GURPS® Fourth Edition

LOW-TECH™

COMPANION 3

DAILY LIFE AND ECONOMICS™

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Introduction

Behind kings in their glittering palaces, priests in their golden temples, and warriors and their walls of spears are the numberless masses who support them. Without weavers and tailors, kings have no royal robes; without masons, priests have no temples; without smiths, warriors have no arms; and without countless farmers, herdsmen, and merchants bringing goods to market, none of them get to eat. While unexciting on the surface, such matters can be the source of surprising adventure! Wars have been fought over things as mundane as alum supplies, and perilous journeys through strange foreign lands have been undertaken just to find a better shade of blue paint. Merchants and craftsmen may become heroes despite themselves by dint of *getting things done,* while concerns such as how goods are made, transported, and sold are vital to everyone – even to adventurers, who often want to possess hard-to-find gear, earn their fortune, and leave their mark on society. And for those who hope one day to *rule,* being able to answer such questions as "How many people can live on this land?" and "How much for the castle?" can mean the difference between glory and ignominy.

GURPS Low-Tech Companion 3 looks at the everyday jobs and industries on which low-tech societies depend, from the fundamentals of subsistence (hunting and gathering, agriculture, and domestication), through making things (extracting resources, erecting buildings, and manufacturing both utilitarian and luxury goods), to how all this enables an individual to earn a living and a society to thrive (jobs, trade, and transport). 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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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.

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Chapter One

Food and Population

The number of people a society can support depends on their subsistence technology, as does how close together they can live. In marginal environments, such as the Arctic or the Kalahari Desert, hunter-gatherers require at least three square miles per person, if not more. In extremely fertile environments, like the coastal forests of California, population density could be one person per square mile.

When hunting and gathering gave way to agriculture, the shift didn't necessarily result in more food production in absolute terms – not right away, at least. However, it *did* vastly reduce the area needed to produce food, allowing more people to live closer together. Farmers *started* with a population density similar to that of the best-situated hunter-gatherers and went up rapidly from there. Even the most primitive agricultural techniques allow population densities of one to five people per square mile; advanced methods can push that much higher. Under absolutely ideal conditions of climate and soil fertility, with allowances for crop rotation and every available inch of land under cultivation, a square mile can support up to 75 people at TL0, 275 at TL1-2, 500 at TL3, and 1,000 at TL4.

Conditions are almost never ideal, though. Historically, regardless of how many people might be packed into a small patch of outstanding farmland, true *regional* carrying capacities were at best 10% of the absolute maximum, and almost always significantly lower than that. In most areas, only a fraction of the land can support any reasonable level of agricultural productivity. For example, slopes over 10° are nearly impossible to cultivate without the labor-intensive construction of terraces; forests are often retained to provide raw materials; rocky and swampy wastelands are difficult if not impossible to cultivate under any conditions; and poor climate and soil reduce any region's overall fertility. Consequently, the population density of early TL3 England rarely rose above five to 10 people per square mile, and even the fertile Nile Delta rarely saw a density greater than 75 people per square mile.

Breeding Plants and Animals

Almost every type of domestic animal and plant has undergone extensive genetic modification at human hands – but usually over the very long run, and often inadvertently. Humans were just one more selective force acting on other species.

Deliberate selective breeding was practiced sporadically, but with little immediate impact. People frequently had to consume too much of what they produced to leave significant room for selection, and those who kept animals mostly owned or had access to very few. Consequently, they bred their stock with whatever other animals they could get to, not necessarily ones they might want. Selective breeding was a game for the very rich, who could afford to keep large herds and trade for specimens with desired traits.

The potential benefits of selective breeding are laid out on pp. 10-11 of ***GURPS Bio-Tech.*** Individuals capable of setting up large, intensive breeding programs are few and far between, however. Assume that historical efforts to breed animals let breeders improve the beasts' traits at the rate of 1 character point per four to 16 generations.

Hunting and Gathering

One of the most fundamental questions about a human society is how people meet the basic survival needs, such as food, water, and protection from the elements. Members of Paleolithic societies draw nearly all of these from resources in the local environment. Wandering adventurers must often do the same.

Environments are graded as *Desolate, Very Poor, Poor, Typical, Good,* or *Excellent,* reflecting weather, number and diversity of useful plant and animal species, availability of water, and other attributes conducive to human survival. Treat most terrain types (see *Survival,* pp. B223-224) as Typical on average, with patches ranging from Very Poor to Excellent.

Arctic and desert zones tend to be Poor or Very Poor, with large stretches of Desolate territory. Hot springs in arctic regions, oases in deserts, and other microclimates may provide areas of superior quality, though – knowing where to find the best foraging spots is an important part of the Area Knowledge skill! The grade of most environments varies seasonally as well; a one- to two-step quality drop between summer and winter is common (and Area Knowledge can help predict when this is likely to occur, too).

For day-to-day requirements, these grades determine the time needed for each attempt to use the Survival skill to find food:

Desolate: 1d+6 hours
Very Poor: 1d+2 hours
Poor: 1d-1 hours (minimum 1 hour)
Typical: 1 hour
Good: 1/2 hour
Excellent: 1d attempts per hour

On the average day, a nomadic group has about 1/4 of its number (typically its adult women and adolescent girls) gathering food and possibly setting traps for small game and fish. Meanwhile, around 1/6 of the group (most often the adult men and older boys) ranges more widely to hunt – although hunters gather food for themselves as they go. If big game is available, then half the hunters might be looking for it while the rest remain closer to the base campsite and pursue smaller prey.

