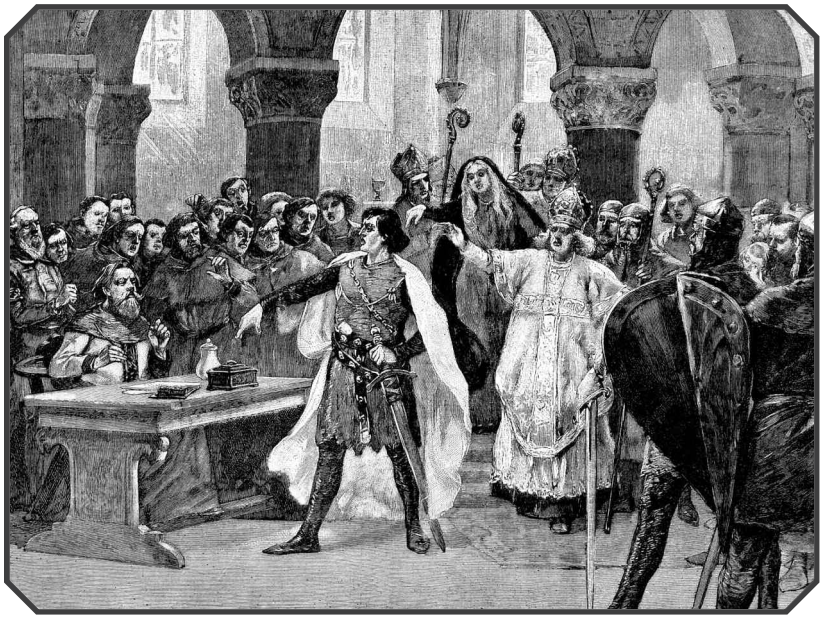
Introduction

The primary meaning of "technology" is "the use of tools." This is mainly the domain of craftsmen. Kings, nobles, priests, scribes, and bureaucrats rarely do physical labor or work with tools. Yet their societies' technology indirectly affects the skills they *do* use – and some technologies, such as record-keeping and medicine, are *mainly* used by such learned folk. More broadly, certain functions of the educated classes can be viewed as a kind of technology. Administration, mathematics, writing, religious disciplines . . . all involve a form of know-how.



GURPS Low-Tech Companion 1 examines these broader aspects of technology. Note that it's an appendix to ***GURPS Low-Tech.*** Many of the concepts discussed here draw on that work, although that supplement isn't *required* to use this one.

About the Authors

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Errata. Everyone makes mistakes, including us – but we do our best to fix our errors. Up-to-date errata pages for all ***GURPS*** releases, including this book, are available on our website – see above.

Rules and statistics in this book are specifically for the ***GURPS Basic Set,*** *Fourth Edition.* Page references that begin with B refer to that book, not this one.

Chapter One
Kings

Not all low-tech societies have actual *kings*. Many have chiefs or simply elders; some are surprisingly egalitarian. But most groups larger than families eventually need leaders, if only to settle disputes and organize labor. This road leads to the state, which requires laws, infrastructure, and an economy more efficient than barter – all of which depend on record-keeping. And if there *is* a king, his goal might be building an empire!

Politics

The most visible "social technology" is a society's political organization. Historically, demands on scarce resources, a need for defense, and a desire to organize trade and mediate disputes led to methods of defining roles for and relationships between individuals.

Stateless Societies

Societies at TL0 and into TL1 had little or nothing in the way of visible government. They conducted themselves more like extended families than like consciously political units. However, as these groups grew and their members came to know one another less well, they developed more formalized mechanisms.

Bands

The earliest human societies were simple family *bands*, ranging from a single nuclear family to around 100 people at most. Such groups of hunter-gatherers would travel across the landscape, occasionally trading or squabbling with other bands (to whom many members might be distantly related).

Bands are very informally organized, and their structure is fluid. Those that become too large split with a minimum of political and personal turmoil, while smaller groups can merge if that suits their members. Younger people often find mates in other bands, joining one band or another, or strike out on their own with a few like-minded friends. While band members are usually related, the sole *requirement* for membership is a willingness to live together.

A distinguishing characteristic of bands is lack of specialization. There are no distinct professions and only vaguely differentiated social roles. Almost every adult member can perform nearly any day-to-day task. No member depends on any other to start fires, hunt or gather food, look after children, build shelter, or petition the gods.

Differences in skill and aptitude *are* recognized; for instance, someone who's better at knapping arrowheads may find himself doing that more often than average. As well, certain tasks might be divided up by age and sex. Among known hunter-gatherer groups, for example, hunting large animals is an overwhelmingly male task, while women typically provide the bulk of care for infants. Even in those societies, though, women sometimes hunt and trap smaller game, and men gather plant foods (if not as much) and spend some time with small children.

Social Traits in Bands

Some social traits associated with complex societies are present in simpler ones but work differently. Others don't exist at all! For example, bands don't have formal, hierarchical advantages like Status and Rank. Most of the traits under *Privilege* (p. B30) haven't been invented yet, either, although the GM might use Claim to Hospitality (p. B41) to represent a mutual gifting relationship with members of related bands. Bands *do* have Social Regard (p. B86), however – notably for elders and particularly skilled individuals.

Cultural Familiarity (p. B23) also needs rethinking. In a world (or a campaign, at least) full of TL0 societies, lack of direct, long-range communication can mean that Cultural Familiarities cover areas comparable in size to mid-sized countries rather than the continent-sized regions of higher TLs.

Social, political, and economic skills that are mostly about personal and small-group interactions *do* exist. For example:

- *Merchant* is used to negotiate exchanges, however technologically unsophisticated the society.
- *Leadership* exists as a skill, if not a profession – although a leader is unlikely to be able to lead more than a small group
- *Public Speaking* is often *very* common for storytelling – a primary means of entertainment for low-tech societies – even if the "public" is limited to a handful of listeners.

Skills for coordinating large organizations and negotiating complex processes haven't been invented yet, though. Examples include Accounting, Administration, Finance, Intelligence Analysis, Law, Market Analysis, Politics, Propaganda, and Strategy.

One of the professions that bands lack is leaders. In many cases, a group will actively resist developing them. Anyone who tries to set himself up as a leader will find himself ridiculed and shunned; in extreme cases, the band will break up. Since band members are capable of surviving independently, there's no political or military structure in place to enforce anyone's demands. With few material possessions that they would regret leaving behind, people can simply walk away. Any "leadership" in a band is exercised through personal influence, swaying others' opinions case-by-case and day-to-day. At most, a band may have a few individuals of recognized wisdom who are called on more frequently than others to mediate disputes or perform important rituals.

While bands aren't necessarily strangers to conflict, they aren't organized enough to carry out warfare as modern folk would understand it. Conquest is simply impossible for groups that hold no territory and that can easily relocate. Thus, most fighting is at the level of family feuds and raids – although these are no less deadly for being individual rather than coordinated efforts.

When bands have a surplus of goods, they might practice barter – but when dealing with familiar groups, they may practice *gifting*. In a gifting economy, one party gives something to another without immediately receiving anything in return or necessarily establishing what he'll get, or when. The initial gift does create a social obligation for the recipient to give a return gift in the future, though, and those expecting return gifts can and do wheedle and scold when they want something. Although gifting is inefficient as a form of exchange, it has the side effects of creating social insurance networks (someone who gives a gift may not need anything today, but when he *is* in need, he has favors to call in) and maintaining social ties.

Social Traits in Tribes

Status (p. B28) exists in tribes, but the maximum is Status 1; Social Regard (p. B86) is more common. Clerical Investment (p. B43) for shamans is a remote possibility, but most such folk aren't sufficiently distinct from fellow tribesmen to merit a reaction bonus. However, they might well have the perks "May perform important ceremonies" and/or "May violate social norms" (e.g., touching the dead, which is often forbidden for others, or eating restricted plants or animals).

Some of the social skills unavailable in bands emerge in tribes – notably Finance and Politics. Tribal big men have a *lot* to keep track of when organizing chains of gift exchanges. While they employ Merchant and Politics in individual transactions, they use Finance to coordinate their activities.

In complex gifting economies, the skill used to negotiate exchanges depends on the prestige of the gifts involved. For low-prestige goods, the usual goal of the deal is to obtain desired items for their own sake. Use the Merchant skill for such transactions.

For high-prestige goods, the aim of the exchange is to make visible displays of friendships and alliances. This goal is more political than economic. To find a partner for high-prestige goods and negotiate a sufficiently prestigious exchange, use the Politics skill.

Exchanges of moderate-prestige goods can involve *both* skills. For example, you might roll against Politics to find someone important with whom to arrange a marriage alliance, but Merchant to arrive at how many pigs he wants to allow your son to marry his daughter. Use Merchant to arrange not just the value but also the timing of a return gift.

Tribes

Bands were an adequate form of organization for nomadic hunter-gatherers, but that structure started to fray when more intensive kinds of resource exploitation became important toward the end of the Paleolithic, as well as in particularly rich environments where hunter-gatherers could be more sedentary and maintain denser populations.

If bands become pressed for land, or closely associated with one another (e.g., if they find themselves trading with each other frequently), broader structures may appear to regularize relationships between groups of people in an environment where individuals unhappy with the status quo can no longer simply walk away. *Tribes* are collections of band-sized groups who've formalized their relationships in this way. The constituent groups might be nomadic hunter-gatherer bands, but could instead be small villages.

A tribe usually consists of a few hundred people. Past about 2,000 people, tribes start to become too large to function as coherent groups. The families that constitute a tribe may be members of allied *lineages* (clearly defined descendents from a known historical ancestor) or *clans* (large families who claim descent from legendary or mythological common ancestors) that cut across the tribe's constituent bands or villages and give them greater social cohesion. For example, in a particular village, someone from the Bear clan might be married to someone from the Heron clan but have contact with other members of the Bear clan in other villages. That gives him cause to maintain good relationships not just with his neighbors in his own home, but also with relatives in other settlements.

Tribes still have an egalitarian political structure. Decisions are the result of public opinion rather than the deliberations of rulers. Semiformal officials start to appear in the form of councils of elders (bands rarely have enough elders for this) or individual headmen, but their power is expressed as influence rather than leadership. They are mediators or courts of appeal, not dictators of policy.

Ritual specialists such as shamans may also appear – and in times of conflict, a tribe might select temporary war leaders whose powers are restricted to military matters. In addition to specific age-related functions and elaborate rites of passage marking transitions into adulthood, larger sex-based social distinctions sometimes appear, such as the idea of "men's work" and "women's work" (e.g., men may do all the hunting, while women make all the pottery), or separate male and female councils. Where bands entrust specific tasks to men or women, these become entire *classes* of tasks in tribes.

The most significant political change is that the groups that make up a tribe are more tightly tied to one another than are freewheeling bands. If one group is starving, the others are expected to help feed it. If one is attacked, the others are expected to come to its defense. The size of the society to which one sees oneself as belonging also expands considerably.

Instead of perhaps 100 people, an individual's social circle may consist of *thousands*. Moreover, while any tribe member can trace some kind of relationship to any other, he belongs to a social group in which he doesn't know every other member personally.

As societies grow more complex and produce more goods, trade becomes more sophisticated. By the time they reach a tribal level of complexity, if not earlier, most societies group goods together in "spheres of exchange": categories of things that can be traded for one another but not – barring rare exceptions to bring new people into gifting networks – for items outside of their sphere. For example, yams, clay pots, and cloth might be traded for one another, as could cattle, iron tools, and spouses, or ceremonial headbands for shell necklaces . . . but never cattle for yams, or shell necklaces for iron. Some spheres are more prestigious than others; a man with a few cattle is counted wealthier than a man with a mountain of yams.

A figure who appears as bands gather into tribes – and particularly as high-prestige goods appear – is the "big man." Big men are skillful traders who make themselves the center of extensive social networks by negotiating elaborate trades to end up with more and, if possible, more-prestigious goods than they had before. They use their wealth as gifts, obligating others to give them better gifts in return, which forms the basis of yet more gifting. They gain prestige not by *acquiring* wealth, but by *giving it away*. They have no formal power, but they are persuasive and can make themselves well-liked, and are therefore as powerful as anyone can be in a society without formal leadership.

It's worth noting that gifting networks have a notable weakness. Rare, imported goods are usually treated as high-prestige wares. Where low-tech gifting economies are in contact only with other low-tech societies, that's rarely a problem. However, when they come into contact with higher-tech societies, they can become overwhelmed with manufactured goods. Higher-tech importers find that their cheap manufactured trinkets can get them anything they want from the natives, so they bring in large quantities. This leads to a kind of hyperinflation. Historically, this was most visible when TL0 societies met TL5 colonists (Pacific Northwest potlatches, where large quantities of very valuable goods were destroyed in elaborate public displays, are the best-known example of a gifting economy overheating), but even a reasonably productive TL3-4 society could introduce large quantities of metal items or cloth processed by water power into a gifting economy, leading to a system-wide disruption of existing social relations.

Because tribes have tighter social ties and more elaborate leadership, warfare among them becomes somewhat more concerted than between bands – although it can be more a matter of warriors acting fierce and getting loot than actually killing people. Raids are larger and better organized, but guerrilla warfare remains the rule. When bodies of armed men face one another, the "battle" may primarily involve exaggerated displays of machismo, with each side hoping to scare away the other. They can fight quite seriously if the situation demands, but few individuals are particularly eager to risk their lives.

Chiefdoms

As trade and warfare grow in importance, and as greater population densities and increases in material wealth make the mediation of disputes a larger issue, more power is concentrated in the hands of informal tribal leaders, causing them to evolve into formal chiefs. Chieftainship may be hereditary or at least tied to clan membership – and indeed, the clan and familial distinctions of tribes start to become hierarchical in general, with some groups enjoying higher status than others. Chiefs might be drawn from the Bear clan, while only Herons may be shamans . . . and this limits the political power of the Bobcat, Turtle, and Wallaby clans. Practical social distinctions between "aristocratic" and "common" clans tend to be slight; e.g., a Bear or a Heron is unlikely to be much wealthier than a Turtle or a Wallaby. Visible distinctions are another matter; each clan is apt to have its own customs, mode of dress, tattoos, religious rituals, and even manner of speaking (the aristocratic tribes of medieval and Renaissance Kongo had their own distinct dialect).

Hierarchical relationships also arise between *chiefs* within a particular society. Each settlement has its chief, but some chiefs are subject to others – if only because they're obligated to provide the superior chiefs with occasional tribute. A high chieftain may nominally lead the entire society, and since he can deal with local subchiefs instead of having to sway the opinions of entire villages, his authority can extend farther than a simple tribal structure allows, perhaps over as many as 20,000-30,000 people. This structure becomes impractical when there are too many subchiefs to deal with, or when settlements are distributed over too great an area to allow easy communication.

Social Traits in Chiefdoms

In chiefdoms, two or three levels of positive Status (p. B28) may exist; e.g., Status 1 for local chiefs and Status 2 for a high chief. Slaves captured during raids might have disadvantages such as Social Stigma (p. B155) or negative Status, although Status -1 is the minimum. Shamans generally have Clerical Investment (p. B43).

The Administration skill – unavailable in simpler societies – appears as a necessary skill for chieftains. The Law skill may also emerge in a society with particularly complex traditions, although laws are transmitted orally.

Economic transactions involving chiefs – particularly large volumes of exchange over long distances, between settlements, and with outsiders – cause a move from the large-scale gifting of big men to more formalized redistribution mediated by chiefs. For example, instead of an individual village deciding how to aid another that has suffered a fire, flood, or other disaster, the chief makes decisions about who receives aid, when, and how much. Still, chiefs typically use their wealth in a way that big men would recognize: giving it away. They redistribute it to friends and allies in order to gain and maintain their support. Although chiefs have formal positions of power, people are always more likely to cooperate with authorities who can do them some good, and chiefs can expend a great deal of wealth to buy that cooperation. Iron Age chiefs in southern France bought large quantities of wine and wine-drinking paraphernalia from classical Greece and early Republican Rome with the aim of providing fine foreign goods to their allies.

At this level of organization, raiding can be quite serious. Chiefdoms can organize determined raiding groups who move quickly and strike with great violence (e.g., early medieval Viking raiders). And while standing armies and formalized ranks don't exist, campaigns, pitched battles, and other recognizable aspects of warfare arise.

States

States occupy the pinnacle of societal complexity. They're characterized by professional specialization; elaborate political and social hierarchies; the appearance of impersonal institutions; and government claims on the power to create and enforce laws, a monopoly on force, and control of economic activity.

States base claims to their citizens' duty and loyalty on something besides kinship. Although familial ties in pre-state societies may become tenuous, even fictional – and while such ties often remain important in the operation of a state's administrative machinery – the ultimate justifications for a state's authority lie elsewhere. Examples include divine favor for a monarch to whom most subjects are unrelated, right of conquest, or agreement of a group of founders.

Compared to simpler societies, states are far more able to mobilize resources and control territory. Physical resources and (typically) superior technology aside, they rely less on the inclinations of individuals. They depend instead on a social hierarchy, and on skilled professionals whose job is to do what needs to be done.

Perhaps as a consequence of that specialization, states recognize formal distinctions between groups of people – on grounds such as sex, occupation, religious beliefs, and social class – and legislate accordingly. This in turn begets further hierarchies, as some groups come out ahead of others.

Scale and Transportation

Physical communications, and therefore transportation technology, limit a state's potential size. The largest early states hugged river valleys: Egypt and the Nile; China and the Yellow River; various civilizations around the Tigris and Euphrates, and the Indus; and several societies based in the river valleys of the Peruvian coast. This was partly because access to resources was tightly circumscribed. Many of these early civilizations were surrounded by deserts, so population growth was focused in narrow areas – but having a river running down the middle made communication far easier.

Through TL1, states were often single cities or small collections of city-states. Many – such as the Egyptians, Hittites, Mycenaeans, and Minoans – controlled a major river valley and its surrounding territory, or an archipelago and surrounding coastline, for the reasons outlined above.

By TL2, states could coordinate activities across large parts of a continent, a deed accomplished via elaborate communications infrastructures. Such far-ranging empires were characterized by large transportation networks crossing both geographical and cultural borders. The first empire to hit the apparent size limit for its era was the Achaemenid Empire, one of a succession of Persian empires, in the sixth century B.C. At its greatest extent, it controlled just shy of 3,000,000 square miles covering modern Afghanistan, Pakistan, Iran, Iraq, and the eastern shores of the Mediterranean from Turkey to Egypt. The Achaemenids had a small paved road system, and with territories bordering three seas and encompassing several large river valleys, including the Tigris and Euphrates, they had sufficient internal communications to maintain their empire, with short-term gains and losses, for nearly two centuries.

Later empires improved on the Persian model, at least in terms of infrastructure. The Romans and Chinese – whose empires were about as large as the Achaemenids' – built extensive road networks. The Romans had the Mediterranean and Black Seas for internal transportation, while the Chinese had extensive canal networks connecting several large river valleys.

Prepared pathways alone don't constitute a transportation network, however. States as early as the Achaemenids maintained way stations along their roads. They had stables for ready horses, and overnight accommodations for official travelers from messengers to inspectors and government ministers. In these early postal systems, messengers could trade off horses every few hours so that they could ride at a gallop for the entire trip, and officials could rest comfortably overnight. Such relays could move information quickly but were extremely expensive; thus, only wealthier nations had them.

Empire-builders at TL3 were able to conquer larger territories temporarily, but TL2 empires seem to have established the limits of a *stable* state. The Umayyad Caliphate – which had many of the Achaemenids' natural avenues of communication – created an empire twice as large as the Romans and their Chinese contemporaries by the eighth century A.D. However, this began to collapse almost immediately after reaching its maximum extent.

The Mongol empire at its height, in around 1240, covered nearly 13,000,000 square miles, encompassing almost all of Asia south of the 60th parallel (excluding Myanmar, Thailand, and most of India), and bits of Eastern Europe into Poland and Hungary. It was over 5,000 miles from end to end. But by the end of the 13th century, it had fractured into four rival empires. Notably, it was almost entirely landlocked. Transportation by pony relays across the vast plans of Central Asia was fast, but apparently insufficient to weld together an empire with an essentially tribal government.

At TL4, a new kind of empire arose. Instead of contiguous, land-based domains, Europe's growing mercantile powers used superior ocean navigation, strongly motivated commercial interests, and top-notch military technology to take over regions overseas. Spain, the era's greatest colonizer, ruled a territory second only to the Mongol Empire: most of the modern United States from the Pacific to the Mississippi, as well as the Florida Gulf coast; the biggest Caribbean islands; all of Central America; about a third of South America, mostly along the Pacific coast, with an extension into Argentina; the Philippines; and outposts in India and Africa. (Granted, many of Spain's territorial claims staked out spheres of influence against other colonial powers rather than real areas of authority, making this "rule" nominal.) While regional governors had considerable autonomy, the rulers of TL4 nations could think in global terms.

Earlier states were sometimes connected mostly by ships rather than roads, but didn't approach this scale. For example, the TL1 Minoans ruled a "thalassocracy" consisting of the islands and mainland coast of the Aegean, while TL3 Venice held territories around the coast of the Adriatic and Eastern Mediterranean. Neither claimed anything like the territory of even a moderately large land-bound state.

The Speed of Information

To keep an empire together, the government must transmit information. Prior to the invention of semaphores and telegraphs at TL5, this meant transporting people and physical documents. Here are some common methods for moving information, with average speeds under reasonably favorable conditions:

Caravan: 10 miles/day. Use this for large groups of lightly disciplined travelers moving overland by foot, wagons, or beasts of burden, making a continuous trip rather than relaying information via fresh runners or animals.

Troops: 15 miles/day. Suitable for groups of fit, disciplined travelers moving without particular urgency (e.g., units rotating through posts on garrison duty). Troops headed for immediate battle can make better time.

Foot Relay: 25 miles/day. Appropriate for delivering letters or word-of-mouth, but not for individual messengers, who sprint between stations and rest for long periods.

Horse: 32 miles/day. A fairly determined, though not necessarily desperate, lone horseman, or a very small group. This is only sustainable for two or three days, after which the horses fatigue, reducing speed to troop or caravan rates.

Riverboat: 40 miles/day.

Horse Relay: 45 miles/day. This includes individuals traveling with several additional horses each, allowing them to switch off to fresh mounts every few hours.

Seagoing Ship: 40 miles/day through TL2; 80 miles/day thereafter. Prior to the development of dead reckoning (see ***GURPS Low-Tech***), sailors typically hugged the coast for 10-12 hours during the day in order not to lose their way, beaching at night to avoid hazards in the dark. Later sailors, who traveled the open seas, could stand watches and sail around the clock.

Travel conditions in low-tech environments are highly variable, however; "average" doesn't mean "typical," or even "common." Under ideal conditions, with healthy, disciplined, motivated travelers (soldiers, official couriers, small groups of adventurers, etc.) traveling over smooth seas or prepared roads, with well-stocked relay stations where applicable, a sustainable maximum is *double* the average. Under truly heroic circumstances – e.g., storms that drive ships quickly at significant risk of destroying them, or punishing overland runs that might injure or kill mounts and runners – up to *triple* the average is theoretically possible.

Conversely, delays and detours for weather, warfare, legalities (e.g., local permissions to travel), and lack of proper equipment or supplies were rife at TL0-4, rendering even the shortest journeys unpredictable. The averages assume a few setbacks; when travelers *can* travel, they move faster than the average, but inevitable snags bring the average down. A very slow journey could take eight to 10 times as long as a very fast one, and *any* speed between twice and 1/5 the average is entirely plausible.

Rulers

Well into TL5, most states were ruled by autocrats such as pharaohs, kings, caliphs, and emperors. In rhetoric, such a ruler often claimed near-absolute power. By law, he was usually the chief judge, the highest (and often the *only*) legislator, and the leader of armies; he might also be the most important priest. In practice, his authority was limited by how far the machinery of the state – the military, the bureaucracy, and quite often the priesthood – would support him. Consequently, whatever powers he claimed, he operated within the bounds of tradition, his ability to enforce his will against rival interests, and, where it existed, the rule of written law.

Rivals to rulers frequently fall into two categories. First are *magnates:* barons, emirs, tributary kings and chieftains, and so on. These individuals have power of their own, but are subject to the ruler's authority. They may well be rulers themselves, with smaller personal domains. Magnates form a class that can provide the ruler with troops, significant tax revenues, and subordinates to whom the ruler can delegate administrative and leadership tasks away from his own court. However, they're also the people most likely to revolt successfully, and can – if united – resist the ruler's commands.

The other category is *priests*. Large, sophisticated states often have equally imposing religious establishments, which can take on tasks of rulership themselves. For example, in Mesopotamia, the earliest rulers *were* priests, with their power based in the ability of temples to uphold moral authority and collect taxes in the name of maintaining good relations with the gods; secular kingship there grew separately out of military leaders. In medieval Europe, the religious establishment grew larger and more sophisticated than any of the states it oversaw, which led to popes claiming the power to install and remove kings. Many other societies combined religious and civil hierarchies: the Egyptian pharaoh, the emperor of Japan, and many New World kings were regarded as divine, and the caliphs of medieval Islam were initially created as an ultimate religious authority. Even in societies such as these, though, lesser religious figures could rise to the power of secular magnates, and divisions of religious opinion could cause as many problems as secular disputes.

Since power in an autocracy comes ultimately from the ruler, the line between the government and the ruler's personal household is blurry, if it even exists. Importance in such a system is often measured by physical proximity to the throne. There's a strong tendency for household servants to take on governmental tasks. As new needs present themselves, rulers are likely to designate the people closest to them to attend to these responsibilities. For example, a servant in charge of overseeing the ruler's personal storehouses might be given overall control of tax revenues. Indeed, many rulers paid for the work of government out of their own income – that is, using revenues from their own and their family's lands and enterprises rather than from taxes paid to the crown – so a king's personal treasurer was often an important official whether or not he had a title.

This tendency makes getting close to the ruler a major political goal. Historically, many groups agitating for change or governmental representation didn't demand formal power or limitations on the crown, but simply the right to be consulted before major decisions were made. Autocratic governments are also vulnerable to the rule of royal favorites. Incompetent or weak-willed rulers are easily influenced by the people nearest to them, making stronger-willed relatives and friends the *actual* rulers.

Rulership is often hereditary, but this has rarely been an absolute imperative; a ruler usually has some latitude to select his successor, often picking from among his children and perhaps other close relatives. If he wants someone who isn't a close relative, he may formally adopt his heir. A poor choice of successors – or no choice at all – was a chronic problem through history. Remedies were attempted, usually to little avail. The Romans instituted a formal system of junior and senior emperors, grooming one ruler to take over for the next well in advance . . . only to see conflict break out between them within a few years of establishing the system. The Ottoman Turks, after a series of disastrous succession wars, essentially jailed princes from birth so that they could be controlled, but years of confinement produced sultans who were at best inexperienced and at worst insane, leaving actual power in the hands of servants and close advisors. With succession determined by favoritism and blood ties, a regime change was always a gamble.

Voting Systems and Popular Assemblies

Simple societies are characterized by communal, if informal, decision-making. More complex civilizations see the rise of autocrats and high-level policy-making laid down on subordinates, but voting and reliance on popular will recur through history.

Communal decision-making is most often found at a very low level. Agricultural villagers frequently make decisions together about the use of shared equipment, the schedule for plowing and harvesting communal fields, and similar matters. A church or a temple might serve as an organizing unit here, but religious authorities wouldn't exercise power over the process.

A communal element remained in some governments with the appearance of states. There are hints that early cities in Mesopotamia combined royal and priestly rule with elements of democracy. Around 2500 B.C., the kings of Ebla were elected to seven-year terms, although it's unclear who the electorate were or what powers the king had during his term. The first clearly democratic governments appeared in Greece and northern India in the sixth century B.C.

However, it would be fair to regard these early democracies as democratic only by comparison. They granted *citizens* a place in the political process, but citizenship had strict requirements. The key to political representation was membership in a privileged group. To participate, one usually had to be a free man who had reached a certain age (from the upper teens to the mid-thirties) and who belonged to a politically favored class. Slaves, women, residents who didn't belong to guilds or similar civic groups, members of the lower classes, followers of minority religions, and resident foreigners and their descendents were usually excluded from both voting and public office. It wouldn't be surprising for as little as 5% of a "republic's" population to be eligible for participation in government!

Historical democratic governments operated on a sliding scale from complex but geographically small to simple but governing a large area. At the small end were the city-states of the early Iron Age and the Renaissance. These were characterized by constant contact between citizens, and by elaborate sets of laws and procedures motivated by the need to deal with the disputes that arise in densely populated cities. Of course, such democratic city-states could and often did rule larger regions *undemocratically.* Cities such as Athens and Venice (and, indeed, Rome) might have had republican features, but they came to control substantial territories where nobody got a vote.

At the other end were the parliaments found through northern Europe. Scandinavian *things* and similar meetings among Germanic peoples periodically assembled to act as supreme courts and, in some cases, legislative bodies with authority over largely rural regions that might be the size of small kingdoms. Often, any grown man could participate, although he might need a good reason to make what could be a long journey. In a few cases, such as Iceland's *Althing,* a handful of regional chieftains acted as a legislature. However, their proceedings were public and people wanting to influence the voting would be able to discuss matters with the voters.

One of the great preoccupations of historical republics was protecting themselves from factionalism. No one in a republic wanted the government in the hands of rivals who might use the power of the state against him, so republics frequently had procedures making it difficult for a determined group to dominate a government completely. For example, many republics selected officers and members of committees by lot so that a powerful faction couldn't vote its own members into all the important positions. Some republics even went to other states to find officials. A number of states in medieval Italy were nominally headed by a *podesta,* recruited for a term of a year or two at a time, who was *required* to be a foreigner. The thinking was that foreigners wouldn't be embroiled in the ongoing feuds of local factions and so would be impartial administrators.

Popular will was also an element within more autocratic systems. Some autocrats were elected, although they served for life once in office. The selection of Roman emperors involved, if not formal voting, then at least acclamation by the people. The people as a whole didn't have to agree on who the next emperor would be, but the emperor had to arrange a display of public support, which might be accomplished by threats or bribery as much as by genuine popularity.

Most popular assemblies didn't have anything like that kind of power, but semi-autonomy was a feature of many voting bodies. Many states had a desire to ensure high-quality work and to have access to skilled labor when needed, but less interest in controlling the day-to-day aspects of craft production.

Consequently, craftsmen were organized into guilds at least as far back as the first century A.D. in the Roman Empire and the eighth century in China. The guild as a whole might be responsible to the government, but internal operations were a matter for the guild to resolve, which it usually (but not always) did democratically. Many guilds elected leaders to limited terms and took major decisions by popular vote, although voting rights might be limited to senior members. A number of towns that appeared in Europe in the early Middle Ages owed their existence to guilds. Bishops and noblemen granted guilds charters to govern their own internal affairs while retaining some authority over them – and since such charters often came with the use of a bit of land, the guild ended up as the democratic, or at least oligarchic, town government.

Bureaucracies

Bureaucracy is a pejorative term today – but next to writing, it's perhaps the single most important invention in the history of civilization. Without a group of professionals keeping records, adding up tax receipts, publicizing edicts, and otherwise coordinating the state's activities, civilizations would be impossible.

In smaller governments, bureaucracy is undifferentiated. A royal clerk may make copies of a recent letter from the Duke of Earl one day, look up tax rates for sheep hurling the next, and examine court records of divorces the day after. More sophisticated governments divide their bureaucracies into *ministries* with specific purposes.

Even the simplest bureaucracy has two core ministries. One of these is the *chancery,* which is a glorified secretarial pool – a body of scribes who compose and copy official documents. In barely literate societies, this is more important than it sounds. The chancery constitutes the government's memory. It keeps track of which laws are to be enforced and how, who inherits property when someone dies, what agreements have been made with other states, and so on. Having written records gives the state a long-term memory far superior to that of any individual.

The other core ministry is the *treasury.* States issue currency, collect taxes, and spend money – and they keep track of all this. As well, some states aren't limited to generating revenue by taxation. Many real-world examples had money-making departments of their own; thus, the treasury could resemble a business as much as it does a pure finance department.

More sophisticated governments create a wide range of ministries. However, unlike modern governments, where departments are typically organized according to a rational, coordinated plan with specific, overarching functions (war and defense, foreign relations, taxation, law, etc.), historical bureaucracies grew organically. Tasks that would be the purview of one modern department might be divided between several ministries, and some tasks could fall into unexpected places.

Useful Political and Social Terms

Historical societies were often built on social and political concepts that aren't widely known today. Some examples:

allod: In a feudal system, land not under an overlord's authority. People with allodial holdings aren't subject to an overlord's whims, but also lack the social connections and political support that such a figure might provide.

caste: A clan or lineage variant appearing in some civilizations and late chiefdoms. Caste members may be limited to certain professions (e.g., farming or priesthood) and typically cannot marry outside their caste, minimizing social mobility.

emancipation: Setting free from authority. Usually applied to freeing slaves, but can refer to removing restrictions on *any* repressed group; e.g., religious or ethnic minorities, or serfs.

lèse majesté: Offenses against the dignity of the state or the ruler. In many societies, insulting the ruler or government – or simply showing insufficient respect – was a serious crime.

manorialism: An arrangement whereby laborers (sometimes called *serfs* or *villeins*) – often tied to a particular piece of land – provide a landlord with labor in return for a share of what they produce and their lord's legal and, often, military protection. A system of relationships between peasant farmers and landowners; relationships between noblemen are *feudalism* (see *Law,* pp. 11-12).

suffrage: The right to vote. May include voting for leaders or representatives, or directly participating in government.

sumptuary laws: Laws that distinguish between social classes by prohibiting or requiring certain kinds of consumption or public display. For example, such laws might restrict use of particularly prized commodities such as silk or murex dye to the ruling class, limit the number of servants one may appear with in public, or require members of minorities to wear distinctive clothing.

tax farming: Selling the rights to collect taxes to private individuals. Practiced by many large empires – including the Romans, Ottomans, and Qing Chinese – this system, like feudalism, "rents out" formal authority. The government charges a large fee for or auctions off taxation rights, taking that as its income. The *publican* who wins the rights is entitled to collect and keep taxes in his district. He does so at his own expense, which is often considerable, as it involves a great deal of accounting and tracking down people to collect from them in person. Tax farmers were known to abuse their authority, and could easily qualify for a negative Reputation.

wergild: Fee paid by a killer to his victim's family as reparations for the deceased's death. Many low-tech societies, for whom long-term imprisonment was an unaffordable extravagance, punished crimes as serious as murder this way as an alternative to capital punishment, which could result in disruptive cycles of revenge killings.

For example, the Byzantine Empire didn't have a single ministry that oversaw foreign relations, like a modern state department. Rather, it had several ministries that handled relations with particular regions or nations. The Byzantine postal system also had a hand in diplomacy, as it dealt with sending messages abroad and providing transportation for foreign visitors within the empire. It became the closest thing the empire had to a generic foreign ministry simply because it was the ministry with which foreigners had the most contact.

In addition to their society's scribal tools, one of the chief resources of bureaucrats from the Imperial Roman period on was the *formulary:* a book providing direction on how to address letters and structure legal documents. Formularies might contain historical examples of official correspondence, partly written documents similar to modern forms, and explicit instructions on how to compose documents.

> *202. If any one strike the body of a man higher in rank than he, he shall receive sixty blows with an ox-whip in public.*
>
> *– Code of Hammurabi*

Law

When states arise, rulers produce laws that bureaucracies can record and apply more consistently than communally held customs. The next step beyond such written laws is law *codes:* authoritative compilations of statutes. Perhaps the first of these was issued in Babylon, around 1750 B.C., by Hammurabi. The Code of Hammurabi was a mishmash of *criminal, civil,* and *family* law (laws concerning marriage, inheritance, and similar personal matters), with a heavy emphasis on the first category. Other early law codes – such as Rome's Twelve Tables and China's T'ang Code – had similar content.

Many early law codes were written on durable media, such as stone or metal tablets, and put where the public could read them. It was fairly easy to copy inscribed tablets with the right materials. Chinese legal scholars used large sheets of thin paper and colored wax to take rubbings of law tablets in order to build their own libraries of legal texts.

Constitutional law, explicitly defining the state's power and structure, was rarely addressed in early law codes. As written constitutional law developed, it did so more slowly in autocracies than in republics – perhaps because it was often unenforceable there. Since the ruler was also the highest court, and ultimately the commander of any police force that might be used against the worst lawbreakers, constitutional law provided a pretext for invasion, revolt, or dynastic struggle rather than an enforceable limit on royal power. Republics, by contrast, often had extensive laws surrounding their system of government.

A number of limits on governmental power weren't so much legal as contractual. One response to a lack of effective bureaucracy was *feudalism.* In this system, instead of ruling everything through a centralized government, the ruling authority farmed out authority to *vassals* who directly governed smaller regions. Vassals exercised most governmental functions in their territories, and owed a limited list of specific duties – such as periods of military service – to their lord. The king's power was curbed less by statutory limitations on the crown than by specific agreements to cede authority in return for certain considerations. But even in less-feudal arrangements, rulers could choose to bind themselves contractually to obligations in return for concessions from others. It was often easier to conduct government by contract that to attempt to impose new laws.