If a group stays in one area for too long, they can overexploit it, killing or driving away all the animals and consuming all the edible plants. Most hunter-gatherers travel back and forth through a well-known landscape, relying on teamwork and an intimate knowledge of their surroundings. For any group living off the land in an environment better than Desolate, roll once a month against the average Survival skill of the adult members, modified for grade.

Modifiers: -4 if Very Poor, -2 if Poor, +2 if Good, or +4 if Excellent.

Failure means the area they currently inhabit, typically one to three square miles per member of the group, drops one grade; the group will probably move on. On a critical failure, the area drops *two* grades and the hunter-gatherers must leave immediately; this might be due to a manmade disaster (e.g., fire) or the misfortune of a natural one, at the GM's option.

Groups in Desolate environments *must* stay on the move constantly, and get no roll.

Gathering

Most hunter-gatherers obtain the majority of their calories by gathering anything that doesn't run away. Represent each gathering attempt with one skill roll – usually against Survival or Naturalist. Success finds one meal of edible leaves, roots, mushrooms, seeds, sap, fruit, nuts, or insects; critical success *doubles* the yield. Failure turns up nothing to eat. Critical failure means food that is mildly poisonous or has other inconvenient effects (e.g., accidental discovery of psychoactive molds). For a typical poison, roll vs. HT; success indicates 1 point of toxic damage, while failure inflicts 1d damage.

People near a large body of water can gather mollusks such as clams and mussels, collecting *two* meals on a success. Gatherers may also search for birds' nests, beehives, or the dens of small animals. Locating these often requires *several* skill rolls – Tracking to follow a creature, Vision or Naturalist to identify its lair, Climbing to reach a nest or hive located in a tree, etc. The effort can be worth it, though: 1d meals of eggs, meat, or honey, if all the rolls succeed.

A meal's worth of gathered food weighs 0.5-1 lb. for most animal foods, 1-2 lbs. for seeds and nuts, 3-4 lbs. for many fruits and roots, and up to 6 lbs. for leaves and fungi. However, gatherers don't usually collect more than they can carry easily, rarely carry it very far, and often consume a significant amount of food in the process of obtaining it.

The keys to hunter-gatherer survival are *seasonality* and *flexibility.* Where agricultural societies get most of their nutrition from one or two cereal grains harvested perhaps twice a year, plus a handful of other species in very small quantities, hunter-gatherers consume *hundreds* of different species over the course of the year. Many environments are abundant enough that hunter-gatherers can get by with just a few hours of effort a day for most of the year – although food resources can become much scarcer during winters or dry seasons.

This means that for long-term survival, one must be extremely familiar not only with general survival principles but also with specific quirks of the local environment. For example, acorns in some regions are immediately edible, while those in other areas are inedibly bitter or even poisonous, and yet other locations have a mix. Bitter acorns are dried, pounded into flour, and soaked in earthen pits to leach out potentially dangerous tannins. Animals can present similar challenges; e.g., shellfish in certain locales are seasonally toxic. In some places and seasons, hunter-gatherers may even consume small quantities of noxious foods, gaining additional nutrition while staying below the threshold of poisoning. Of course, it's important to know just how much of such things can be consumed safely! The GM may opt to apply *Familiarity* (p. B169) to the Survival skill to cover different geographical regions.

The GM may also let Area Knowledge substitute for Survival and survival-related skills, for certain rolls. For example, hunter-gatherers usually have a sophisticated mental map of their range. Consequently, if they're in their home territory, they don't need to search for water sources because they *already* know where all the streams and watering holes are. Area Knowledge can also provide insights on where best to start looking for game, or where clusters of fruit and nut trees are. In general, a successful roll against Area Knowledge provides +2 to a subsequent Survival roll.

Hunting

Hunting calls for a combination of several skills. A hunter needs Tracking, Survival, or Naturalist to find game; Stealth or Camouflage to get near enough to strike; and then weapon skills for the kill. The most efficient methods (see *Other Hunting Techniques*, p. 6) also require Animal Handling, Area Knowledge, and/or Tactics.

To locate game, big or small, roll against the hunter's *best* game-finding skill. When several hunters travel together, roll once using the group's highest skill. Success by 0-4 locates small game, success by 5+ reveals signs of a large animal, and a critical success *sights* big game.

Butchering

Whether an animal was hunted, trapped, or raised and slaughtered, edible meat is 40% of its weight plus 5% per point of success on a Professional Skill (Butcher) or Survival roll, to a maximum of 70%. *Familiarity* (p. B169) applies; a South American butcher might be able to dismember a llama with one hand behind his back, yet be flummoxed by a freshly slain elephant, while Survival focuses on dressing game. Butchering takes an hour per 100 lbs. of whole body weight; each pound of meat counts as one meal. Many remaining parts are useful – skin for leather, gut for bowstrings, bones for construction and weapon tips, etc.

Low-Tech Butcher's Tools

Some of the first stone tools were used for cutting up animal carcasses:

Flake (TL0). A single flake knocked off of a core, quickly produced and used as a disposable tool. Very sharp for initial cuts, but dulls quickly thereafter. Does thrust+1(0.5) cutting on the first cut, but each subsequent cut suffers a damage penalty equal to the previous target's DR, minimum -1. This is cumulative; e.g., if cutting something with DR 2, it does thrust+1 the first time, thrust-1 the second, thrust-3 the third, and so on. Flakes cannot be carried in pouch without breaking. They're worthless as weapons unless the victim is immobile – although the GM might allow warriors with Throwing Art to hurl them. $1, 0.05 lb. (or made from a core in a few seconds).

Hand Axe (TL0). This is a core, small enough to fit comfortably in the hand, with at least one flaked edge. While primarily for butchering, it can also be used for very light woodworking, scraping hides, or cracking nuts. Wielded in combat as an edged fist load, it's an improvised weapon that attacks at Brawling-2 or DX-2 and inflicts thrust-1 cutting damage. $5, 0.75 lb.

See also *Flaked Stone Tools* in ***GURPS Low-Tech.***

Small Game

Handle hunts for birds, small mammals, etc. with a few dice rolls. After sighting prey (see above), the hunter may attempt to close with it. This requires at least one Stealth roll; see *Stealth* (p. B222). Treat most animals as being on the alert, making this a Quick Contest: Stealth vs. the beast's *best* sense.

If the hunter isn't detected, he may have the benefit of surprise on his first attack. This usually means a shot with a missile weapon: blowpipe, bow, sling, or throwing stick. If the hunter can close, he can even attack using a melee weapon.

If the hunter *is* detected, the animal bolts. He can try *one* attack, suffering whatever range penalties apply.

Big Game

Hunts for large animals – especially dangerous ones – should be roleplayed. If the hunter finds tracks or other visual signs, he may recruit a hunting party before setting out in pursuit. Getting within visual range of the beast may take from 30 minutes to 2-3 days, depending on the age of the tracks, the terrain, and the results of skill rolls; see *Tracking* (p. B226).

Once the hunting party reaches a range of (2d-2)×10 yards, handle the final approach as a Quick Contest, exactly as described in *Small Game* (above). Roll every 10 yards until the hunters are either discovered or ready to attack. If the beast senses the hunters and flees, the GM should allow the hunters a parting shot. They may also chase their quarry. A typical strategy is to let the animal get away, running at top speed, and pursue it at half speed. The prey will become too fatigued to run long before the hunters do.

When hunting predators (e.g., bears) and aggressive herbivores (e.g., Cape buffalo), alerting the prey can prove deadly. Some beasts may choose fight over flight, attacking immediately. Others might flee only to circle around and attack the hunters!

Other Hunting Techniques

Many hunting strategies require less individual exertion and offer a greater chance of bagging game.

Target-Rich Environments: Where possible, hunters generally go after large groups of animals rather than individuals. Pursuing flocks and herds allows hunters to choose their targets – or at least be reasonably assured of hitting *something* if their attacks go wide of the intended mark.

Dogs: Hunters often use dogs to track game. If anyone in a hunting party has Animal Handling at 12+, use the *dog's* Tracking skill (typically 16-18), with a bonus for multiple dogs: +1 for 2-5, +2 for 6-9, or +3 for 10 or more dogs. Using dogs as trackers makes a stealthy approach almost impossible; the dogs will bark and alert the prey, meaning that most shots will be at fleeing targets. Hunters might use this to their advantage, however, splitting their forces so that the dogs' noise flushes the game toward an ambush.

Driving Game: Some hunters don't just track and attack their prey – they attempt to contain and drive it, making it easier for other hunters to make kills. For example, two groups might approach a herd from opposite directions; the hunters on one side attack first, possibly hitting some animals and flushing the rest toward the other hunters; then the second group strikes, catching some prey and driving the beasts back toward the first group; and so on, continuing until the remaining animals manage to escape. When a hunting party tries to prevent a group of animals from fleeing, roll against the hunters' *best* Tactics skill. Success prevents the escape of a number of animals equal to two *per hunter* plus the margin of success; those beasts might flee in another direction, where they can be stopped by other groups, but the remainder will run through the line of hunters. Failure means only one animal per hunter is turned back; the rest escape. On a critical failure, a panicked herd overruns the hunters, who must dodge to avoid being trampled!

Nets and Barriers: Many hunting techniques benefit from extended preparation. Long nets or barriers might be placed to intercept escaping prey, making the beasts turn and flee in another direction. Roll against Tactics for this; the number of animals contained is twice the margin of success. Failure means the barrier was poorly or insecurely set up and doesn't contain any animals. Preparing nets takes at least a day; spending extra time (see *Time Spent,* p. B346) setting up more extensive barriers gives a Tactics bonus that lasts for a week or until the area's environmental quality drops.

Fire: Hunters occasionally employ fire to drive game. A group of hunters sets fire to underbrush (something they might do for other reasons anyway; see *Firestick Farming,* p. 8) around a wide perimeter, open at one end. Naturally, animals within the perimeter will flee the fire via the only apparent exit, where waiting hunters take whatever animals they want from the distracted crowd going by. Treat this as containing animals with nets, but the base time is 30 minutes and any bonus applies only to a single hunt. Critical failure means the hunters are caught by the fire; they must roll vs. DX to avoid 1d burning damage.