The maintenance of separate social classes was explicitly written into law from the very beginning. For example, the Code of Hammurabi listed four different punishments for assault, depending on the relative social classes of the attacker and the victim, while the Twelve Tables prohibited marriage between upper and lower classes, and required male guardians for unmarried women. As legal institutions developed, the social distinctions they enforced became more complex. In medieval Europe, clergy and a few related groups – notably university graduates – were subject to a separate body of church or *canon* law; they were tried in special church courts, which were more favorable to churchmen than to lay accusers. Multiethnic states often bundled minorities together into administrative units overseen by their own rulers. For instance, Orthodox Christians in the Sassanid Empire of Persia were subject to the authority of their local bishops.

As states became more sophisticated, law codes grew longer. In the large empires of TL2, legal codes expanded to the point where posting them publicly was impractical, although *sections* of the law were posted by major states through TL2 and sometimes beyond. Bureaucrats occasionally compiled *digests:* catalogs of known laws. Like philosophical and religious texts, these acquired commentaries as judges and lawyers recorded interpretations and precedents.

The business end of all of these laws was the courts. Many societies combined judicial and executive functions – and often legislative ones, where applicable. In addition to kings, tribal chieftains, and other top-level leaders, lesser officials – such as Roman civic governors, medieval Japanese lords, and elected legislators in classical Greece and Renaissance Italy – might be called on to decide legal disputes. Since parties to such proceedings often had to pay the judge, the right to dispense justice was a coveted and lucrative one, particularly if it was an exclusive right, as it was in many territories in medieval Europe. In other societies, though, men of recognized wisdom (or of demonstrable education) could resolve legal disputes without actually holding office. Holy men in the Muslim world and Chinese scholars who had passed official exams could act as judges, at least in family and civil cases.

Law *enforcement* in most societies was aimed first and foremost at preserving public order and preventing the easiest crimes of opportunity. Urban police forces going back as far as the early cities of Mesopotamia had much in common with military units and royal bodyguards. They functioned almost exclusively as "beat cops," stopping riots and overt criminal activity, and preventing crime by shows of force. One recurring aspect of such police forces was the use of slaves and foreign mercenaries; using troops with no local ties, and thus no local support, enabled rulers to protect themselves from being overthrown by the soldiers who were supposed to protect them. Smaller towns that couldn't afford standing troops and cities that didn't trust or want to pay them had to rely on their own manpower.

In pre-Norman Conquest England, the adult men of small settlements were organized into groups that had to supply night watchmen on a rotating basis, and all were required to help apprehend criminals in the event of larger emergencies. Criminal investigation was a matter for parties to a legal dispute or, occasionally, judges – not for the police themselves.

Economic Laws and Concepts

From a modern standpoint, most historical economic thinking was – with some justification – pessimistic and intensely conservative. Stability was prized over risk, particularly in less-developed economies, and there was little expectation of innovation providing economic improvement. Basic ideas such as supply and demand were recognized, if imperfectly, at least as early as the fifth century B.C. However, concepts such as comparative advantage and the potentially positive role of finance didn't develop until more recent times.

A basic distrust of monetary exchange was at the root of much economic legislation. Many ancient societies couldn't shake the idea that people who simply traded goods or lent money were fundamentally untrustworthy. They produced nothing tangible, so their contribution to society was questionable at best. In some cases, merchants were members of the lowest classes; they might even be prohibited from certain official posts, as in China and Rome. To remain free of the taint of commerce in such settings, wealthy aristocrats acted as financial backers for lower-class merchants and split the profits.

This sentiment also manifested in laws against usury, or lending money at interest, widespread in medieval Christian and Islamic law. Usury laws fell afoul of the need for credit, so expanding mercantile societies found loopholes. For example, such restrictions were found to apply only to loans between coreligionists. Christians couldn't lend to Christians, nor Muslims to Muslims, but either could lend to the other – and Jews could make loans to anyone. Thus, members of minority religions became important financial middlemen. Another dodge was to disguise interest as fees for services rendered.

Medieval Christian philosophers proposed a doctrine of *just price:* producers should not charge more for goods than they cost to produce. A small profit might be allowed as a necessary evil, but anything more was tantamount to theft. Philosophers recognized market forces that would drive prices higher, but regarded acting on them as deeply immoral, the equivalent of charging a drowning man a fortune for a rope.

In many societies, *land* represented true wealth. Once money was spent, it was gone, but land produced a new crop every year. The desire for economic stability frequently led to restrictions on selling real estate. Both medieval Japanese and European law often recognized property rights lingering after a sale. Someone selling land could repudiate the sale for some period after the fact, as could his relatives, and in disputes over land rights, the person who could show that he or his ancestors had held the land earlier had a tremendous legal advantage.

Far from breaking up monopolies to encourage competition – as some modern states do – many historical governments *enforced* monopolies in lucrative areas of trade and manufacturing. They either charged monopolists a fee for exclusive rights or owned monopolies themselves, which they exercised through government-owned factories or state-funded merchants. For example, in the Byzantine Empire, only the state was permitted to manufacture silk, while in 14th-century England, a group of merchants was granted a royal charter to control wool exports.

In more-developed economies – such as the Byzantine Empire around Justinian's time or the global powers of the late Renaissance – greater emphasis was placed on stocks of precious metals than on agricultural land. Policies on international trade in many such economies prohibited or at least discouraged precious metals exports. By the end of the Renaissance, concern with capital developed into the doctrine of *mercantilism,* which drove economic policy for most of Europe. Mercantilists were concerned with building up capital and driving a positive balance of trade. Their policies resulted in the most extensive economic legislation to date. Instead of merely protecting precious metals or local monopolies, as earlier laws had done, national governments actively encouraged mercantile ventures (including colonizing the rest of the world!) and the import of raw materials, while discouraging importation of expensive manufactured goods.

Accounting

Businesses and bureaucracies have kept financial records since the dawn of literacy in ancient Mesopotamia (TL1). But how do they know those records are accurate? If a dishonest servant or clerk misreports some transactions, or doesn't report them at all, he can enrich himself at his masters' expense. At TL4, Italian bankers and merchants came up with a way to protect themselves against this: *double-entry bookkeeping.* Despite the traditional jokes (usually taking it as "keeping two sets of books"), this isn't a method of fraud but a countermeasure against it.

In double-entry bookkeeping, every transaction produces changes in two different accounts, which can be checked against each other, like a computer using a check digit to verify accurate transmission of data. For example, sale of merchandise requires both an addition to the business' cash balance and a subtraction from its inventory. If a sale goes unrecorded, the two won't match.

An Accounting skill roll can identify employee fraud. This roll is at -5 for an organization that isn't using double-entry bookkeeping. If two separately kept single-entry records can be compared, as in reconciling a checkbook with a bank statement, roll at only -2. Medieval accounting (TL3) made extensive use of duplicate records. It was standard practice to have two separate scrolls, the *roll* and the *counter-roll,* later shortened to *control* – from which came the term *controller* for an official who verifies financial records.

Chapter Two
Philosophers

"Philosophy" means "love of wisdom"; thus, a "philosopher" is someone wise. But a philosopher doesn't just sit around making profound statements! Wisdom advances art, religion, and science. Those who seek it often apply it, whether as musicians, physicians, or teachers. And wisdom, however abstract, inspires technologies – especially those for recording and disseminating information – as well as structures built in its honor.

Temples and Monuments

Simple societies often built surprisingly massive structures. As soon as people settled in one place – if not earlier – many started to erect monuments and religious edifices.

Prehistoric Monuments

Megalithic structures are found across the Old World, generally corresponding to dates in the local Neolithic. The earliest megaliths, in the Near East, date to around 9000 B.C. Some are clearly tombs. The simplest are single burial chambers made from a few enormous stone slabs covered with earth, but larger monuments may contain multiple burial chambers with halls connecting them.

The purpose of other megalithic monuments isn't as clear. Many societies erected standing stones and very simple stone slab structures such as *dolmens* (stone tables) and Stonehenge's *trilithons*. The alignments of standing stones at Stonehenge and Avebury in England, and Nabta Playa in Egypt, mark out the position of the sun at certain times of year. However, the precise significance of those events to their builders is unknown (see *Stonehenge,* p. 30).

The Americas saw the construction of large earthworks with similarly obscure purposes starting around the same time as megalithic monuments in Europe. The New World mounds were mostly as simply fashioned as their Old World counterparts, although some were shaped like animals. They could be extremely large, however. The mound at Cahokia is about 100' tall and has a base covering about 795,000 square feet – a larger footprint than the Great Pyramid at Giza! Some earth mounds had a complex internal structure, with alternating layers of earth and sand to facilitate drainage, improving durability.

The New World has one other unique kind of monument: the Nazca lines, long lines and figurative shapes in the deserts of Peru. Like the figurative mounds of North America, the shapes of the Nazca lines are only apparent from above. The builders would never have been able to see the lines properly, but constructing them was relatively simple. The region where they're found consists of light-colored sand with a great many rocks darkened by weathering. Making the patterns merely required moving rocks around to expose areas of sand. Although the job of the individual worker was simple, building the extensive network of lines required planned, coordinated effort.

Probably the best-known monuments, though, are pyramids. These and similar structures were constructed by the Mesopotamians, Egyptians, Maya, Aztecs, Chinese, and others, and spanned prehistoric and historical periods. The architectural similarities aren't surprising; pyramids are among the easiest monuments to construct. Piling up lots of material naturally produces something with a triangular cross-section. Squaring that off – and almost all societies moved from essentially round to more-or-less square or rectangular structures as they became more complex – yields a pyramid. Their purpose, however, varied from place to place. American and Mesopotamian pyramids served as platforms for temples built atop them, while African and Chinese ones were tombs.

Iconography

Temples and churches often contain art depicting gods, prophets, saints, or heroes, and key events in their lives. In many societies, however, most of the worshipers are illiterate. To help them recognize the characters shown in temple art, artists developed *iconography:* standard ways of portraying legendary figures.

The term comes from medieval Christian churches, where, for example, the Virgin Mary was shown robed in blue, and St. Sebastian pierced with multiple arrows. But the practice goes back long before the Middle Ages, to ancient Greek images of Heracles wearing a lion skin and carrying a massive club, and possibly to Egyptian animal-headed gods. The same technique is used even today for comic-book supers with their distinctive, bright-colored costumes; e.g., regardless of who draws him, Superman is readily identified by an S bounded by a pentagonal shape.

Iconography grants a bonus to Connoisseur (Art) – and possibly to other skills – to recognize a legendary character. This ranges from +1 for a rare minor figure to +4 for a near-omnipresent one such as Buddha, Heracles, or the Virgin.

What all such prehistoric monuments have in common is a need for organized labor. The technical skills required of the workmen were relatively simple – particularly compared to the stonework of later monuments. However, the labor requirements would have been enormous for a Neolithic tribe or an early Bronze Age state. Whatever the structure's purpose, its local significance would have been as great as the construction of the Pyramids or a cathedral.

Religious Monuments

The purpose of monuments built by more-literate civilizations is clear – if only because they're conveniently labeled, or at least use well-documented artistic motifs (see *Iconography,* p. 13). Such structures are frequently religiously themed. Asia is home to massive statues of the Buddha carved from cliff sides, and monumental tombs of Muslim holy men are important pilgrimage sites.

Religious buildings are typically on the leading edge of architectural development. Across areas with the same climate, a peasant's hut or a small urban building might change little from the early Bronze Age to the Renaissance. By comparison, religiously themed architecture during that period would undergo great leaps in technological sophistication – from clay ziggurats to classical temples to Saint Peter's basilica at the Vatican.

Most temples have a focus for worship at their center. In many religions, this is a physical representation of the divine, such as a sacred stone, or a painting or statue of a god. Depending on beliefs, this may be open for visiting or hidden from public view, maintained by specially selected priests. The Abrahamic religions explicitly forbid worshiping objects but nevertheless build their holy places around important ritual features, such as an ark for the Torah, an altar for communion, or a *mihrab* pointing the way to Mecca. Bigger temple complexes may have multiple locations for worship. The larger Egyptian complexes have separate shrines to a number of different gods, while Gothic cathedrals are full of small niches where semi-private ceremonies can be held.

Many faiths require that people entering a temple perform some brief ritual, often a symbolic purification, and therefore provide facilities for that. For example, visitors to mosques and Shinto shrines are expected to wash their hands, so fountains are located near the entrance. It's also extremely common for temples to expect guests to remove shoes, and thus to include niches in which to leave footwear.

Because temples had to be supported by the community as a whole, they served as early centers of taxation and control in some places. Originally, they might have been supported by voluntary (if strongly socially sanctioned) donations, but contributions became obligatory in some areas, and in effect the first formal taxes. In addition to being a significant step toward the development of the state, this evolution spawned important technological advances. Some of the world's oldest surviving written documents are tax records from temples in Mesopotamia. Thus, writing might well have been a spinoff of temple economies; at minimum, it got a significant boost from its use for such accounting.

To store the donations for their support, temples had to add warehouses onto their ritual spaces. Offices and libraries followed as the growing power of civic temples made them administrative centers. By the late Bronze Age, temples associated with cities could be palace-like districts with living quarters for priests, storage for taxes, and workspaces for clerks – all in addition to areas for ritual and religious items.

At some point during the Iron Age, perhaps as early as the fifth century B.C., temples started to become the centers of entire communities. Buddhist monks in India began to settle in temporary quarters during the rainy season, when travel and begging for alms were difficult. Within a few centuries, these became permanent settlements, where residents could focus their entire lives on religious activities. Buddhist monasticism quickly spread through eastern Asia, and similar institutions sprang up in Europe in the first centuries of Christianity. Because supporting monasteries was universally regarded as virtuous, monasteries across the Old World could accumulate enough wealth to rival the power of secular lords.

Religious buildings came to be centers for other kinds of activities, too. In Greece, temples at pilgrimage sites became tourist destinations as they added facilities to accommodate visitors. Complexes dedicated to gods of healing, or at healthful places such as natural hot springs, could grow into hospitals, where visitors would combine therapy with ritual (see *Healing Shrines and Pilgrimages,* p. 25).

Temples could also act as treasuries. Lavish gifts to religious institutions are common in many societies, so temples can end up with a lot of valuables. In good times, they can make loans to individuals; in difficult times, they can donate stored wealth to disaster relief, armaments, or other expensive causes. Even if a temple doesn't act as a public financier, the gold, silver, and other fine goods used in ceremonies can be sold to support its more basic needs during lean periods. And as international religious ideologies arose during the Middle Ages, the wealth of the associated organizations – particularly in Europe – allowed religious centers to take on an early role as international bankers. A wealthy traveler could deposit funds at one church or monastery in Europe, receive a letter of credit, and withdraw his funds (minus a small fee) at a different church in the Levant.

First National Bank of the Divine

Churches and temples can act as banks, but don't do so lightly or cheaply. A temple acting as a moneylender will charge *at least* 15% interest, and probably more. This reflects not rampant greed but simply the state of finance in low-tech societies; private moneylenders, if any can be found, are unlikely to beat temple rates. For a letter of credit from a religious institution, the fee might be 3-5% of the amount deposited. Higher rates are possible if the temple network serving as a bank is very strained.

Private and Political Monuments

In states with powerful rulers, individuals who aspired to power naturally assumed some of the burden of paying for temples in order to claim credit for it. Thus, the construction of religious buildings inevitably acquired political overtones. For example, despite its purpose as a temple dedicated to all gods, the prominent inscription on the façade of the Pantheon in Rome proclaims only that Emperor Augustus' supporter Marcus Agrippa built it.

. . . Made Possible By An Endowment . . .

Wealthy and powerful folk may want to build up religious establishments. One option is to endow an existing institution with enough money or goods to support priests, monks, and other religious professionals. This is equivalent to paying their cost of living (p. B265). Such people are usually at least Status 0 – although those with self-denying Disciplines of Faith may have an effective cost of living appropriate to at least one Status level lower.

Those who want to make *large* endowments can provide permanent support by giving the religious establishment money or goods with a value equal to about 20-30 *years'* cost of living per person. Properly invested (churches and temples are among the few long-term investors in low-tech societies), this sum can return enough to pay a priest or monk's living expenses indefinitely – or at least until the next major political or economic upheaval.

An even more expensive but also more visible and permanent way to build up a religious establishment is to *construct* it! See *Building Monuments* (below).

Other works were exclusively political. The Egyptians and Persians produced monumental sculptures and friezes glorifying their rulers. The Greeks popularized monuments and pioneered displaying statues of living or recently deceased public figures to celebrate important events. It was the Romans who perfected the use of public monuments as propaganda, however. While an emperor was unlikely to visit most places in the empire, statues of him could be mass-produced and sent anywhere, making his image part of the empire's shared cultural knowledge.

But not all monuments need be so grand. Privately erected markers memorializing the dead appeared in Egypt at least as far back as the 16th century B.C. To the extent that the buyers could afford them, such monuments shared the attributes of more elite ones. For example, private tombs in Egypt contained goods for the afterlife, while Chinese family tombs of the fourth century B.C. were built into small mounds and equipped with small temples like the monumental grave sites of some emperors.

Building Monuments

The earliest and simplest monuments were basically big piles of rock and dirt. These came in a variety of sizes, but many societies discovered that 52° was nearly ideal for the slope of a *pyramid*.

It's straightforward to find a pyramid's cost and weight. A small one is approximately 20' tall and covers 1,000 square feet (about 31.5' on a side). Made of stone, it weighs 500 tons and costs $9,100,000. For a larger pyramid, select a ground area. Next, find the *square root* of (area in square feet/1,000). Finally, scale the small pyramid's dimensions by multiplying height by this amount, and weight and cost by the *cube* of this factor.

Example: For an 8,000-square-foot pyramid, the height multiplier is the square root of (8,000/1,000), or 2.83. Multiplying by 20' gives a height just under 57'. The weight and cost factor is 2.83 cubed, or 22.6. Multiplying 500 tons and $9,100,000 gives a weight of 11,300 tons and a cost of roughly $206,000,000.

For *earthen* pyramids and ziggurats, divide weight by 2.3 and cost by 192.

Later religious edifices were more diverse. The table below describes basic structures that might be put to a religious purpose. Prices exclude the elaborate decoration common in such buildings; for instance, statues and paintings. Such features could easily double or triple cost!

Building	*Cost*	*DR*	*HP*	*Notes*
Wooden Temple	$13,340	4	192	[1]
Stone Temple	$41,600	73	387	[2]
Monastic Dormitory	$61,890	72	485	[3]
Big Temple	$4,733,950	73	1,873	[4]
Palace	$8,543,880	130	1,781	[5]

Notes

[1] A small (15'×30', 12' tall) building with one large room, suitable for the sole church in a small town or as a minor center of worship in a larger settlement.

[2] Like the wooden temple, but made mostly from rough stone, with a fine finished-stone exterior.

[3] A rough-but-durable stone building containing 14 small (5'×7') cells for monks.

[4] A fairly large (80'×150', 40' tall) church with a mostly open floor plan, but a few small rooms for chapels or offices off the sides.