Lay of the Land: In any terrain other than completely open plains, Area Knowledge can help hunters select a particularly attractive spot where animals are likely to pass by; e.g., a narrow canyon, or a clearing between patches of trees too dense for large animals to pass between. An attempt to use Area Knowledge takes a day and, if successful, adds a bonus equal to the margin of success to subsequent Tactics rolls for the hunt. Taking extra time (p. B346) can give a bonus to Area Knowledge ("Wait until Wednesday . . . buffalo go through Perfect-For-Ambush Canyon *every* Wednesday on their way home from the comic-book store.").

Note that game-driving techniques don't work equally well for all animals. It's harder to intimidate larger beasts; if the target species has a higher SM than the hunters, then all Tactics rolls suffer a penalty equal to the SM difference. Such methods also don't work against animals that can move in more dimensions than the hunters. For instance, birds can fly *over* hunters, while burrowing animals often have holes to hide in.

Dressing Game

See *Butchering* (p. 6) to dress game after a successful hunt. Hunters normally roll against Survival for this.

Trapping

Traps offer an alternative means of obtaining meat. Use Survival to set simple snares, box traps, etc. for small game. Roll against Traps for any trap that could capture, maim, or kill human-sized or larger prey – big deadfalls, tiger pits, etc. Naturalist skill can help determine optimal locations for traps, while Camouflage is valuable for concealing traps from animals with good eyesight (e.g., humans).

Some common traps:

- *Snares:* Typically loops of rope set where animals are likely to pass – on the ground where they walk or in narrow passages they might traverse (e.g., a gap between thick bushes). An animal that passes through catches its neck or a limb in the slip-knotted loop, which tightens as the beast tries to escape.
- *Box or Net Traps:* These enclose prey rather than simply snagging it. They drop a box or cage on the animal, or scoop it up in a net. They're harder to set up than snares, but hold prey more effectively.
- *Deadfalls:* These work much like box traps, but drop a heavy weight on the victim.

Rules for snares, nets, and deadfalls appear in *Traps* in ***GURPS Low-Tech.*** Assume that a box trap takes 2-4 man-hours to construct.

For each trapping expedition, roll against Naturalist, or Survival at -2, to determine the location's desirability. This gives a modifier to trapping rolls: +2 for critical success, no modifier for ordinary success, -2 for ordinary failure, or -4 for critical failure. Then make one Survival or Traps roll per string of 10 small traps. Success means that one trap has been sprung, plus an additional trap per point of success. If the traps aren't checked regularly, animals may roll against ST to escape snares or ST-2 to escape box traps.

Pit traps, sometimes dug to catch large prey such as pigs or tigers, work differently. Roll as above for placement. However, when an animal encounters the trap, the hunter must *win* a Quick Contest of his Camouflage skill vs. the beast's Vision (+3 if it's alert, or +5 if it has cause for suspicion) for the prey to fall in. The pit has to be large enough to hold the animal (at least as long as it is) and deep enough to prevent it from climbing out (the creature's height is usually sufficient – or at least twice its height, for good climbers and leapers). If the animal has significant leaping ability, like a tiger, the pit also needs to be small enough to keep it from getting a running start.

Small traps yield one meal each. Any trap large enough to require the Traps skill yields at least two; see *Butchering* (p. 6) for guidelines.

Mass-Trapping Techniques

As with hunting, trapping was often a group effort. For the methods below, roll against the *highest* Survival skill among the trappers. Success means they get meals equal to the number of trappers plus the margin of success.

Birds: Societies that already used large nets for fishing could use them to capture birds, too. The nets – tended by people hidden in nearby underbrush – were laid on the ground and baited with seeds. When enough birds landed on the net, the tenders quickly folded it over, trapping many of them.

Small Game: Techniques for directing herds of animals past hunters sometimes developed into methods for driving them into traps instead. For example, some societies erected long, temporary wicker fences fitted with conical tunnels. People would start some distance away from the fence and beat the grass while walking toward it, driving small game such as rabbits and quail ahead of them. The animals would try to escape through the tunnels, which quickly became so narrow that they'd get stuck and could be collected later.

Bugs: Even edible insects can be trapped! Some Native American groups would dig pits and then, starting a distance away from the pits, walk toward them beating the grass. Surprised grasshoppers would flee; many fell into the pits. The pits were deeper than the grasshoppers could jump, containing them until the trappers collected them.

Fishing

Bodies of water often provide fish to catch. Aquatic animals have proportionately more edible tissue than land-dwelling ones, so a successful day's fishing can frequently produce more food than a good day's hunting.

A fisherman might try to catch fish by hand in shaded areas or in very shallow water. He could muddy the water in small pools to cause fish to swim to the surface to breathe, or use a lure to bring them close enough to club them. He may spear or harpoon them in shallow water, or from a boat or a raft. Or he might use a line and baited hook, or a net. *All* of these methods require a roll against the Fishing skill.

Modifiers: -5 if wholly unequipped, or -2 if using improvised tools (e.g., a sharpened stick for a spear).

Success catches 1/2 meal of edible fish, plus a further 1/2 meal per point of success; e.g., a roll of 7 vs. an effective Fishing skill of 12 would yield three meals. *Triple* this yield for two fishermen handling a large net together. Critical failure on any roll means the area is fished out for the remainder of the day.

Riverine fishermen can alter the environment to increase their chances of catching a fish. Streams and sections of swamp can be blocked or diverted into artificial pools with brush, loose nets, or earthen barriers. Fish might escape from these arrangements, so it would be exaggerating to call them "traps," but anything that slows down fish or brings them closer to the surface makes them easier to catch.

Simple fish traps could be constructed on the seashore as well. Some American Indians built low stone "corrals" on the beach with walls lower than high-tide level, essentially creating artificial tide pools. When the tide went out, fish would be trapped behind the wall, ready to catch.

A fisherman can spend time preparing an area of stream, wetlands, or coastline for better catches by making a Survival roll. Future Fishing rolls in that area get a bonus equal to 1/4 the margin of success (round *up*), to a maximum of +4. This bonus lasts until the area's environmental quality drops.

Firestick Farming

One of the more spectacular uses of fire was to control plant growth. Without sufficient labor to control weeds, farmers would – every few years – intentionally set fire to areas they used. Patches ranging in size from a few acres to several square miles might be put to the torch in controlled burnings. This enriched the soil by returning some (though, in the final analysis, not many) nutrients to it, and beat back any weeds and useless shrubs that might have sprung up.

In forested areas, periodic burning by hunter-gatherers also kept undergrowth down while leaving useful trees largely untouched; removed smaller plants that they didn't exploit; and made it easier for them to find desirable animals and plants. Landscapes subjected to regular burning didn't appear cultivated to the eyes of higher-tech visitors (e.g., European colonists in Australia and the New World, where the natives routinely used fire, just saw remarkably clear forests), but the practice of killing off useless undergrowth ensured that most of the plants one could see were used by humans. In some areas – notably the American prairie and parts of Australia – repeated burning may have encouraged the growth of hardy grasses instead of trees, leading to better grazing for herd animals.

Whaling

While dangerous, difficult, and available only to societies with well-developed seafaring technology, whaling is *immensely* profitable in terms of food produced for the amount of effort. Whales hunted historically weighed up to 100 tons. A single expedition could feed a tribe for weeks, even months.

Whaling is a seasonal activity, with hunters pursuing whales as they pass by on known migration routes. Whales already in relatively shallow waters can be surrounded by boats and driven toward the shore with loud noises and missiles; driven far enough, a whale might beach itself. Whales farther out at sea must be chased to exhaustion. Harpoons and arrows with floats attached to the end of long ropes are used in initial attacks; even if the whale dives to a moderate depth, its position is marked and the hunters can follow it to strike again when it surfaces. After repeated attacks – assuming the whale can't shake off the markers and escape at great depths – the exhausted whale becomes safe enough to approach for more forceful and deliberate attacks with hand-held weapons.

Like hunts for large animals, whale hunts should be played out. Use Tracking to find a whale; anyone familiar only with tracking on land rolls at -2 (see *Familiarity*, p. B169). Roll against Boating to properly position the hunters to cut off the whale's escape, with critical failure meaning that a boat ends up close enough to the whale to be attacked.

Water Supplies

An active adult needs 2 quarts of water per day; a child, roughly half that. Any less causes dehydration over time; see *Dehydration* (p. B426). Campsites must be close to permanent water sources, where available.

In arid climates, foraging for water requires daily Survival rolls. This task can prove quite challenging! In the Kalahari Desert of Africa, for example, many areas are virtually without surface water for 10 months of the year. The Bushmen who live there use great ingenuity to find additional water wherever possible. Small amounts are collected from hollow trees, or from *sip-wells:* hollowed reeds joined together into 5' lengths and sunk into the moist sands that indicate groundwater close to the surface. Tubers are dug up, peeled, and grated, and a potable liquid is squeezed out of the pulp.

Agriculture

Farming is hard, dirty, tedious work . . . and what the vast majority of people did every day from the Neolithic into the modern era. For practical purposes, agriculture means growing *grain*. Except for tubers, whose significant cultivation was confined to the Andes and the Pacific, cereals provide more calories than any other food for the effort and land area required, and most can supply an adequate amount of protein and a number of other nutrients. Farmers cultivated smaller quantities of other crops for truly balanced nutrition and additional flavors – often legumes for more complete protein, plus a few vegetables for vitamins and other nutrients. However, low agricultural productivity meant that they had to grow grain first and other things second, if at all. Meat and other animal foods were luxuries!

An active adult – including a warrior or an adventurer – requires about 750 lbs. of grain a year. Someone with a more sedentary lifestyle can get by on just 600 lbs. Peasant farmers, who alternated periods of activity during plowing and harvest with periods of inactivity in winter and when crops were growing, might survive on that little.