[5] An impressive, though not epic, urban structure (90'×90', 30' tall) made from fine stone. Appropriate for a prince, bishop, or imperial governor's residence, or as the public palace of an urban republic. It contains a mix of large chambers for official events and small rooms for use as apartments and offices.

Temples, palaces, and other monuments are known for being elaborately decorated. Some ornamentation takes the form of portable décor, such as tapestries (see ***GURPS Low-Tech***) or statuary. At TL0, large figurines may be carved from wood. At TL1+, statues may be made from terracotta, stone, or cast metal. To determine a statue's cost and weight, estimate its approximate volume (a typical human body is about 2.5 cubic feet) and multiply this by the cost and weight for the desired material on this table:

Material	*Cost/cu. ft.*	*Weight/cu. ft.*
Wood	$37.80	32 lbs.
Terracotta	$100	92 lbs.
Stone	$350	186 lbs.
Bronze*	$1,725	250 lbs.

* Figures assume a *hollow* bronze statue; if *solid,* double cost and weight. Compute cost and weight for silver and gold statues as explained in *Jewelry* in ***GURPS Low-Tech.***

Statues may be painted, enameled, gilded, and otherwise adorned using the rules under *Decorated Equipment* in ***GURPS Low-Tech.*** The building itself may be decorated, too, with texts or figurative displays carved into walls, inlaid stone floors, etc.

This can be as expensive as it is impressive! The next table gives cost per square foot of surface:

Decoration	*Cost/sq. ft.*
Painting	$2.52
Gilding (Copper/Bronze)	$7.50
Gilding (Silver)	$30
Gilding (Gold)	$300
Inscribed Wood	$4
Inscribed Tile	$5
Inscribed Stone	$17.60

Particularly elaborate inscriptions give +2 CF. Inlaid surfaces *start* at +2 CF for common materials and range to +10 CF for especially fine ones.

Elaborately decorated buildings were built to impress. The occupants enjoy a reaction bonus corresponding to the total value of the decorations, as explained under *Decorated Equipment* in ***GURPS Low-Tech.***

In many societies, monuments are LC3. A prospective builder needs the permission of civil or religious authorities to build a temple or dedicate a statue. Certain structures may even be LC2! For example, in Classical Athens, only statues of gods were permitted in the Agora. However, notable individuals – e.g., victorious generals and Olympic athletes – could be declared *isotheos* ("like a god," at least to the extent that they were held in public esteem), and they or their friends could erect statues.

Technicians of the Sacred

A widespread feature of religions is a connection with altered states of consciousness (e.g., trance states). People's experiences with these can inspire religious beliefs, while the faithful may spontaneously or deliberately attain such states, having what's known in religious terms as *mystical experiences*. Some traditions provide long-sustained courses of action – that is, Disciplines of Faith (p. B132) – that enable adherents to achieve this goal fairly frequently. A few have methods that allow large numbers of devotees to do so on special occasions, often simultaneously. Anthropologist Mircea Eliade coined the term *technologies of the sacred* for these practices, which can indeed be regarded as a kind of technology.

There are two basic strategies for inducing deep trance states: *reduced sensory input* and *sensory overload*. The effects of trance induction are comparable to those of the Autohypnosis skill (p. B179) – and at the GM's discretion, a trance state may grant the same benefits as a successful roll against Dreaming (p. B188). The person entering the trance doesn't directly control the process, however.

Deep trance may occur after an hour of meditation in an intensely restricted environment, such as a hermit's cave, or after a day of meditation in ordinary quiet surroundings, such as a shrine or a forest glade. Roll against the trance-seeker's Meditation skill at -4. A successful Religious Ritual or Teaching roll by a guide (priest, shaman, etc.) gives +1; critical success grants +2.

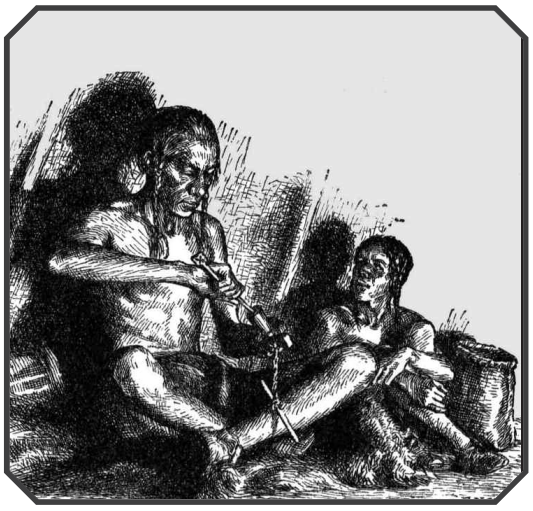
Deep trance may also occur through sensory overload – such as chanting, drumming, and rhythmic movement – lasting at least an hour. Roll against the Religious Ritual skill of the officiating priest or shaman at -4.

For either process, taking extra time provides a bonus to the *primary* skill; see *Time Spent* (p. B346). Several other techniques can aid or replace these skill rolls:

Controlled Breathing: Spiritual practices such as yoga emphasize breathing in a controlled pattern. A successful Breath Control roll grants +2 when seeking trance through reduced sensory input. Various other body disciplines may provide similar bonuses (see *Body Disciplines,* below).

Stressful Conditions: Physical pain inflicted through methods that cause no more than minor damage – e.g., flagellation or piercing – gives +2 to trance rolls. Physiological stress from fasting, heat (as in a sweat lodge), or prolonged rhythmic movement (such as dancing) grants +4 to trance rolls once the subject is reduced to less than 1/3 of his FP. In either case, the trance state provides the same benefits against the stressful condition that a successful Autohypnosis roll would offer.

Drugs: Many cultures have incorporated the use of drugs into their religious rituals. Pharmacy (Herbal) often includes the ability to identify and prescribe such *entheogens*. Mild drugs (e.g., alcohol, hemp, or tobacco) at proper doses grant +1 to the primary skill for attaining a trance. Hallucinogens (such as belladonna in Europe, fly agaric in Siberia, jimsonweed in California, or peyote in Mexico and the American Southwest) produce altered states of consciousness directly. Treat the recipient as hallucinating (p. B429) – but a priest or shaman, if present, can frame this experience in religious terms with a successful Religious Ritual roll.



Body Disciplines

A number of physical skills can serve as a focus for attaining trance states. They don't *routinely* provide this benefit, but can do so in conjunction with the following new perk.

Body Discipline (Skill)

You can apply a particular DX-based skill as a spiritual discipline. A successful skill roll grants +2 to *your* rolls to attain trance, for Acrobatics, Dancing, or a Combat Art skill, or +2 to *your partner's* rolls, for Erotic Art (as in tantra or some alchemy variants). You must specialize by skill.

Musical Instruments

Musical instruments – like weapons – come in near-limitless variety. Every culture has its own styles. It's often reasonable to regard instruments from different backgrounds as variants on the same basic design, however. For example, Ancient Greek musicians played flutes, although these weren't identical to those of modern orchestras, and the Japanese *shakuhachi* (among others) is commonly described as a kind of flute . . . just as a Roman *gladius* or a Japanese *wakizashi* can be described as a shortsword.

Accordingly, while the Musical Instrument skill (p. B211) requires specialization, each specialty includes *all* instruments that are played in essentially the same way. For example, all flutes are played by blowing across a lipped opening to make a column of air vibrate, and by covering and uncovering finger holes to change column length. Use *Familiarity* (p. B169) to handle differences in size, shape, tuning, scales, and how the instrument is held (e.g., vertically for a shakuhachi vs. horizontally for a Western flute): all of the variants share a specialty, but unfamiliar ones give -2. The penalty is merely -1 if size is the only significant difference, as for alto, tenor, and baritone saxophones.

Below are several lists of distinct specialties. These are grouped into broad categories based primarily on the instruments' acoustics, although keyboard instruments receive their own category. Related specialties default to each other at from -3 to -6. Post-1730 developments – such as valved brass instruments (TL5) and the theremin (TL6) – are absent. Brass instruments at TL1-4 mostly have a limited range of notes determined by the natural harmonics of the metal tube.

Musical Instrument specialties are IQ/Hard unless indicated otherwise. A noteworthy exception is specialties encompassing instruments that aren't tuned to a specific pitch, and that can produce rhythm but not melody or chords; these are IQ/Average. The GM may elect to allow a single IQ/Hard specialty – Rhythm Instruments – which includes *all* untuned membranophones and idiophones, with specific types of instruments as *optional* specialties (and thus automatically IQ/Average).

Note that some instruments can be played with more than one skill – just as a bastard sword can be wielded either one-handed with Broadsword or two-handed with Two-Handed Sword. For example, one can play a violin by either bowing the strings, which is Musical Instrument (Fiddle), or plucking them, which is Musical Instrument (Guitar).

Making a Joyful Noise

The human body itself can serve as a musical instrument! When singing or whistling, it's an aerophone; when clapping, snapping fingers, or stamping feet, it's an idiophone. There's already a Singing skill – but what skill covers making *other* sounds?

Represent any rhythmic percussive activity with DX. Use Dancing+5, if better (e.g., for a tap dancer's rhythmic stamps) – but apply the usual -5 for unfamiliar dances (cancelling the +5), or just use straight DX, if the type of movement isn't customary in the dancer's style. For clapping and finger-snapping (but not for stamping), use Musical Instrument (Small Concussion)+5, if higher.

Treat whistling as a *HT*-based Hobby Skill (p. B200) that defaults to *HT*-based Musical Instrument (Horn, Recorder, Serpent, or Trombone)-3 or Singing-5.

Aerophones

Instruments played by blowing into or across a column of air. Blowing differently usually produces different notes, but in many aerophones, the column length can also be changed: by finger holes, as in woodwinds; by valves, as in modern brass; or by a slide, as in the trombone.

Bagpipe: Played by squeezing a bag to force air through a single or double reed, and opening and closing finger holes. *Defaults:* Double Reed, Flute, Recorder, Serpent, and Single Reed at -6.

Didgeridoo: A long wooden tube played by blowing through vibrating lips into the open end, altering pitch by changing lip position. The technique is quite different from Horn and other "brass" instruments. *Defaults:* Horn, Serpent, and Trombone at -6.

Double Reed: Played by blowing through a pair of reeds, which vibrate against each other, and opening and closing finger holes. *Examples:* bassoon, nadaswaram, oboe, shawm, taragato. *Defaults:* Recorder and Single Reed at -3; Bagpipe, Flute, and Serpent at -6.

Flute: Played by blowing across a lipped opening, and covering and uncovering finger holes. *Examples:* fife, flute, shakuhachi. *Defaults:* Panpipes at -3; Bagpipe, Double Reed, Recorder, Serpent, and Single Reed at -6.

Horn: Played by blowing through vibrating lips into a cup-shaped mouthpiece. The instrument has no finger holes, slide, or valves. *Examples:* alpenhorn, bugle, conch, hunting horn, shofar, trumpet. *Defaults:* Serpent and Trombone at -2; Didgeridoo at -6.

Panpipes: Played by selecting one of a row of cylindrical tubes and blowing across it, as for a flute. *Default:* Flute at -3.

Recorder: Played by blowing into a whistle that directs the airstream at an edge, and opening and closing finger holes. *Defaults:* Double Reed and Single Reed at -3; Bagpipe, Flute, and Serpent at -6.

Serpent: Like a horn, but with finger holes that can be opened and closed. *Examples:* ophicleide, serpent. *Defaults:* Horn at -4; Trombone at -5; Bagpipe, Didgeridoo, Double Reed, Flute, Recorder, and Single Reed at -6.

Sheng: An instrument with multiple pipes, each with a free reed (the kind of reed in a harmonica, which vibrates back and forth through an opening at its natural resonant frequency), played by blowing into a mouthpiece and fingering the holes in the pipes to make them sound. *Defaults:* Panpipes at -5; Bagpipe at -6.

Single Reed: Played by blowing through a reed that vibrates against a mouthpiece, and opening and closing finger holes. *Examples:* clarinet, hornpipe. *Defaults:* Double Reed and Recorder at -3; Bagpipe, Flute, and Serpent at -6.

Trombone: Like a horn, but with a slide that can make the air column shorter or longer. *Examples:* sackbut, trombone. *Defaults:* Horn at -4; Serpent at -5; Didgeridoo at -6.

Chordophones

Stringed instruments, almost always with a resonant cavity attached to the strings to amplify the sound. On some, the strings can be fingered to change the pitch; on others, there's a separate string for each pitch.

Dulcimer: An instrument with multiple strings stretched parallel to a flat body; the strings are struck with hammers or sticks. *Defaults:* Tuned Percussion at -4; Keyboard, Psaltery, and Zither at -5; other chordophones at -6.

Fiddle: An instrument with one or more strings stretched parallel to a body and along a neck that's used for fingering, held horizontally and played by rubbing the strings with a bow. (To *pluck* the strings, use Guitar.) *Examples:* ravanastron, viol, violin. *Defaults:* Rebab at -3; Guitar and Psaltery at -5; other chordophones at -6.

Guitar: An instrument with one or more strings stretched parallel to a body and along a neck that's used for fingering, played by plucking or strumming. *Examples:* balalaika, banjo, double bass (plucked), guitar, pipa, shamisen, violin (plucked). *Defaults:* Fiddle, Lute, and Rebab at -3; other chordophones at -6.

Harp: An instrument with multiple strings of different lengths rising perpendicularly from a base to a crossbar. *Examples:* harp, kora. *Defaults:* Lyre and Zither at -4; Keyboard at -5; other chordophones at -6.

Lute: Similar to a guitar, but with pairs of strings tuned to the same note and both plucked at the same time. Some of these instruments have drone strings tuned to bass notes, for rhythm. *Examples:* kora, lute, mandolin, oud, sitar. *Defaults:* Guitar at -5; other chordophones at -6.

Lyre: An instrument with multiple strings of the same length stretched parallel to a body and rising to a crossbar. *Defaults:* Harp and Zither at -4; other chordophones at -6.

Psaltery: An instrument with multiple strings stretched parallel to a flat body; the strings are rubbed with a bow. *Example:* crwth (the actual bowed psaltery is TL6!). *Defaults:* Dulcimer, Fiddle, Keyboard, Rebab, and Zither at -5; other chordophones at -6.

Rebab: An instrument with one or more strings stretched parallel to a body and along a neck that's used for fingering, held vertically and played by rubbing the strings with a bow. (To *pluck* the strings, use Guitar.) *Examples:* double bass, rebab, viola da gamba, violoncello. *Defaults:* Fiddle at -3; Guitar and Psaltery at -5; other chordophones at -6.

Zither: An instrument with multiple strings stretched parallel to a flat body; the strings are plucked. *Examples:* koto, zither. *Defaults:* Harp and Lyre at -3; Dulcimer and Psaltery at -4; Keyboard at -5; other chordophones at -6.

Idiophones

Instruments played by causing a solid piece of material to vibrate, using a variety of methods. May be either tuned or untuned. A few have resonators to make the sound more audible.

Bell: A *large* bell, played by pulling a cord to make a clapper strike the inner surface of a tuned resonating body. (Small bells use one of Rattle, Tuned Percussion, or Untuned Percussion.) This specialty covers playing a whole set of bells, but it's more common to assign one person per cord and roll against average skill; treat playing a single bell as an IQ/Average optional specialty. *Defaults:* Large Concussion, Tuned Percussion, and Untuned Percussion at -3.

Jew's Harp: Played by plucking a single tongue of solid material; the mouth cavity is used as a resonator, and pitch is varied by changing its shape. *Default:* Singing at -6.

Large Concussion (IQ/Average): Instruments played by striking together two similar objects or pieces, usually untuned. *Example:* cymbals. *Defaults:* Bell, Rattle, Scraper, Small Concussion (*IQ*-based), and Untuned Percussion at -3; Untuned Drum at -4.

Mbira: Instruments played by plucking tongues of solid material tuned to different notes. *Examples:* kalimba, mbira. *Defaults:* Tuned Percussion at -3; Harp, Lyre, and Zither at -4; Dulcimer and Keyboard at -5.

Rattle (IQ/Average): Instruments shaken so that pieces of them strike against other pieces. *Examples:* hand bell, maracas, sistrum, tambourine (shaken). *Defaults:* Large Concussion, Scraper, Small Concussion (*IQ*-based), and Untuned Percussion at -3; Untuned Drum at -4.

Scraper (IQ/Average): Instruments played by scraping a rough surface. *Examples:* washboard, yü. *Defaults:* Large Concussion, Rattle, and Untuned Percussion at -3; Small Concussion (*IQ*-based) and Untuned Drum at -4.

Small Concussion (DX/Average): Two small pieces tapped together in one hand, used mainly to accompany dance (most dancers wear *two* sets). This specialty benefits from High Manual Dexterity. *Examples:* castanets, zils. *Defaults:* Dancing, Large Concussion, and Rattle at -3; Scraper, Untuned Drum, and Untuned Percussion at -4. Use DX-based levels.

Tuned Percussion: Instruments with a row of solid pieces, each with a different resonant frequency, played by striking with a stick or hammer. *Examples:* bell lyre, chimes, saron, xylophone. *Defaults:* Bell and Untuned Percussion at -3; Dulcimer, Keyboard, and Mbira at -4.

Untuned Percussion (IQ/Average): Instruments played by striking an untuned solid object, usually with a drumstick or a hammer. *Examples:* gong, triangle, wood block. *Defaults:* Bell, Large Concussion, Rattle, Scraper, Tuned Drum, Tuned Percussion, Untuned Drum at -3; Small Concussion (*IQ*-based) at -4.

Keyboard Instruments

Instruments with keys arranged in a line, played by striking the keys with the fingers. The keys activate a sound-generating mechanism, which may be based on air columns, strings, or solid materials. Keyboard instruments are a distinctively Western invention.

Hurdy-Gurdy: A small, handheld keyboard instrument with a rosined wheel that rubs against its strings when turned with a hand crank. *Defaults:* Keyboard at -4; Psaltery at -6.

Keyboard: A large, freestanding keyboard instrument. *Examples:* carillon, clavichord, harpsichord, organ, virginal. *Defaults:* Dulcimer and Tuned Percussion at -3; Harp, Lyre, and Zither at -4; Psaltery at -5.

Membranophones

In ordinary language, *drums:* instruments based on setting a stretched skin in motion, usually by striking it with the hands or a stick. Most membranophones have a resonant cavity beneath the skin.

Tuned Drum: A drum with a skin that vibrates at a specific note. Often used in sets with different tunings; some tuned drums can be retuned by changing the tension on the skin. *Examples:* bongos, tabla, timpani. *Defaults:* Untuned Drum at -3; Untuned Percussion at -4.

Untuned Drum (IQ/Average): A drum used purely as a rhythm instrument, with no specific tuning. *Examples:* bass drum, bodhran, snare drum, tambourine (struck). *Defaults:* Tuned Drum and Untuned Percussion at -3; Large Concussion, Rattle, Scraper, and Small Concussion (*IQ*-based) at -4.

Other Instruments

A few instruments don't fit any of these categories. For example:

Bullroarer (IQ/Average): A shaped piece of wood or other material at the end of a long cord, played by whirling it through the air to make a loud noise.

New Musical Traits

If music is important to the campaign, then in addition to detailed Musical Instrument specialties, the GM may opt to use two new traits.

New Quirk: Can't Read Music

Like languages, music can be read and written. In societies that have written music, learning to sing or play an instrument normally includes learning musical notation. A musician can sight-read a new piece with a Singing or Musical Instrument roll at -2. One with the quirk Can't Read Music can only learn new pieces by ear. Musicians from cultures without musical notation *always* have this quirk, and need to memorize tunes. You must have at least one point in Singing or Musical Instrument to take Can't Read Music.

New Technique: Sight-Reading

Hard

Defaults: Musical Instrument-2 or Singing-2.

Prerequisites: Musical Instrument or Singing, *and* cannot have Can't Read Music; cannot exceed prerequisite skill.

In societies that have musical notation, playing a new piece from written music gives -2 for unfamiliarity. A musician who improves Sight-Reading can roll against it instead to play *any* unfamiliar piece straight from the written music.

Musical Scales

The ancient Greek mathematician Pythagoras discovered that musical scales had a mathematical basis. By dividing a string into halves, thirds, and other fractions, he showed that length ratios based on small numbers produced notes that harmonized with each other. For example, a string tuned to G was 2/3 as long as one tuned to C. Because of this discovery, the word "harmonics" was used for centuries to mean the study of fractions.

At TL2-3, Western music was based on ratios of whole numbers: multiples of 2, 3, and later 5. Each musical key had a different set of ratios and required instruments built to fit those ratios. At TL4, composers began to use *equal temperament,* with scales built on the 12th root of two, an irrational number; none of the resulting scales was perfectly harmonious, but they were close enough to satisfy listeners. Johann Sebastian Bach helped to popularize the new system, with musical works such as *The Well-Tempered Clavier.*

Other cultures use different scales: East Asian music is often pentatonic (five notes per octave rather than seven), Near Eastern music uses quarter-tones (halfway between the half-tones of Western scales), and Indian music has many different scales. Penalties for Cultural Familiarity (p. B23) apply when playing an instrument or a musical work with an unfamiliar scale.

Mathematics and Astronomy

GURPS Low-Tech discusses advances in mathematical technology, including measuring devices and notation. However, *mathematics itself* moves forward as technology progresses. Each TL brings new mathematical concepts and methods, enabling mathematicians to solve problems that earlier TLs couldn't handle. The following list summarizes these developments by TL, along with which Mathematics specialties are available.

TL0 – There are *no* mathematical skills! Very simple mathematics is possible: deciding which of two objects is larger, recognizing how many objects are in a small group (up to about half a dozen), matching objects with tally marks, etc.

TL1 – *New Mathematics Specialties:* Applied, Surveying. *Key Mathematical Developments:* practical geometry, used to calculate areas and volumes; nonpositional numerals; basic arithmetic, including addition, subtraction, and simple fractions.

TL2 – *New Mathematics Specialties:* Pure. *Key Mathematical Developments:* use of definitions and proofs in mathematical theory; plane and solid geometry; identification of prime numbers and other special categories of numbers.

TL3 – *Key Mathematical Developments:* positional numerals; long division and other sophisticated arithmetic; algebraic equations; plane and spherical trigonometry.

TL4 – *New Mathematics Specialties:* Cryptology, Statistics. *Key Mathematical Developments:* analytical geometry (graphing equations); calculus and infinite series; logarithms; binary arithmetic; mathematical theory of probability.

Applications of Mathematics

The need to solve practical problems was one of the major forces driving the invention of new mathematics. Mathematical innovations, in turn, often proved to have completely *new* applications. Below are two examples; for two more, see *Accounting* (p. 12) and *Musical Scales* (p. 19).

Calendars

Civilized societies found it useful to date their records; when a court made a decision, when taxes were due, or how many days' wages or rent someone was owed were very practical questions. People measured the passage of time both by the moon's going from full to new to full again, and by the yearly cycle of solstices and equinoxes. A year isn't an even multiple of a lunar month, though – and *neither* is an even number of days! Many early calendars had "years" that were an even number of months and therefore didn't match the turn of the seasons. As time passed, the fit between the two would get steadily worse; e.g., the annual harvest festival might end up in the middle of winter.

At TL2, societies can use Mathematics (Applied) and Astronomy to come up with a calendar that's a fairly close fit to the year's true length. An example is the Julian calendar, which took centuries to drift 11 days. The Gregorian calendar, at TL4, is a near-exact fit.

Statistics

Statistics emerged at TL4, when John Graunt and William Petty collected records on ages and causes of death for London residents from 1604 through 1661. The first life-insurance company, founded in 1699, used this information to calculate profitable prices for insurance policies, based on life expectancies. Governments were quick to see the utility of systematically collected information; Charles II recommended Graunt for membership in the Royal Society (p. 33), despite his being a draper rather than a nobleman or a professional scholar. Indeed, the term "statistics" originally meant "the study of conditions within a *state*."

Statistical information can be used to guide political or economic decisions. A suitably detailed statistical study can grant +TL/2 (round down) to a roll against Administration, Finance, Politics, Propaganda, or similar skill dealing with large populations. A successful Research roll for an appropriate archive may identify an existing study that provides relevant information, giving +1.

Astronomy emerged at roughly the same time as mathematics. Both the Maya and the Babylonians, for example, kept detailed records of the movement of the planets through the sky, and developed numerical methods for predicting where they would be in the future, and for forecasting eclipses and other celestial events. See *Calendars* (above) for applications of this kind of calculation. Purely observational astronomy goes back to TL0.

At TL2, the ancient Greeks developed two rival visions of the solar system: the *Ptolemaic* or *geocentric* model, in which the planets (including the sun and moon) revolved around the earth, and the *Hipparchean* or *heliocentric* model, in which the earth and other planets (not including the moon) revolved around the sun. The Ptolemaic picture won out, and remained dominant throughout TL3. Cumulative observations showed that the planets didn't just circle the earth steadily, though; Mercury and Venus always stayed close to the sun, and all the planets other than the sun and moon sometimes appeared to move backward rather than forward. This led to a model in which planetary motion was the sum of big circles around the earth and smaller circles, called *epicycles*, around points on those big circles. Medieval astronomers elaborated on Ptolemy's approach with steadily more complicated systems of epicycles.

In 1512 (early TL4), Polish astronomer Nicolaus Copernicus (1473-1543) revived the heliocentric theory. Later astronomers – including Johannes Kepler, Galileo Galilei, and Isaac Newton – developed it further, giving rise to modern science.

The development of the telescope at TL4 was equally important to the rise of modern astronomy. Tycho Brahe (1546-1601) was the last great naked-eye astronomer, achieving 10 times the accuracy of ancient astronomers (1 minute of arc versus the previous limit of 10 minutes of arc). Ironically, he never accepted the heliocentric theory. The Keplerian telescope made possible extremely precise angular measurements, by placing a micrometer – with two parallel edges whose separation was controlled by a screw – at the focal point between the two lenses. At TL4, angles as small as 1 second of arc can be measured. For details on telescopes, see *Observational Astronomy* (pp. 21-23).

Computational Mathematics

Counting and doing arithmetic don't normally require special skills; these abilities are included in IQ for individuals without the Innumerate disadvantage (p. B140). Complex arithmetic, however, may benefit from or *require* advanced skills. Such *computational skills* include Accounting, Mathematics (Applied), and Mathematics (Statistics); the GM is welcome to extend the list. Among other uses, these skills let one operate calculating devices. At a given TL, each device is a different familiarity (see p. B169). Calculation *without* mechanical aid is also a familiarity, and the first one everybody learns in low-tech societies.

In most campaigns, doing arithmetic is rarely dramatic enough to roll dice for. Still, the GM may want to know *how long* it takes to "do the math." Defining dice rolls for simple computation can help with this. Naturally, if the GM wants to check whether, say, an accountant figures the wrong tax payment, he can actually have players roll the dice.

To determine the time required for a calculation, assume that an effective skill of 16 is good enough that one can disregard the chance of failure. If the arithmetician's modified skill is at least that high, he can solve the problem in the task's base time. If it's lower, figure out how big a skill bonus he needs and apply the corresponding multiplier for extra time (see *Time Spent*, p. B346) to the base time to find the actual time required.

Example: Base time to match a flock of sheep against a tally is one second per sheep. The bailiff of an estate has effective skill 15 for this task. To get +1, he must take twice as long, or *two* seconds per sheep. For a flock of 120 sheep, he needs 240 seconds, or 4 minutes.

Base times and skill rolls for various mathematical tasks are as follows:

Counting or Tallying: Base time is one second per item. Roll IQ+4 regardless of notational system.

Simple Arithmetic (includes addition or subtraction that you could do on your fingers, and doubling or halving): Base time is one second. Roll IQ+4 for written arithmetic with either nonpositional or positional numerals; roll IQ+2 for mental arithmetic. Taking extra time often involves counting on your fingers.

Complex Arithmetic: Base time is 15 seconds. If using nonpositional numerals, roll against a computational skill or the default of IQ-6. With positional numerals, roll vs. the better of unmodified IQ or a computational skill at +6. Mental arithmetic gives an extra -4. Taking extra time involves setting up the steps of the problem carefully, going through them repeatedly, and/or working the problem backward to check the answer. For a discussion of nonpositional vs. positional numerals, see ***GURPS Low-Tech.***

Using an abacus *requires* a computational skill. Roll at +10 for simple arithmetic or at +8 for complex arithmetic. A pebble abacus reduces these bonuses to +7 and +5, respectively. A mechanical calculator requires *no* skill roll for simple arithmetic, but calls for a computational skill roll at +8 to set up a complex problem.

Mechanical Calculators (TL4)

Several TL4 inventors worked on mechanical devices that could perform arithmetic, rather than simply being tools for human arithmeticians. None of these gadgets actually entered common use, however. Operating them requires a computational skill *and* familiarity with the type of machine.

At the GM's option, low-tech calculators have Malf. numbers. If this number comes up, the machine has jammed in some way and must be cleared to get it working again. Use the TL-based values given for firearms on p. B407. Higher-quality calculators can have +1 to Malf. for +0.25 CF, or +2 to Malf. for +1.25 CF. Below, the stepped reckoner has Malf. 14, while the pascaline has Malf. 16 – that is, +2 to Malf. – which is already reflected in its price.

Pascaline (TL4). Invented by Blaise Pascal, the mathematician who created probability theory, the pascaline is *literally* an adding machine: a one-function calculator that can only add. An internal mechanism like that in an odometer enables it to carry digits. It's designed for keeping accounts in French currency, with six dials for *livres,* a dial for *sous* (1/20 livre), and a dial for *deniers* (1/240 livre). A skilled user can work out tricks for subtracting, multiplying, and dividing. It's housed in an elegantly carved rectangular wooden box (14"×5"×3"). Available in 1653; Pascal made 50 of them. $1,300, 5 lbs.

Stepped Reckoner (TL4). Inspired by the pascaline, the stepped reckoner was the invention of Gottfried Wilhelm Leibniz, Newton's rival as the inventor of calculus. Leibniz designed it in 1674 and actually had one built in 1694. Unlike the pascaline, it can both add and subtract; a skilled operator can multiply and divide. The user can input eight-digit numbers, but internal registers can store and display 16-digit numbers as products of multiplication, or even divide such numbers by up to eight-digit numbers. Unfortunately, it has a design flaw – in the terms used on p. B474, a minor bug – that produces errors in carrying when it's used to multiply. This problem can be found by testing it; roll vs. Mathematics (Applied) at -3. The GM could introduce a perfected model as a TL(4+1) device! It's housed in a metal box (26"×8"×6"). $800, 60 lbs.

Arithmetic the Hard Way

In societies that used nonpositional numerals, part of training in computational skills involved learning workarounds to reduce a complex problem to a series of simple ones.

For example, a trick first invented in ancient Egypt used a combination of adding, doubling, and halving to avoid more-complicated multiplication. Suppose Roman clerk Abacus Maximus needs to multiply XXXVII (37) by XLIX (49). He writes these numbers at the top of his tablet. Then in two columns, he repeatedly doubles one, halves the other, and puts a mark beside each odd number in the second column:

XXXVII	XLIX	•
LXXIV	XXIV	
CXLVIII	XII	
CCXCVI	VI	
DXCII	III	•
MCLXXXIV	I	•

Finally, he adds up the numbers in the first column for each row that has a mark at the end: XXXVII plus DXCII plus MCLXXXIV gives MDCCCXIII (1,813), the same result that an abacus or an adding machine would give. The method is slow and complicated (it's equivalent to translating both numbers into binary!), but the individual steps are easier than actual multiplication.

Observational Astronomy

At TL0-3, astronomy relies on the unaided human eye. Celestial objects are so big and so distant that it's inconvenient to use the *Size and Speed/Range Table* (p. B550) to describe them. It's certainly possible to equate an apparent angular width to a range modifier; e.g., the sun is half a degree wide, equivalent to a two-yard-tall man 230 yards away, or roughly a -13 range modifier. Obviously, though, no one has to make a Vision roll to see the sun, or even the moon, which is the same apparent size. And the planets and stars look like single points of light – but they, too, are readily visible.

The big question for low-tech astronomers isn't whether they can *see* a heavenly body but whether they can *measure its position.* Astronomical calculations – from Babylonian priests predicting eclipses to Newton discovering the law of gravity – are based on such data. Astronomy's progress depends largely on the increasing accuracy of angular measurements.

At TL4, the telescope makes it possible to magnify objects' apparent angular width – for instance, the planets now appear as discs of measurable width – thereby permitting better measurement of their positions. For observations of the planets, the telescope also allows making out visible features, such as Saturn's rings. And its increased light-gathering power brings fainter stars into view . . . although stars *still* appear as single points of light!

Astronomers who *did* manage to measure the positions of heavenly bodies recorded the data on star maps (TL1) and celestial globes (TL2). An important astronomical device, the astrolabe (see ***GURPS Low-Tech***), incorporates a star map.

Standing Stones (TL0)

According to some theories, these were the original astronomical observatories (see *Stonehenge,* p. 30). An observer standing at a fixed point can watch between two pillars for the rising of the sun or other heavenly body. This doesn't increase accuracy, but the body's position is predetermined when the stones are set up – the builder rolls against Astronomy at that time, with success indicating that all measurements from then on will be correct. If the body is the sun, then the day when it appears can be used as a calendric reference (see *Calendars,* p. 20).

Camera Obscura (TL1)

The *camera obscura* (Latin for "darkened room") is the simplest optical device ever invented, with neither lenses nor mirrors: a room with a hole placed to let in the light of the sky, which shines onto the opposite wall, forming an inverted image. Applications include observing solar eclipses without damaging the eyes. As well, an astronomer can use a specific mark on the wall as a reference for a heavenly body's attaining a precalculated position, in the same way as for standing stones.

In Renaissance Europe (TL4), artists began to use the camera obscura as an aid to drawing. Giambattista della Porta described this application in 1570.

Observatories (TL2)

Both ancient astronomers and medieval Muslim ones used instruments for angular measurement, such as the astrolabe and the quadrant (see ***GURPS Low-Tech***). At TL3, some of these were extremely large; for example, the 118' sextant in Samarkand (see *The Observatory of Samarkand,* p. 31). Apparatus of this kind could measure position to the nearest 10 minutes of arc. The early TL4 astronomer Tycho Brahe, funded by the king of Denmark, achieved measurement to the nearest 1 minute of arc, very close to the limit of the unaided human eye.

Orreries (TL2)

An *orrery* is a mechanism that uses a system of gears to simulate the movements of celestial bodies. The name comes from the fourth Earl of Orrery, for whom the first modern orrery was made in 1713. The term has also been applied to ancient Greek machines that worked similarly (see *The Antikythera Mechanism,* above). Actively using such an apparatus – e.g., to make predictions – requires Astronomy or Navigation skill.

A hand-cranked orrery that shows the sun, the moon, and the planets from Mercury to Saturn: $750, 12 lbs. A simplified model that shows only the sun, earth, and moon: $300, 10 lbs. Adding clockwork to power either device: +$150, +10 lbs.

The Antikythera Mechanism

Found in a sunken ship near Crete by sponge divers in 1900, the Antikythera mechanism baffled archaeologists for half a century. Starting in 1951, advanced scientific imaging methods such as X-rays were used to reconstruct its complex internal workings and – after another half a century – to build modern copies. Powered by turning a handle, it displayed the motions of the sun and moon in relation to the signs of the zodiac. Within were 39 bronze gears, making it the ancient world's most complex device. It appears to have been made in the first or second century B.C., possibly on the island of Rhodes; a native of Rhodes, Posidonius, is recorded to have built an apparatus that could track the motions of the planets as well as the sun and moon.

Telescopes (TL4)

Telescopes were the great astronomical innovation of TL4. Astronomical telescopes have two basic forms: *refracting* and *reflecting.* The refracting telescope is essentially a more powerful spyglass (see ***GURPS Low-Tech***). Galileo built one in 1609 and made discoveries that revolutionized astronomy, including Saturn's rings, Jupiter's moons, and the phases of Venus. Kepler developed a more advanced version better suited to astronomy specifically.

Reflecting telescopes use mirrors instead of lenses: a large curved mirror gathers light from a wide area and focuses it onto a smaller mirror that directs it to an eyepiece. Isaac Newton built the first one in 1668. At TL4, telescope mirrors are made not of glass but of *speculum metal* (described under *Glass* in ***GURPS Low-Tech***).

Astronomical telescopes are used to view a single celestial object at a time. For bodies within the solar system, they provide an enlarged image. Stars are so far away that they still appear as points – but the telescope collects more light, revealing stars that unaided human eyes can't see.

Locating the desired object requires either orbital calculations (roll vs. Astronomy) or scanning the heavens (a Vision roll on a clear night; bad weather gives penalties). For scanning, apply modifiers for the telescope's Bulk – which can be offset by taking extra time to maneuver it (p. B346) – and for its optical quality, but *not* for its magnification; celestial objects are too far away for range calculations to make sense. After acquiring the object, perform an Aim maneuver to observe it closely; make a Vision-based Astronomy roll, modified by optical quality. It's up to the GM what magnifications are needed to observe various objects.

The telescopes here are small, portable models. Observatories may have instruments many times larger, with correspondingly greater magnification.

Galilean Telescope: A refracting telescope with 32× magnification. Vision and skill rolls are at -2 from chromatic and spherical aberration. Bulk -4. $250, 8 lbs.