On a pound-per-pound basis, most grains provide about the same calories, but there are nutritional and culinary differences. For example:

- *Maize* delivers greater yields per acre than any other grain, but must be eaten with legumes or animal foods (at least 10% of the diet) to provide complete proteins. Other grain eaters can get by on somewhat smaller proportions of legumes or meat and dairy. As well, if used as a staple food without processing with *nixtamal,* a solution of lime, maize doesn't provide enough niacin, causing deficiency diseases. This was a chronic problem in Europe, where peasants who lacked alternate niacin sources adopted maize without knowing about the nixtamal process.
- *Rice,* another high-yield crop, is also implicated in deficiency diseases – in this case, thiamine deficiency caused by polishing brown rice to turn it into better-tasting white rice.
- *Wheat* provides more protein than any other grain, and has excellent flavor. Its protein also allows the production of raised breads and distinctively textured noodles. However, it requires high-quality farmland and has relatively low yields.

In the Pacific and parts of the New World, tubers and other root crops – including cassava, taro, and potatoes – became the primary source of calories, rather than grains. (Taro was consumed through most of the Old World, including the Roman Empire, but never achieved grain's prominence.) Tubers can deliver a much higher yield per acre by weight. However, higher-yield tubers tend to provide fewer calories per pound: about half of the calories of wheat or barley for cassava, a third for taro, and less than a quarter for potatoes. Thus, their large yields are partly offset by the need to eat much more; e.g., 3,375 lbs. of potatoes for an active adult, or 2,700 lbs. for a low-activity adult. Root staples also contain almost no protein, so a healthy diet requires more supplementary items. Cassava has the additional drawback of being mildly toxic; like bitter acorns, it requires soaking before being eaten.

Whatever one grows, the basic procedure has been the same from the beginning: break up the soil to clear out unwanted plants and make it easier to get your own seeds in, plant your seeds, wait for the plants to mature, and hurry to harvest the ripe crop before animals and bad weather get there first. Early farmers used *digging sticks* to poke holes in the ground, putting a few seeds into each. While this was labor intensive, it let farmers plant seeds relatively deeply. Such cultivation uses the Gardening skill, not Farming.

Early *scratch plows* replaced digging sticks around 4000 B.C., inaugurating true agriculture (and the use of Farming rather than Gardening). Instead of poking individual holes in the ground, the plow scratched a continuous gash in the soil. Plows allowed farmers to start using animal labor to till their fields. With the development of plowing, seeds were planted by broadcasting, tossing handfuls into the furrows. Plow designs were refined over the next few millennia, but the process remained much the same.

The early Middle Ages saw the development of *harrowing.* The harrow, a grid of metal spikes, was drawn over the ground before planting to break up large lumps of earth that plowing missed, and/or after planting to even out the soil and help cover the seeds. Heavy plows equipped with *moldboards,* which turned over old soil, appeared at TL2-3 (early first millennium B.C. in China, but late first millennium A.D. in Europe).

Most farming societies practiced *crop rotation.* Growing crops on the same piece of land year after year – particularly if it's the same kind of crop every time – removes necessary nutrients from the soil, eventually rendering it infertile. Instead of using the same fields for the same things over and over, farmers would use different fields, or change the crops they planted in them. Some early farmers may have "rotated" crops by abandoning one field after several years and clearing another on previously uncultivated ground.

Crop-rotation schemes typically let a portion of the cleared fields lie *fallow* (go uncultivated). Many early farmers adopted a "two-field" system: any given field was cultivated one growing season and left fallow the next. At TL3, a range of more complex crop-rotation systems appeared. The medieval "three-field" system involved alternating two years of crops (in different seasons) and one of fallow. Other societies adopted somewhat different but equally sophisticated rotations. "Four-field" rotation, developed at TL4, added fodder plants such as clover and turnips, and often removed fallow phases.

An early alternative to crop rotation was to grow several crops in the same field, such as alternating maize and bean plants in a single row. Particularly complex arrangements might have five or six crops growing in the same patch of ground (e.g., maize, beans, squash, avocadoes, and yucca). Such gardening schemes preserve soil better than intensive single-cropping, but planting and harvesting are far less efficient. Gardening worked well in the New World, where maize's high yields allowed some leeway in efficiency, but not in the Old World.

Vermin Control

Early farmers soon encountered a new problem that threatened their food supply: *rodents,* attracted by their crops. Rodents, in turn, drew wild cats. Cats became lightly domesticated – at least to the point of being able to live near humans – but weren't bred to work as closely with people as dogs already had been.

By the middle of TL2, the Greeks and Romans were using ferrets, which also became lightly domesticated, to hunt rabbits. Ferrets were particularly well-adapted to pursuing vermin into holes too small for cats. Some dogs were bred to control vermin, too. With their greater size, terriers were used to hunt not just rats, mice, and rabbits, but sometimes larger prey, such as badgers and foxes.

Of course, vermin can be discouraged as well as hunted and killed directly. Ceramic containers are heavy, but do a good job of keeping out pests; raised platforms serve a similar purpose. Certain herbs repel vermin, and some pottery vessels dating to the Bronze Age are thought to be rat traps. Sulfur compounds were used for fumigation by TL2.

Irrigation caused several revolutions in agriculture. Intensive farming in dry areas, including such cradles of civilization as Mesopotamia and central Mexico, required more water than rainfall alone could provide. The construction of irrigation canals in the former example and earthen platforms in lakes in the latter led to much larger and more reliable crop yields. Around the third century A.D., a wet-farming technique was discovered for rice, in which flooding the rice fields early in the growing season led to much greater production.