Keplerian Telescope: A more advanced refracting telescope with a convex eyepiece lens placed behind the focal point. Suffers from chromatic and spherical aberration, but the image in the eyepiece is enlarged (+1 to Vision and skill rolls), for a net quality of -1. Adding a set of crosshairs between the two lenses allows measurement of position to the nearest 1 second of arc. Magnification is 125×. Bulk -4. $500, 8 lbs.

Newtonian Telescope: An early reflecting telescope, with the eyepiece mounted at the side. Vision and skill rolls are at -1 from spherical aberration. Magnification is 40×. Bulk -1. $375, 3 lbs.

Cassegrain Telescope: A more advanced reflecting telescope, invented by the French physician it's named for. The small mirror at the focal point directs the image straight down to a hole in the center of the main mirror, and is curved to eliminate penalties for spherical aberration. Magnification is 250×. Bulk -4. $750, 10 lbs.

Telescope Mount: A device for steadying a telescope, so that its aim can be maintained without effort. Must be on a level surface. $50, 5 lbs.

From Alchemy to Chemistry

Chemistry's beginnings were thoroughly practical: on one hand, methods for extracting useful substances from plant and animal tissues; on the other, metallurgical techniques, especially for converting ores into metals. Such processes go back at least to TL1. There was almost no theory to guide them. In particular, the difference between a physical process that changed a substance's form or mixed substances together, and a chemical one that actually changed substances into other substances, wasn't clearly understood. Applied chemistry of this kind takes the form of practical skills such as Metallurgy, Pharmacy (Herbal), and Poisons.

Early experiments in turning one material into another – starting at late TL2 – gave rise to the practice of alchemy at TL3 in Europe, the Near East, and China. Alchemists developed elaborate theories of what they were doing, based partly on mythology and partly on philosophical speculations; they seemed to believe that anything could be turned into anything else, if the alchemist found the right methods and applied them in the correct order. In Europe, the classic example was the idea of transforming base metals into gold. This was mixed up with the idea that alchemy was a *spiritual* discipline that purified the alchemist, making him fit to perform seemingly miraculous transmutations; every external chemical operation had a corresponding inward spiritual process. In ***GURPS*** terms, alchemy might be described as Disciplines of Faith!

At the same time, alchemists took the first steps toward scientific knowledge by observing and classifying what actually happened in their laboratories. For example, European alchemy distinguished 12 processes:

calcination: Heating minerals in flame in the air.
congelation: Cooling and thickening liquids.
fixation: Turning a vapor into a solid or a liquid.
solution: Dissolving a solid.
digestion: Warming a substance without boiling it.
distillation: Turning a liquid into a vapor.
sublimation: Turning a solid into a vapor.
separation: Dividing a mixture into its pure constituents.
ceration: Softening a hard material, as by warming wax.
fermentation: Inducing the release of gas bubbles in a liquid; inducing the conversion of sugars or starches to alcohol.
multiplication: Strengthening the potency of the Philosopher's Stone.
projection: Applying the power of the Philosopher's Stone to other substances.

This combination of practical techniques with imaginary magical processes was typical of alchemy. A realistic practicing alchemist is skilled in Chemistry at his TL; in Expert Skill (Natural Philosophy) and/or Occultism; and possibly in Fast-Talk or Sleight of Hand. He might also know the Alchemy skill – but only in a world with chi, magic, or other mystical forces. As noted in ***GURPS Low-Tech,*** Chemistry is at -3 for analytical and synthetic use before TL5, because it lacks a well-founded theoretical basis.

Alchemical experiments developed a variety of new substances: *aqua fortis* (nitric acid), *aqua regia* (a mixture of nitric and hydrochloric acid, able to dissolve gold), *aqua vita* (ethanol), and *oil of vitriol* (sulfuric acid), among others. As the names suggest, most of these were thought of as modified forms of water, able to dissolve other materials more effectively than water could. Similar purification methods could be used to produce sulfur and saltpeter, two of the ingredients of gunpowder. As these substances were identified, alchemists evolved an elaborate shorthand where every material had its own distinctive symbol.

Archaic Chemical Terms

alkahest: A universal solvent, as imagined by alchemists.
avolation: Evaporation.
brimstone: Sulfur.
calcined: Heated to form a *calx,* or white powder.
crocus: A metallic oxide, often with a planetary name indicating the metal. Iron oxide, for example, is *crocus of Mars,* while lead oxide is *crocus of Saturn.*
elixation: Boiling.
exsiccation: Drying.
natron: Naturally occurring deposits of mixed salt and bicarbonate.
scorification: Producing slag.
spirit: Anything derived by distillation. Alcohol is *spirit of wine,* ammonia is *spirit of hartshorn,* and hydrochloric acid is *spirit of salt.*
vitriol: A sulfate ore. Copper sulfate was *blue vitriol,* while iron sulfate was *green vitriol.* They were processed to produce *oil of vitriol,* or sulfuric acid.

Geber (the Latin name for Abu Musa Jabir ibn Haiyan al-Azdl, 721-815), a native of Persia, brought systematic experimentation into alchemy and attempted a rational classification of substances; his discoveries included aqua regia and the various strong inorganic acids. The German physician Paracelsus (Philippus Aureolus Theophrastus Bombastus von Hohenheim, 1493-1541) pioneered the use of inorganic materials – such as antimony, arsenic, and mercury – in medicine, using various acids to reduce their toxicity and enhance their medicinal effects. This became the basis of TL4 medicine (for rules, see ***GURPS Low-Tech***). Paracelsus also founded scientific toxicology, stating the principle that every chemical could be toxic in large enough doses, and harmless or even beneficial in smaller doses. Followers of Paracelsus distinguished acids from alkalis (such as bile), and later recognized that combining the two produced salts. The British chemist Robert Boyle (1627-1691) proposed the first systematic test for acidity or alkalinity, reporting that acids turned syrup of violets red and alkalis turned it green.

These insights led to the first scientific theory of chemistry, the *phlogiston* theory of Georg Ernst Stahl (1660-1734). Phlogiston was effectively the "element" of fire, as described by the ancient Greeks, under a new name. Burning a fuel was thought of as forcing it to give off its phlogiston content, leaving behind ash. Heating a metal ore in a fuel such as charcoal, producing the metal, was described as making the "earth" of the ore absorb phlogiston. Similarly, heating phosphoric or sulfuric acid with charcoal produced phosphorus (discovered in 1669 by distilling urine) or sulfur.

The phlogiston theory was the basis of TL4 and early TL5 chemistry. It was finally rejected because work with balances showed that metals weighed less than the ores that produced them, suggesting that phlogiston had negative weight, which chemists thought unbelievable. The identification of oxygen as an element, and the redefinition of combustion as oxidation rather than as giving off phlogiston, was the point where mature TL5 chemistry emerged.

Phlogiston theory is part of Expert Skill (Natural Philosophy). The associated laboratory methods are Chemistry/TL4 – still with the -3 for analytical and synthetic applications.

Medicine

The rules for medical treatment in the ***Basic Set*** provide a quickly played version of the process – and, for low-tech societies, a somewhat optimistic one. The material below is for players who prefer more detail and realism. *Everything* here is optional!

Hospitals

Hospitals were associated with temples as early as TL1 – a tradition that continued into TL4. Christian monks and nuns often cared for the sick, and a good-sized monastery or abbey often had beds for patients. Similar facilities were attached to mosques. Large scholastic communities might both teach medicine and operate hospitals for the sick, as at TL2 Alexandria (p. 31) and TL3 Salerno (see *The Birth of the University,* pp. 31-32). The Roman legions built infirmaries in their camps and forts, as part of their effort to keep soldiers healthy and fit for duty. Some arenas provided similar facilities to keep valuable gladiators alive.

Running an organized hospital requires the Administration skill. Roll monthly. Any success means the hospital provides +1 (quality) to the skill of all medical practitioners working there. This is *instead* of the standard supervision bonus to long tasks (p. B346). With this bonus, any practitioner with basic skill 11+ at Physician – or, under low-tech conditions, Esoteric Medicine or Pharmacy (Herbal) – counts as a competent physician, able to give +1 to rolls for natural recovery; see *Medical Care* (p. B424). In addition, the hospital environment itself counts as good conditions for natural recovery, granting a separate bonus of +1.

Surgery: Optional Rules

In a realistic historical campaign, the GM may want to play out the grim details of low-tech surgery.

Surgery and Pain

It's difficult for a patient to hold still during surgery performed without anesthesia. His movement penalizes the healer's Surgery skill: no modifier if the subject remains completely still, -1 for small involuntary motions, -3 if he's held down by force, or -6 if he moves violently. This is *over and above* the general -2 for surgery without anesthesia (see ***GURPS Low-Tech***).

Castration

Male domesticated animals are often aggressive and hard to control. At TL0, they're normally slaughtered young. When animal traction comes into use at TL1, though, their greater size and strength become useful. This leads to the widespread practice of castration (surgical removal of the gonads). The procedure is used only with males; a fertile female's offspring are an economic asset.

The same practice is also applied to human slaves at TL1-4. A castrated man, or *eunuch,* can be assigned to guard a harem without fear of his impregnating the women he guards. The procedure is sometimes used for other purposes, such as preserving a boy's soprano voice into adulthood; for centuries, the Vatican had a choir of eunuchs. A eunuch has the quirk Neutered or Sexless (p. B165) and usually, as a slave, suffers from Social Stigma (Valuable Property). A free eunuch instead has Social Stigma (Second-Class Citizen).

In terms of the optional surgery rules, castration is *minor* surgery. It requires a roll against Surgery (for humans) or Veterinary (for animals). It can be improved separately as a Hard technique.

Wondrous Cures

Religion and superstition often come with the expectation that faith can solve medical problems.

Charms and Amulets

People have used magical healing charms since time immemorial. Ancient Roman medical texts were often dubious about whether such amulets had any actual power. Yet they encouraged physicians to tolerate them, because the patient's faith might itself help cure him.

Exorcism

Some cultures attribute illness to demonic possession. In settings where this is true, a successful exorcism will cast out the disease spirits, curing the patient! In other backgrounds, the GM might still let exorcists roll – once again, because the patient's own faith might help cure him.

Healing Shrines and Pilgrimages

Most religions have holy sites, which the sick might visit in hope of a cure. Conversely, if someone visits a place and recovers from sickness or disability, his good fortune may be taken as a sign of natural holiness. Some healing shrines have steady streams of visitors, and develop temples and guesthouses to provide for their needs.

In ancient Greece, temples of the physician god Asklepios, son of Apollo, were built on the sites of springs reputed to have healing powers, such as on the Acropolis in Athens, on the island of Kos, and at Epidauros, Lebena, Pergamon, and Trikka. Pilgrims fasted, sacrificed, bathed in the waters, and then slept within the temple, hoping for dreams that would show them how to be cured. In Roman Britain, the settlement of Aquae Sulis (now Bath) was a destination for pilgrims. In India, the entire Ganges River is considered sacred, and the city of Varanasi (formerly Benares), located on its banks, is filled with shrines and temples. Medieval Christianity and Islam had similar beliefs.

Effects

The effects of such cures are similar to those of placebos, but stronger – normal HT and medical skill rolls *already* include any benefits from ordinary placebos. The GM could fairly allow a charm or sufficient time at a holy site to grant +2 to HT rolls for long-term resistance or recovery to patients who have True Faith or observe Disciplines of Faith. Believers who faithfully uphold a suitable Vow might get +1.

Alternatively, benefits may depend on a Religious Ritual roll aimed at blessing the charm, curing the patient, etc. For an exorcism, this would become a Quick Contest: Religious Ritual or (non-supernatural) Exorcism vs. the subject's Will. Success (victory) might grant +1 to believers – maybe even to *nonbelievers,* on a critical success!

The patient must make a Will roll to hold still.

Modifiers: -2 for surgery on the torso, or -4 on the head, hands, or groin; +3 if the patient has High Pain Threshold or -4 if he has Low Pain Threshold; +1 if he's tipsy, +2 if drunk, hypnotized, or drugged with sedatives such as opium, or +5 if unconscious.

Success by 4+ allows the patient to remain completely still. Success by 0-3 limits his movement to small involuntary motions. Any failure means he moves violently unless held down.

Treat holding the patient still after a failed Will roll as a Quick Contest of ST. Up to three assistants may hold onto the patient. Use the ST of the strongest plus 1/5 the total ST of the others (round down).

Surgery and Damage

Because surgery is performed in great haste – to minimize the patient's suffering – it *always* inflicts injury: 1d HP for minor surgery, such as dental extractions or cutting for the stone; 2d HP for amputation at the elbow or knee (or lower); or 3d HP for amputation above the elbow or knee, or for internal surgery. A successful Surgery roll means one of the dice counts as an automatic 1; critical success reduces injury to just a point per die. Failure inflicts normal injury; on a critical failure, roll injury normally and double it.

In addition, apply the optional bleeding rules (p. B420) after any amputation or any surgical procedure that inflicts substantial injury. After very minor surgery, such as circumcision, a *failed* Surgery roll causes bleeding.

Bonesetting

Setting broken bones is a noninvasive procedure. Such treatments normally require a roll against Physician rather than Surgery, but Physician is unavailable in many pre-TL5 societies – and even in societies where it *does* exist, many battlefield practitioners are trained as surgeons but not as physicians. In backgrounds like these, a cruder set of methods (briefly discussed in ***GURPS Bio-Tech***) constitute a secondary, noninvasive application of Surgery. The optional specialty of trauma surgery includes these.

As noted in ***GURPS Low-Tech,*** bonesetting can be improved as a Hard technique. For added realism, the GM may require specialization by hit location. At TL0-4, it's available only for limbs and for broken noses.

A lasting crippling injury (p. B422) to a limb or an extremity caused by crushing or cutting damage is likely to involve a broken bone (GM's option). Setting a broken bone can be described by a variant on *Repairing Lasting Crippling Injuries* (p. B424). It's a noninvasive procedure that takes only 15 to 30 minutes – but success does *not* reduce recovery time to weeks. Roll against Surgery, including any relevant equipment modifiers. Any failure results in permanent crippling, and a critical success is needed to avoid cosmetic disfigurement. Setting the bone is *painful;* the patient will suffer agony (p. B428).

Herbal Pharmacy: Sample Herb List

GURPS Low-Tech describes general categories of medicinal herbs. Each culture will have its own list of specific plants with recognized effects. Here's a sample list of herbal cures available in medieval Europe. Rules for most of the indicated uses appear in ***Low-Tech;*** for spermicides and abortifacients, see *Contraception* (p. 27) and *Abortion* (p. 27), respectively.

Herb	*Uses*
Agrimony	Astringent, Vulnerary
Aloe Vera	Cathartic, Vulnerary (especially vs. burns)
Arnica	Anti-inflammatory (vs. arthritis)
Balm	Astringent, Calmative, Carminative
Broom	Emetic
Buckthorn	Cathartic
Calendula	Vulnerary
Catnip	Calmative
Chamomile	Carminative
Cinnamon	Cathartic, Purgative
Comfrey	Vulnerary
Dandelion	Cholagogue
Fennel	Carminative, Expectorant, Tonic (women's)
Feverfew	Analgesic (vs. headaches), Febrifuge
Foxglove	Aquaretic, Tonic (vs. heart disease)
Garlic	Tonic (general), Vermifuge, Vulnerary
Gentian	Cholagogue
Goldenrod	Aquaretic
Hemp	Analgesic, Antiemetic, Tonic (women's)
Hops	Calmative
Horehound	Cholagogue, Expectorant
Horse Chestnut	Anti-inflammatory
Hyssop	Expectorant
Juniper	Abortifacient, Aquaretic, Spermicide
Lovage	Aquaretic, Calmative
Mallow	Demulcent
Meadowsweet	Analgesic, Febrifuge
Mustard	Rubefacient
Oak (bark)	Astringent
Pennyroyal	Abortifacient
Peppermint	Carminative, Cholagogue, Expectorant
Pomegranate	Spermicide
Poppy	Sedative
Raspberry	Tonic (women's)
Rue	Abortifacient, Sedative, Vermifuge, Vulnerary
Sage	Astringent
Senna	Cathartic, Purgative
Shepherd's Purse	Coagulant
Silphium	See *Contraception* (p. 27)
Spearmint	Spermicide
St. John's Wort	Calmative, Sedative, Vulnerary
Tansy	Abortifacient, Vermifuge
Thyme	Expectorant
Valerian	Calmative, Sedative
Vitex	Tonic (women's)
Wild Carrot	Spermicide
Willow	Analgesic (vs. headaches), Anti-inflammatory, Febrifuge
Wintergreen	Rubefacient
Wormwood	Vermifuge
Yarrow	Cholagogue, Vulnerary

Glossary: Pharmaceuticals

For *game effects* for most of these drugs, see ***GURPS Low-Tech.***

abortifacient: Causes a toxic reaction that induces labor; see *Abortion* (p. 27). In addition to herbs, small doses of *cantharides* (described in ***Low-Tech***) can be used this way.

analgesic: Diminishes pain by decreasing the sufferer's sensitivity to it. *Local* analgesics suppress the sensory receptors for pain. *Central* analgesics decrease the brain's response to pain.

antiemetic: Counteracts nausea and prevents vomiting.

anti-inflammatory: Decreases inflammation of the muscles and joints.

aquaretic: Promotes urination, helping to flush out bladder infections, and preventing the recurrence of kidney stones.

astringent: Counteracts inflammation of the skin and suppresses itching.

calmative: Diminishes anxiety or excitement, and encourages sleep.

carminative: Lessens abdominal pain from gas.

cathartic/purgative: Speeds the passage of food through the digestive system, leading to rapid and/or voluminous excretion.

cholagogue: Enhances the secretion of bile.

coagulant: Helps stop bleeding.

demulcent: Soothes throat pain from respiratory infections and prevents coughing.

emetic: Promotes vomiting.

expectorant: Promotes the flow of nasal phlegm.

febrifuge: Reduces the severity of a fever.

rubefacient: Produces a mild inflammation that counteracts muscle pain when applied to the skin.

sedative: Suppresses overall central nervous system activity.

spermicide: Lessens the chance that sexual activity will lead to pregnancy; see *Contraception* (p. 27).

tonic: Term for two distinct categories of substances: (a) *general* tonics promote overall health and fitness; (b) *women's* tonics stabilize female hormonal cycles.

vermifuge: Promotes the expulsion of worms from the digestive system.

vulnerary: Applied externally to a wound to aid healing and resist infection.

Neglect of an effective birth control policy is a never-failing source of poverty which, in turn, is the parent of revolution and crime.

– Aristotle, ***Politics***

Reproductive Medicine

Human childbirth is stressful and risky. Most births can be managed with noninvasive procedures performed by any physician or midwife, but emergencies call for surgical intervention. Some women – including those who lead lives of adventure – may attempt to avoid these difficulties through contraception or abortion.