The *Agricultural Productivity Table* (below) lists the amount of work farming requires per growing season (most areas have *two* growing seasons per year), typical harvests for a number of crops in pounds per acre, and the ratio of the amount harvested to that sown (and thus how much grain must be reserved for the *next* season's planting). At TL1/2, these figures assume the use of a pair of oxen and a wooden plow, and/or sophisticated irrigation networks; at TL3, they assume a pair of horses and a plow; and at TL4, they assume a pair of horses and a *metal* plow. Farmers without appropriate beasts and tools are restricted to the productivity of lower TLs.

The figures on the table are unremarkable average values for a single growing season. Depending on local weather and soil conditions, yields could be as high as those typical of the next-higher TL or as low as *nothing*. Water supply is particularly important. For example, grain requires from 600 (for maize) to 1,500 (for wheat) times its own weight in water; that's 5"-12" of rain over the growing season, or less rain supplemented by irrigation. Every 10% shortfall results in a 25% reduction in the harvest!

Agricultural Productivity Table

	TL0	*TL1/2*	*TL3*	*TL4*
Labor (man-days/acre)				
Field Preparation	5.75	2.5	1.75	1.25
Harvest	13.5	6	5.75	5.5
Harvest (pounds/acre)				
Barley	705	705	880	1,320
Legumes or Oats	280	280	350	550
Maize	790	790	990	1,485
Potatoes	2,815	2,815	3,520	5,280
Rice	355	355	800	1,200
Wheat	355	355	440	660
Yield				
Harvest:Seed Ratio	3:2 to 2:1	2:1 to 4:1	2:1 to 8:1	4:1 to 8:1

HERDING

In many societies, the average peasant farmer had a good chance of owning a domestic animal or two – particularly after the *secondary products revolution*, a series of developments around 3500 B.C. that led to beasts being used as renewable supplies of milk, feathers, eggs, and labor rather than as one-time sources of meat and hides. However, the time, labor, and food requirements for keeping livestock prevented most such farmers from breeding more animals than absolutely necessary. They would consume old animals that could no longer provide labor and young ones they couldn't afford to support. In Europe, there was a regular practice of slaughtering excess young livestock in the fall, before feeding them would impact the farmers' own food supplies. Many peasants only had meat seasonally, but when they did, it was usually veal, lamb, and suckling pig.

Most herders weren't typical peasant farmers, however. People who grew grain had to spend too much time tied to a single plot of land to raise many animals or to keep them moving between fields. While some herdsmen remained close to a home base, many migrated seasonally with their herds, moving tens of miles to new fields and temporary homes with the changing weather. Thus, herding was a separate profession from farming – and the fact that good pasture was also good farmland threw herdsmen and farmers into competition.

The *Animal Productivity Table* (above) lists *sustainable* yields of animal produce in pounds per acre per year. Someone with one or two animals may use the stats given in *Domesticated Animals* (pp. 14-15) to determine how much they produce, but for larger herds, consult the table. It assumes that most meat comes from a handful of juveniles and that the herdsman maintains a sex ratio that favors female animals (to produce more offspring and secondary products), but also that a number of young, pregnant, and elderly – but still useful – beasts are kept that give a reduced quantity of secondary products such as milk and eggs. The "Animals/Acre" column indicates how many animals occupy an acre of typical grazing land; divide one by that number to determine how many acres it takes to support a single beast. Cattle are particularly expensive to keep, while smaller animals are cheaper to keep and therefore much more common.

A herdsman can look after Animal Handling × (4 - SM) animals. For a team, use the sum of their Animal Handling skills; do the same for herdsmen with dogs. For example, a typical herdsman with Animal Handling-12 could handle 36 cattle (SM +1) or 48 sheep (SM 0) by himself. With a pair of dogs with Animal Handling-8, he could manage up to 84 cattle or 112 sheep.

Animal Productivity Table

Animal	*Yields (lbs./acre/year)*	*Animals/Acre*
Cattle	7 (meat), 4 (cheese), 3 (leather)	0.25
Sheep/Goats	13 (meat), 4 (wool), 2 (cheese), 1.5 (leather)	2
Pigs	21 (meat), 1 (leather)	2.5
Poultry	20 (meat and eggs), 1 (feathers)	100

Agricultural Environmental Quality

Like land used by hunter-gatherers (see *Hunting and Gathering,* p. 4-5), farmland may be rated as *Desolate, Very Poor, Poor, Typical, Good,* or *Excellent*. If farmers take over land from hunter-gatherers, or vice versa, the properties that make land decent for these two activities are sufficiently similar that the same quality grade may be used. However, quality changes over a different timeframe for farming.

Farmland's quality can decline over time, but increasingly sophisticated farming techniques slow soil degradation considerably. At TL0, anyone cultivating land must roll against Gardening once a year. At TL1+, he rolls against Farming, and has a bonus equal to TL. Any failure reduces his plot's quality by one step.

The *Agricultural Productivity Table* (p. 10) and *Animal Productivity Table* (p. 10) assume Typical land. For particularly high- or low-quality areas, adjust yields as shown on the *Quality and Productivity Table* (below). Modifiers for animal produce also affect the "Animals/Acre" column of the *Animal Productivity Table;* e.g., Desolate land supports 0.5 sheep/acre or requires 2 acres/sheep.