Childbirth

Giving birth involves two stages:

Early Labor: The mother is in moderate pain (p. B428). As well, make a HT+1 roll for her, at +TL if she's attended by a midwife or other trained medical practitioner. Success costs her 1d FP. Critical success *halves* this (round down); any failure *doubles* it.

Late Labor: The mother is in terrible pain (p. B428). In addition, roll again as noted for early labor – but if the earlier roll was a critical failure, then this one is at -5. Success means the mother loses 2d FP. Critical success *halves* this (round down); any failure *doubles* it. On a critical failure, the mother also suffers from bleeding (see *Bleeding,* p. B420). Stopping this bleeding requires a roll against Professional Skill (Midwife) or any medical skill that includes obstetrics, but *not* First Aid.

If the cumulative FP loss exceeds the mother's FP, apply the excess to her HP. If she suffers injury from the birth due to this effect and/or bleeding, then the baby suffers the same number of HP of injury.

An attending physician or midwife may be able to prevent injury from a difficult birth. Roll against Professional Skill (Midwife) or a suitable medical skill. Success prevents injury to *either* mother *or* infant – the practitioner must choose. Critical success helps both mother *and* infant. Failure gives no help. Critical failure *doubles* the injury from the birth.

A *Caesarean section* opens the uterus to remove the unborn infant. At TL0-4 the mother won't survive; thus, this is normally done only when she's clearly dying.

Contraception

A sexually active woman must roll 3d for pregnancy each month unless she's *already* pregnant. If she takes no special countermeasures, she becomes pregnant on a 6 or less. Contraceptive techniques can lower this target number. If using two different methods simultaneously, start with the reduction for the more-reliable method on its own and apply a *further* -1.

Nonprocreative Sexual Acts (TL0). Engaging in such acts exclusively eliminates all risk of pregnancy. Knowledge of these may be commonplace, rare, or even *illegal,* depending on cultural attitudes. If they aren't commonplace, roll against IQ or IQ-based Erotic Art to invent them – or make Research rolls to find information, with a penalty equal to CR if they're illegal.

Herbal Contraception (TL0). Most of these methods involve direct application of spermicides. Roll against Pharmacy (Herbal) to prepare them properly. Success gives -1 to the target number but costs 1 FP; double or triple doses multiply both penalty and FP cost by 2 or 3, respectively. The herb *silphium,* taken orally, has *no* FP cost; thus, it can be used safely at maximum doses for -3.

Barrier Methods (TL1). The *cervical cap* (TL1) and *condom* (TL4) give -1 to the chance of pregnancy. Versions of the cervical cap include a coating of honey in ancient Egypt, oiled silk paper in East Asia, and a scooped-out lemon half in Renaissance Europe. Condoms were first described in the 1400s by anatomist Gabriele Fallopio; they were originally made of thin, chemically treated linen, but other materials include animal intestines and oiled silk paper (again, in East Asia).

Abortion

A woman who becomes pregnant may resort to abortion. Under low-tech conditions, this is always risky, regardless of method. It may also be illegal or religiously prohibited.

Induced Labor (TL0)

A variety of interventions can start labor early, often resulting in miscarriage. Early in pregnancy, delivery is less difficult than for normal birth; use the rules under *Childbirth* (above), but the roll for early labor is at +5 in the first trimester (and the pain is one level less), +3 in the second, or +1 in the third.

Physical Strain (TL0). Strenuous physical activity (anything that leaves the woman with less than 1/3 of her FP), or a fall or knockback of 2+ yards, can induce labor. A pregnant woman caught in a fight or an accident may suffer this outcome involuntarily! Inducing labor in this way isn't reliable; on a roll vs. HT+4 for exercise, or HT for a fall, the pregnancy continues.

Abortifacients (TL0). These are herbal or other toxins that induce labor. Roll against Pharmacy (Herbal) to administer them. Any success results in miscarriage. Critical success means there are no toxic effects; ordinary success or failure inflicts 1 HP of toxic injury; and critical failure costs 1d+1 HP.

Massage Abortion (TL3). Developed in Cambodia by 1150, this requires a Regular Contest of Professional Skill (Midwife) against the pregnant woman's HT+2 to induce labor.

Surgical Abortion (TL2)

Treat this as minor surgery. Success removes the fetus without labor. Critical failure causes internal bleeding, and a roll to avoid infection is always required. Many medical practitioners have a Code of Honor that prohibits abortion!

Public Health

The rise of urban civilizations at TL1 led to a *decrease* in overall health. Diseases in small populations tend to run their course, infecting the susceptible and then dying off, whereas larger populations can sustain a constant percentage of infected people. Cities created large, dense populations, which acted as disease reservoirs – and close contact with domestic animals there, especially pigs, added another reservoir. Moreover, cities were mostly built on rivers, where diseases thrived. And long-distance trade and warfare enabled diseases to spread to *other* cities, effectively multiplying the population that sustained them.

Another problem with urbanization is that in any large city, rivers and groundwater become contaminated with sewage. People who drink tainted water must make a HT roll at the end of the day. Failure indicates that the victim is stricken with diarrhea (or worse, on a critical failure). Apart from the obvious problems involved, this doubles the daily water requirement and costs 1 FP – or 3 FP, if extra water isn't provided. Those who recover from this illness (see pp. B442-443) have +4 to HT to resist further attacks; a city's adult natives get this bonus automatically. City dwellers often don't drink much water, though, preferring beer or wine – and while they use water in cooking, the high temperatures involved kill many bacteria. Such measures give an additional +2.

At TL2, the ancient Greeks believed that the physical environment had a strong influence on health. For example, they attempted to make sure that their cities had sources of pure water. The improved sanitation that resulted helped mitigate the public-health problems of urban life. Roman sewers also made for a healthier city environment.

The Roman Empire spread such ideas over much of the Mediterranean and Near East. Roman legions examined recruits for general health and tried to maintain that vigor through diet, exercise, and sanitation. The army also trained wound-dressers and surgeons. In peacetime, Roman soldiers outlived civilians by an average of five years.

The Middle Ages developed the practice of *quarantine,* in which households with sick members were required to avoid contact with other households. The name comes from the Italian for "forty," from the Venetian practice of making foreign ships wait that many days before their crews could enter the city. The earliest quarantine laws were adopted in 1348, during the start of the Black Death. However, Persian Muslim physician and philosopher Abu Ali ibn Sina (Avicenna) first proposed the basic idea in 1020. It can be classed as TL3.

Funeral Customs

Funeral observances are a distinctive form of human behavior. Neanderthals buried their dead, and one such burial in Shanidar Cave, Iraq – dated to 60,000 years ago – has pollen from wildflowers next to the skull, which some archaeologists interpret as evidence of a burial ritual. Many aspects of funerals are symbolic. But corpses are also hazardous to health, and funerary customs often help to minimize such hazards.

Cremation sterilizes and destroys a dead body. *Burial* puts it out of direct contact with the living – especially burial in a sealed tomb, or *urn burial* in a large ceramic vase. *Burial at sea* by dropping a weighted corpse into the ocean has the same effect. Viking funerals combined cremation with burial at sea. A rarer method, *excarnation,* puts the cadaver in an exposed place where carrion birds can eat it; Zoroastrians built special towers for this purpose, which kept the body out of contact with the living. Medieval European societies sometimes left dead traitors or criminals exposed in this way (e.g., on a gallows) as a mark of contempt, but burial was the normal practice.

On the other hand, some funeral customs actually increase the health risks of exposure to corpses. The New Guinean disease *kuru,* caused by prions (infectious protein molecules), has been interpreted as a result of ritual cannibalism. The prions are present in the brain tissue of victims, and infect people who consume such matter.

Instruction

Methods of learning new skills are relevant to technology in at least two ways. On one hand, a society's technical sophistication – in game terms, its TL – depends on the tools that its members can actually create, maintain, and use, and therefore on means of educating people in how to do so. On the other hand, technological advances bring new instructional techniques and teaching aids.

Apprenticeship

Apprenticeship is most familiar in its medieval form, practiced in TL3 Western Europe. Similar customs go back at least to TL1, however – whether as formal contracts between a master and an apprentice (or, likely, the apprentice's family), or as informal arrangements, often with a parent or other family member. In TL0 societies, the latter shades into general child-raising.

Apprenticeship is a lot like on-the-job learning, but slower. Apprentices spent much of their working day on housekeeping or on boring, repetitive tasks such as grinding pigments or pumping a bellows, which didn't really teach them the main job skill. On the other hand, they did get *some* actual teaching, if the master was carrying out his contract with their parents.

A good guideline is that each year of apprenticeship grants 1-2 points to spend on job-related skills.

Tutoring

A wealthy man may be able to hire a master to train his son in a skill full-time. This is different from apprenticeship – the son doesn't need to spend any time on work, while the tutor doesn't have to earn a living at a trade and doesn't require the son's services. Alternatively, a father may be able to buy a slave to tutor his children. Such contracts go back to TL1.

This method is used more often for imparting knowledge than for teaching practical skills. Tutors can pass along both memorized information and methods of reasoning or problem-solving. A tutor must have a Teaching skill of at least 12, as well as mastery of one or more subjects or skills.

Tutoring counts as *Education* (p. B293). A full-time tutor can provide up to 1 point of skill in his subject per month. Progress will be slower if he must divide his time among several pupils.

Formalized Drill

Military drill as we know it today is a surprisingly late invention. It developed at TL4, in the army of Dutch general Maurice of Nassau (1567-1625), although he was inspired by ancient Roman books on military subjects. The use of muskets required systematic training, both to ensure that soldiers performed all the complex operations needed to load and fire their weapons, and to make this so habitual that they would keep doing it under fire. (Formal musket drill required a recurring sequence of up to 24 different orders, though multiple steps might be combined under one order in actual combat.) Age of Sail navies developed comparable drills for firing the ship's guns and for handling the sails.

Most skills can't be learned through drill alone – they require flexibility, not merely precision in carrying out stereotyped series of actions. Drill is mainly useful for training in techniques (pp. B229-233). However, it can be applied to a few, mostly DX-based Easy skills, such as Fast-Draw. In this case, handle it as *Education* (p. B293). It definitely requires a professional teacher; for example, the average army sergeant should have Teaching at 12+. For other skills, it's reasonable to have training scenes include drilling in the skill's specific techniques.

Learning From Books

Starting at TL1, books emerge as the most important educational technology. They hugely increase the amount of information that a student can master. This is both because they give access to knowledge from many more people, and because they enable one to learn where to look up a key piece of information instead of memorizing the information itself.

At TL1-3, books are mostly hand-copied and expensive; see *Book Production* (pp. 33-34). Once a student has learned to read and write, however, there's a way around this. The teacher needs to own one copy of the text, while each student needs a blank book, pen, and ink. Over a period of time, the teacher reads the entire book aloud to the class, line by line, slowly and carefully, possibly repeating lines to make sure his pupils get them. The students then write down the lines. After reading each line, the teacher talks about what it means, and answers the class' questions. This practice is the source of traditional academic titles such as "lecturer" or "reader."

At TL3, block printing develops, followed by movable type at TL4. This makes books cheaper; most students can just buy them. As a result, modern-style lecturing – where the teacher doesn't read the book, but presents and discusses its contents – becomes practical.

Writing down a book as a teacher reads and discusses it counts as *Education* (p. B293), if the teacher has sufficient skill. If the teacher has inadequate skill, or simply reads the book aloud without explanation, treat it as *Self-Teaching* (p. B293). After copying the book – or buying a printed one – the student can use his copy for further self-teaching.

Learning Environments

The basis of ancient Greek learning, especially in Athens, was the concept of *paideia.* This referred to the city itself as a form of education. In Greek thought, this included belonging to a group that met regularly for socializing and sophisticated conversation; having a close relationship with an older man who acted as a patron, mentor, and lover (the poet Sappho appears to have had similar relationships with some of the girls at her academy); and engaging in competitive activities to prove one's growing physical and intellectual accomplishments.

Enhanced Memory

In preliterate societies, knowledge is limited to what can be memorized. Even in cultures that *do* have writing, there are situations where people must rely on memory; e.g., Greek and Roman orators were expected to present legal cases without notes. Such environments inspire the development of methods for enhancing human memory.

Poetry and Songs (TL0)

The rhythm of poetry makes the words easier to remember. Poetry set to music works even better – people who've lost the ability to speak because of brain injuries may still be able to sing the lyrics of familiar songs. Poetic devices such as repeated refrains, rhyme, and alliteration give a little extra help. Treat such knowledge as a new Expert Skill (pp. B193-194):

Bardic Lore: A body of *factual* (not *practical*) knowledge in the form of poetry. This isn't fine literature! It's the equivalent of "Thirty days hath September . . .," but for a vast amount of information. It can substitute for Diagnosis, Geography (Regional), History (one's nation or local community), Law, Naturalist, Occultism, or Theology. More generally, use it in place of Research to dig out simple factual information in any field the GM permits.

Artificial Memory (TL2)

Roman treatises on oratory discuss a method for training the memory: The orator practices visualizing a large house with many rooms, until he can imagine moving about it at will. Then he envisions objects that symbolize the things he wants to remember, such as the facts of a legal case, placing them close together in a specific room. When he wants to recall them, he pictures himself in that room. Jesuit priest Matteo Ricci (1552-1610) used this technique to astonish Chinese friends with feats of memory.

Treat this as Eidetic Memory (p. B51) acquired through training, and possibly limited with Preparation Required (p. B114).

Other sorts of learning environment are possible. The Rule of St. Benedict provided medieval Christians with a system of education and a way of life centered on prayer, work, and scholarship.

Living in a paideia counts as *Learning on the Job* (p. B293) without necessarily requiring work. A resident may be supported by Independent Income (p. B26) or by a Patron (often his family). He spends time in the community's activities, and gains skills in whatever activities are highly valued there. If unusually disciplined, he may *also* gain 1 point/year in a personal interest (2 points/year, if a senior resident actively encourages him).

The governess was always getting muddled with her astrolabe, and when she got specially muddled she would take it out of the Wart by rapping his knuckles.

– T.H. White, ***The Sword in the Stone***

Institutions of Knowledge

New knowledge is produced in a scattered way throughout a society, as a byproduct of everyday work and personal curiosity. In some cases, this might be the whole picture – but even low-tech cultures sometimes develop institutions that specialize in collecting, passing on, or applying knowledge, and perhaps even in breaking entirely new ground. The growth of such traditions eventually leads to the emergence of science, which in turn gives rise to high-tech societies. This process begins in the late Stone Age.

Stonehenge

For many centuries, Stonehenge was a mystery. The 12th-century writer Geoffrey of Monmouth believed that Merlin built it using great stones brought from Ireland! In the 18th century, writers linked it to the Druids; in the early 20th, Alfred Watkins connected it with his theories about ley lines. It's certainly the world's best-known megalithic structure (see *Prehistoric Monuments,* pp. 13-14). Construction took place in three phases thought to have lasted from 3100 to 1600 B.C., and may have required 1,000,000 man-days of labor. This wasn't a casual project – especially for a Stone Age culture without cities or writing – but the result of a long-sustained purpose.

In 1963, Gerald Hawkins offered a theory of what that purpose was, based on computer analysis of the stones' positions: an aid to astronomical observation. Hawkins described Stonehenge as a "Neolithic computer," claiming that it could be used to predict astronomical events such as eclipses. Traditional prehistorians resisted this idea; they were reluctant to believe that nonliterate societies could have attained sophisticated mathematical and astronomical knowledge.

More recent scholars have accepted the idea that astronomical observations played a part in prehistoric societies, providing a basis for the timing of rituals, and for orienting structures or processions in specific directions, mainly in relation to the sun. This didn't require high-precision measurements or elaborate calculations. For further discussion, see *Observational Astronomy* (pp. 21-22).

Early Fossil Collectors

The science of paleontology emerged at TL4, when Danish physician Nicholas Steno (1638-1686) proposed his theory of "solid bodies within solids" – meaning, for example, fossilized sharks' teeth found inside rocks. Many scholars believed that they grew inside the stone! In his *Prodromus* (1669), Steno pointed out that the pressure of the stone around such an object would have distorted its growth and shape, and argued that the rock must have taken form around the tooth.

Certain fossils were recognized as parts of plants or animals long before Steno's time, though. The ancient Greeks kept some – especially large ones – as relics in their temples. They knew that these were remnants of the past, not the remains of familiar life forms of their own time, and came up with a logical theory: These were relics of legendary giants and monsters, suitable for display as evidence for Homeric legends. Along similar lines, the Chinese identified many fossils as "dragon bones," and used them for medicinal purposes. The Chinese paleontological site called Zhoukoudian (or Chou-Kou-Tien) in the international literature is known locally as Longgushan, meaning "Dragon Bone Mountain."

Historian Adrienne Mayor proposed a daring extrapolation of this idea, later used by H.N. Turteltaub as the basis for a historical novel, *The Gryphon's Skull.* She suggested that the Greek legend of the "gryphon," a lion-eagle hybrid, was inspired by fossil remains of *Protoceratops,* a quadrupedal dinosaur with a birdlike beak. She theorized that skulls of these dinosaurs – found in the Gobi Desert, where Greek myth said gryphons lived – were brought to Greece as exotic trade goods by Scythian tribesmen. The Gobi is rich in dinosaur fossils, which gives some plausibility to Mayor's speculation, and to her portrayal of the ancient Greeks as actively curious about fossils.

The Workshops of Dionysius

In 399 B.C., the tyrant of Syracuse, Dionysius I, announced that he would pay high wages to weapons-makers who came to his city. Armorers from all over the Mediterranean set up workshops in every available space, and a friend of Dionysius supervised each shop. No doubt most of these craftsmen simply turned out weapons of existing types, but they developed at least one major invention: the *gastraphetes,* an early version of the crossbow and probably the first artillery weapon ever made (for stats, see ***GURPS Low-Tech***). When Dionysius fought the Carthaginians at Motya in 397 B.C., his use of artillery seems to have been a complete surprise to them. Ancient historians credited Syracuse with introducing artillery, and described the production of many different types of bolts and missiles – probably in order to test their effectiveness.

Syracuse preserved its tradition of advanced military technology for some time. In 217 B.C., the later tyrant Hieron II persuaded Archimedes to help stand off the Romans with his engineering skills.

Alexandria

Alexander the Great founded new cities from Greece to Central Asia, and named at least 13 of them "Alexandria," after himself. But *the* Alexandria was the one in Egypt, at the mouth of the Nile. It was Egypt's capital for over a millennium, and became one of the Roman Empire's most important cities. It has a strong claim to have been the ancient world's greatest center of learning.

The basis for this claim was the Mouseion (a cognate of the modern word "museum"), meaning not merely a set of buildings, but the community of scholars who occupied them. To serve their endeavors, the library collected books from all over the known world, through the efforts of active departments of acquisitions and cataloging. It isn't clear how big the collection was, but Ptolemy II is said to have set a goal of half a million scrolls, comparable to about 20,000 modern books. The staff made regular trips to book fairs at Athens and Rhodes. In game terms, treat it as a fine library on any branch of knowledge known to the ancient world, giving +2 to Research.

Scholars at the Mouseion compiled the standard ancient editions of many classic literary works, including Homer's *Iliad* and *Odyssey.* This was the first systematic textual criticism, which tries to produce an edition of a book that has the highest attainable fidelity to the original work – a constant problem in an era when all books were hand-copied! A group of Jewish scholars living in Alexandria (home to the world's largest Jewish community of its time) produced the Septuagint, a translation of the Hebrew Scriptures into Greek, named for the 70 sages who supposedly worked on it.

The Mouseion was also a center of scientific research. It was where the mathematician Euclid wrote the *Elements,* a geometry textbook regarded as setting the standard for rigorous proof until the 19th century. The astronomer Eratosthenes, second head of the school, was the first person to measure the Earth's circumference; his accuracy is debated, but he may have come within 1% of the correct figure. Physicians at the Mouseion pioneered dissections, led by Herophilos and Erasistratos, who worked on both animals and condemned criminals; their theories made the brain the seat of intelligence, and they noted the human brain's greater size and complexity. Much of this scientific work was speculative, producing theories that were never tested, but it included some genuine experimentation and measurement.

The Observatory of Samarkand

The grandson of Tamerlane, Mirza Mohammad Taregh bin Shahrokh – usually called Ulugh Beg (an epithet meaning "great ruler") – was not merely a ruler but a scholar, who used his position as governor of Samarkand to turn the city into a major intellectual center. In 1428, he built an astronomical observatory, the Gurkhani Zij, which he used in his personal research. His accomplishments included a new catalog of 994 stars, which corrected the errors of previous Arabian catalogs, and an estimate of the length of the year that was off by less than one minute. Unfortunately, he was less skilled as a ruler, and was eventually murdered by his eldest son while on pilgrimage to Mecca.

The Gurkhani Zij was a huge building, able to house astronomical instruments that achieved high precision through size. A sextant 118' long enabled Ulugh Beg to attain an accuracy of 3 minutes of arc. For time measurement, he used a *gnomon* (the vertical bar in a sundial) over 160' high. (Smaller versions of these devices appear in ***GURPS Low-Tech.***) During his lifetime, the interior of the Gurkhani Zij was faced with marble; its ruins have since deteriorated.

The Gurkhani Zij and several other Muslim observatories – mainly in Central Asia and Persia – made substantial advances in astronomy, which influenced the work of European astronomers. Star names such as Aldebaran and Algol, and astronomical terms such as *azimuth,* derive from Arabic. As well, Muslim astronomers, including Ulugh Beg, played a major role in developing trigonometry and spherical geometry.

The Cosmic Engine

In 1086, Chinese bureaucrat Su Song undertook the construction of an elaborate timekeeping device, which he called the Cosmic Engine, in Kaifeng. This was an enormous water-driven clock (for the operating principles, see *Time* in ***GURPS Low-Tech***). It included a celestial globe showing the positions of the stars, and bell-ringing automata that sounded the hours. The whole device was 40' high and *massive* – one of its astronomical displays weighed over 10 tons! Smaller versions never entered common use in China; this was a prototype that wasn't followed up.

The Birth of the University

In medieval Europe, universities evolved out of cathedral schools. Their original purpose was to train clergymen in canon law and theology. Wealthy families saw this education as a valuable asset for their sons – leading to careers in the church, government, medicine, or law – and began paying fees for teachers' services. In 1231, Pope Gregory IX issued a bull making the University of Paris a self-governing body, along the lines of medieval guilds. By the end of the Middle Ages, some 50 universities had been chartered all over Europe. Legally, a scholar who was licensed to teach at one of these could teach at any other; thus, the scholastic community became international.

The Medieval Curriculum

Trivium and *quadrivium* are all well and good . . . but what do medieval university students learn in *game* terms?

- *Grammar* is knowledge of Latin. A student is expected to speak and write Latin at the Accented level, at least. Theoretically, students are supposed to prove that they've studied basic Latin to gain admission, but many universities will accept a memorized Latin speech (roll vs. IQ to recite it correctly).
- *Rhetoric* is primarily the Public Speaking skill. Advanced instruction covers figures of speech and literary forms, though; represent this with some points in Literature.
- *Dialectic* is Philosophy – in particular, Aristotelian and medieval scholastic philosophy.
- *Arithmetic, Geometry,* and *Music* are all Mathematics. Arithmetic is Mathematics (Applied), and can be used to solve problems in nonpositional notation (Roman numerals) without getting lost; see *Calculation and Computation* in ***GURPS Low-Tech.*** The other two are both Mathematics (Pure) – music is actually the mathematics of fractions, or harmonics, which is important in music theory. The GM may optionally represent advanced studies with Accounting, Mathematics (Surveying), and Musical Composition (normally for voice choirs; most students will have some training in Singing and be able to read music).
- *Astronomy* is, of course, Astronomy. It isn't limited to observational astronomy – students are expected to do astronomical calculations.

University charters made students legally clergymen, who couldn't be tried by secular courts. These were young men – they started their studies at 14 or 15 years of age, on average – and not closely supervised, so universities were often fairly lawless. Older lads sometimes abused younger ones, and students behaved arrogantly toward townspeople. Lacking legal recourse, the townsfolk occasionally struck back violently; university towns often had recurrent "town versus gown" riots. To make things worse, most universities admitted large numbers of foreigners who didn't know the local customs, might not speak the local language, and often had no interest in learning either. In ***GURPS*** terms, these people would have 10-point Legal Immunity, yet lack Cultural Familiarity.

The first six years were spent on a standard curriculum: the seven liberal arts (see *The Medieval Curriculum,* above). These started with the linguistically focused *trivium* of grammar, rhetoric, and dialectic (or philosophy, emphasizing logic) – subjects that were considered easier, whence the word "trivial." Students went on to study the mathematical *quadrivium* of arithmetic, geometry, astronomy, and music. Those who finished the entire program became *bachelors of arts,* eligible for advanced studies in law, medicine, or theology. Individuals who completed one of these latter courses were licensed to teach, admitting them to the international community of scholars. The majority of the Middle Ages' greatest thinkers and most powerful churchmen had such an education.

Teaching involved the instructor reading from a standard text, sentence by sentence, and explaining each sentence as he went. Students were encouraged to ask questions, and more advanced ones could gain recognition (and a Reputation) by debating what texts meant. Gaining the *doctorate,* or license to teach, required taking part in a formal debate – the origin of today's oral examination for the Ph.D.

Important medieval universities included:

The University of Paris: The first school formally recognized as a fully autonomous body, and the most acclaimed of all medieval universities. Its faculty of theology was preeminent, associated with such figures as Pierre Abélard, Albertus Magnus, Thomas Aquinas, and Robert Grosseteste. Aquinas played a major role in introducing Aristotle's ideas – which he learned from studying Jewish and Muslim philosophy – into Roman Catholic thought. This encouraged the growth of science by legitimizing the study of nature and the idea of natural law, but also hampered it by encouraging an over-rigid reliance on Aristotle's theories.

The University of Salerno: The city of Salerno, in southwest Italy, had medical traditions going back to the Roman Empire. In 1077, a Benedictine monk, Constantine the African, moved there and devoted his life to translating classical and Near Eastern medical works. This led to the growth of a medical school that was internationally famous for the next three centuries (in ***GURPS*** terms, medical skills learned at Salerno are TL3, while the rest of Europe is retarded in medicine – TL2 at best). Faculties of law, philosophy, and theology were added, but never became as famous. The school was unusually liberal for its time, encouraging the study of Jewish and Muslim texts; legend said that it was founded by four masters: an Arab, a Jew, a Roman, and a Greek. The medical faculty even accepted women as both students and teachers.

Non-European Universities

Other medieval cultures had their own institutions of higher education, such as:

Nalanda: A major Buddhist university that operated in northeastern India from 427 A.D. until 1197, when it was destroyed by a Turkish invader, Bakhtiyar Khalji. It provided housing for 10,000 students and 2,000 teachers. Its library held hundreds of thousands of volumes. Instruction focused on four schools of Buddhist thought, but also included science and philosophy. *Vikramasila,* a similar institution, was founded somewhat later.

Gundeshapur: Established in 531 A.D. by Persian emperor Anushirvan as a refuge for pagan Greek scholars exiled from the Eastern Roman Empire, this became a center for translation of Greek and Syriac books, and later of Indian and Chinese knowledge. Its main focus was on medical training, not by apprenticeship but under an entire medical faculty that staffed a great hospital. Originally Zoroastrian, it continued to operate under Muslim rule after 638 for over two centuries; in 832, Caliph al-Ma'mun recruited its scholars for his "House of Wisdom" in Baghdad, which survived until the Mongol invasion of 1258.

Sankoré: Founded in 989 A.D. with the support of a wealthy Mandinka woman, Sankoré became one of Timbuktu's three great *madrasahs* (schools associated with mosques), reaching its height in 1327 under Kankou Musa, *mansa* (emperor) of Mali. All instruction was based on the Qur'an, each pupil worked under a single teacher, and students were expected to copy manuscripts for the library.

The school offered degrees at four levels: Arabic literacy and the Qur'an; science, law, and theology; specialized professions; and recognition as a judge or scholar.

The Guozijian: Established in the 13th century in Beijing under the Yuan Dynasty (founded in 1271 by Kublai Khan), the Guozijian trained Chinese administrators through the Ming and Qing Dynasties (ending in 1912). More than 50,000 graduates are recorded to have passed the civil service examinations. Foreign scholars were welcomed; two standing stones at the entries say "Dismount Here" in six languages.

Gundeshapur and Sankoré can serve as models for Muslim institutions in other lands; e.g., Cordoba in Muslim Spain, whose students included non-Muslims such as Gerbert d'Aurillac (later Pope Sylvester II).

The Royal Society

During the English Civil War, a group of scholars began meeting privately to discuss scientific questions. Robert Boyle, one of their founders, took to calling them "the invisible college." In 1660, the newly restored Charles II gave them an official charter as the Royal Society of London for the Improvement of Natural Knowledge. The society's goal was to establish the truth through observation and experimentation, not relying on anyone's authority. Its official motto, *Nullius in verba,* could be translated as "Don't take anyone's word for it." The Royal Society didn't limit its membership to aristocrats, clergymen, or scholars; for example, the draper John Graunt was elected to membership for his work on life expectancy (see *Statistics,* p. 20).

The Royal Society became one of Europe's preeminent scientific organizations. Its journal, *Philosophical Transactions of the Royal Society of London,* published the work of the greatest British and European scientists – including Isaac Newton, who became the society's president in 1703. The *Philosophical Transactions* helped establish the custom of open publication of scientific findings, which made possible the rapid growth of knowledge, by adopting the rule that credit for a discovery went to whoever published first.

One of these priority disputes was the debate between Newton and Leibniz over which of them had invented calculus, one of the key mathematical developments of TL4 and the basis of mathematical physics. Newton not only claimed priority but accused Leibniz of plagiarism. The Royal Society endorsed his claims, but they weren't exactly impartial, since Newton not only was president of the society but actually wrote the conclusion of its report! British and continental European mathematical traditions developed separately for the next century after the quarrel.

Even so, the Royal Society made a tremendous contribution to the emergence of modern science, both by publishing many important results, and by helping establish its values and customs. It remains active now, and the *Philosophical Transactions* is the oldest scientific journal still being published.

Book Production

Book prices can vary widely in any era, with texts ranging from cheap entertainment for the masses to expensive collectibles for the fabulously wealthy. For example, in Ming China, a simple almanac might cost 0.02 tael (a day's pay for a laborer), while a luxurious illustrated work could cost over 10 taels! ***GURPS*** doesn't assume *any* standard price for books in *any* period.

GURPS High-Tech does define standard sizes for *libraries,* though, with weights and prices based on rough averages for books. These assume printing on paper with movable type, but suitable multipliers can handle other document formats and reproduction methods. At TL4, library sizes are:

Small Collection. Perhaps a dozen works on a single topic (say, 1 linear foot). This is "improvised equipment"; if the GM allows a Research roll, it should be at -2 or worse. $350, 25 lbs.

Basic Library. A large shelf or a small bookcase (about 10 linear feet). Allows an unmodified Research roll. $3,500, 250 lbs.

Good Library. A couple of bookcases (around 50 linear feet). Gives +1 to Research. $17,500, 1,200 lbs.

Fine Library. A dozen large bookcases (several *hundred* linear feet). Gives +2 to Research. $70,000, 5,000 lbs.

Research modifiers assume that all the books relate to *one* skill (or specialty, for skills that require such). To cover multiple skills, buy several libraries.

A library's value can be higher if it contains exceptionally well-made books. Treat it as good-quality (+4 CF) for calligraphic script, or for limited editions with fine printing and binding. Call it fine-quality (+19 CF) for pages that are works of art in themselves. Good quality gives +1 to reaction rolls from collectors and potential buyers, and to Merchant skill rolls made as influence rolls; fine quality grants +2.

New Perk: Shorthand

Marcus Tullius Tiro, a freedman in Cicero's household, invented the first widespread shorthand – the *notae Tironianae* – in 63 B.C. It saw use through most of the Middle Ages. Shorthand lets you record spoken words in real time instead of at the speed under *Can You Read It?* (p. 34). Each form requires its own perk.

Hand Copying

Permanent hand copying can be done in three different formats: *tablets, scrolls,* and *codices.* All three take much longer than printing, and therefore cost more; multiply the base price of a library of any size by 10. The labor of hand copying costs far more than the medium; for simplicity, disregard the specific material when estimating library cost.

Handwritten text isn't as dense as print, increasing the bulk and weight of these three formats. For *codices,* multiply base weight and shelf length by 4 – or by 3 if the script is based on Chinese logograms, which are more compact. Media thickness further modifies this:

Paper: ×1
Papyrus or vellum: ×2
Parchment: ×5

Scrolls take up even more space than codices! The equivalent of a single modern book would be two dozen scrolls, filling 6 linear feet of shelves, costing $300, and weighing 36 lbs. For clay *tablets,* the equivalent of that book would be about 1,200 tablets, occupying 100 linear feet, still costing $300, and weighing 6,000 lbs. Multiply either set of figures by 12 for the equivalent of a small collection.

Can You Read It?

The skill of writing in an elegant script is Artist (Calligraphy), but routine writing need not be beautiful; legible will suffice. To achieve this, roll against DX – or *DX*-based Artist (Calligraphy) at +6, if better. At the GM's option, Professional Skill (Scribe) may exist, defaulting to IQ-5 or Artist (Calligraphy)-3; if it does, then a *DX*-based Scribe roll, also at +6, will work here. In all cases, High Manual Dexterity helps, while Ham-Fisted hinders. Slow, careful writing gives a bonus (see *Time Spent,* p. B346); assume a base writing speed of 4,000 words per day. Success yields a document that anyone literate can read, failure produces a scrawl, and the results of a critical failure can be read only with painful effort!

The GM decides whether a found manuscript is easily readable (as for success), readable with difficulty (as for failure), or almost illegible (as for critical failure). Printed texts are nearly always easily readable. Easily readable manuscripts require no roll; those readable with difficulty require an IQ roll; and nearly illegible ones require a roll vs. Professional Skill (Scribe) or a scholarly skill. Again, taking extra time gives a bonus.

Printing

"Printing" can mean either of two processes: block printing or printing with movable type. Both are normally used to produce codices. For notes on TLs and equipment, see *Printing* in ***GURPS Low-Tech.***

For simplicity, treat both approaches as having the same cost – just pick the one that better reflects the local culture. The reality is more complex: movable type costs more for Chinese-style scripts with thousands of different characters, which raise the setup costs; wooden or ceramic type lowers setup costs, but requires more frequent replacement; and while the cost savings from movable type are significant for large print runs, this process may actually cost more for small runs. All this is more detail than a band of adventurers needs, though!

On the other hand, block-printed pages have the same text density as handwritten ones. Multiply weight and linear feet by 4 for alphabetic and syllabic scripts, or by 3 for Chinese-style logographic scripts.

The medium from which the pages are made significantly affects the cost *and* weight of printed books. For rag paper, use standard values. For bamboo paper, *halve* cost. For parchment, multiply weight and linear feet by 5, and cost by 10.

Example: Fu Xiaoma, an actress with an interest in song lyrics, spends a significant fraction of her earnings on collections of these, published on bamboo paper using block printing. This is a basic library, allowing her to make unpenalized Research rolls for the Literature skill; base stats are $3,500, 250 lbs., and 10 linear feet. Tripling weight and length for Chinese block printing changes these to 750 lbs. and 30 linear feet. Halving cost for bamboo paper reduces it to $1,750.

Scripts

The oldest scripts are based on word signs: each word has a separate character, as is still true in Chinese. Signs began as pictures, but by the time a fully functional writing system develops, calling it "pictographic" would be inaccurate. Pictorial elements are drastically simplified, signs exist for words that can't be pictured (e.g., "and" or "soon"), and there are ways to represent the sounds of words used too rarely to rate standard signs (like foreign terms and people's names). Typically, the latter follow the "rebus principle" of using a sign for a word with a similar sound – as an English rebus would use an eye for the letter "I" or a teacup for the letter "T." Word-based systems have *thousands* of different signs that must be memorized for full literacy. Accented written comprehension means knowledge of around 1,000 core signs, but not of the full written vocabulary; you may be familiar with a word but never have seen its sign.

Other writing systems have signs for syllables, as in Japanese *katakana* and *hiragana,* or for individual sounds, as in the Roman and Greek alphabets. These may have evolved from the sound signs of word-based systems. Syllable-based writing typically involves 100-200 signs, and evolves mostly in languages with only a few syllable patterns; e.g., those where the standard syllable is one consonant followed by one vowel. Most sound-based scripts have 20-50 letters – ideally one for each of the language's sounds, although many examples (such as English) have fewer. Even imperfect syllable- or sound-based scripts are easier to learn than word-based writing, though; on encountering a new word, you sound it out and write the signs for its syllables or phonemes instead of memorizing a new sign. In such languages, anyone who has mastered the script can sound out almost any word, and Accented written comprehension mostly reflects a limited speaking vocabulary.

Another important difference between the two types of scripts is that word-based ones can often be read by speakers of different languages. For example, speakers of different forms of Chinese – as different as English and Swedish – can read the same text, each pronouncing the characters as words in his own language. *Kanji,* one of the three Japanese scripts, is essentially the same, even though Japanese has no linguistic relationship to Chinese. Treat someone with Native comprehension of a language written in a word-based script as having Accented facility with the written forms of other languages that use that script, but Broken or no fluency in the spoken forms.

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