Quality and Productivity Table

Quality	*Grains*	*Cattle*	*Sheep*	*Pigs*	*Poultry*
Excellent	+25%	×4	×2	×2	×2
Good	+15%	×2	×1.75	×1.75	×1.75
Poor	-15%	×0.5	×0.75	×0.5	×0.5
Very Poor	-25%	×0.25	×0.5	×0.25	×0.25
Desolate	-80%	N/A	×0.25	N/A	×0.1

Beekeeping

Humans didn't just domesticate mammals. A few insects were domesticated, too – the most important of which was the honeybee. Bees were domesticated at least as early as 2500 B.C. By TL2, beekeepers kept bees in artificial clay hives and, much as is done today, calmed the bees with smoke before harvesting.

Bees provide two important products: *honey* and *wax*. Honey was universally the most prized sweetener until the development of sugar. Beeswax had a huge range of applications: waterproofing, lighting, cosmetics, encaustic painting, etc. A single hive can produce up to 20 lbs. of honey and half as much wax; however, it must be destroyed to harvest it, and requires years to rebuild. An acre supports up to five hives.

Environmental Impact

Agriculture can be its own worst enemy. Cultivation may pollute the soil or destroy it by overuse. And nutrient depletion is only part of the problem. For example, water used for irrigation carries minute quantities of salt, which is left behind in the soil. In the short term, that's not a problem; over centuries, though, it can render fields all but unworkable. By the Roman period, some places in Mesopotamia could no longer support wheat and would only grow sparse crops of barley.

Deforestation is an issue for any expanding or technologically advancing society: higher technology demands more wood for charcoal, while growing populations require more lumber for buildings, industrial equipment, furniture, and vehicles. Archaeological soil analysis indicates that the Mediterranean was heavily forested after the last Ice Age. Human occupation completely changed that environment, however, as people cut down trees to supply flourishing cities with metals (an active local metal industry can consume square miles of forest yearly), pottery, and shipbuilding. The decline of forests led to the land being covered with a variety of grasses and shrubs. Even low-tech firestick farming (p. 8) might have transformed forested areas permanently into grassland – after repeated burnings, grasses recover more quickly than trees and eventually dominate the landscape.

Grinding and Milling

The most important staple foods – such as grains and acorns – can be made easier to handle and cook by grinding them into a powder. Though heavy, grinding stones were sufficiently important that they were standard gear for small military units. Realistically, traveling adventurers are likely to carry them around, too. Grinding grain is hard work, costing 1 FP per hour.

Simple Hand Grinders (TL0). The earliest grinding tools were, essentially, two rocks. Typical examples are the *mano* (flat-sided handheld stone) and *metate* (coarse stone plate against which grain is ground), and the *mortar* (stone bowl) and *pestle* (stone beater used to grind grain against the inside of the mortar). Simple grinder that can process 4-5 lbs. of flour per hour: $50, 40 lbs. Small grinder for kitchen or laboratory use: $10, 8 lbs.

In rocky areas, make a Scrounging roll to find flat stones that can be pressed into service for free.

Improved Hand Grinders (TL1). Several improvements were made to the simple back-and-forth grindstone: grooves to let grain escape faster, a curved inner surface to improve contact between the upper and lower stones, and a hopper drilled into the upper stone for faster adding of grain. Grinds 6-7 lbs. of flour per hour. $75, 40 lbs.

Rotary Hand Grinders (TL2). One disk-shaped stone set atop another on a short axle, the upper held a fraction of an inch above the surface of the lower. A common variant uses a conical lower stone and a hollow cone above. Grain is poured into a hole in the center, and is ground and pushed through the mill as the upper stone is rotated. Grinds 15 lbs. of flour per hour. $95, 60 lbs.

Anything that walks, swims, crawls,
or flies with its back to heaven is edible.
– Chinese proverb

Cooking Methods

Once gathered, harvested, or killed, many foods were cooked to make them easier to chew and digest – or simply to improve their taste! Low-tech kitchens were very spare by modern standards, but TL0-4 cooks developed some remarkably sophisticated cooking techniques.

Direct Heat

The obvious way to cook food is by exposing it to direct heat, holding it over flames or setting it on hot embers. Tools were developed to keep fingers out of the fire and for heating liquid mixtures directly. Below, vessel costs and weights are relative to those under *Containers and Storage* in ***GURPS Low-Tech.***

Skewers and Spits (TL0). Most people cooked bits of food on the end of green twigs; these are free where live vegetation is available, and have negligible weight. From TL1, a metal skewer ($3, 0.2 lb.) – or a knife or a thrusting sword – could be used for slightly heavier foods or longer cooking. Repeatedly heating a blade isn't good for high-quality weapons! Roll 3d whenever a fine or very fine blade is used as a cooking skewer; on an 18, its quality drops by a step (e.g., very fine becomes fine). A large metal spit ($200, 11 lbs.) set up on posts can hold an animal carcass up to 200 lbs., enabling it to be rotated and roasted slowly over a fire; supports may be improvised from wooden poles or integral to large fireplaces.

Clay Cooking Pots (TL0). Heavy, round-bottomed clay cooking pots – available late in TL0 – went *in* the fire, resting securely on the coals. An uncovered cooking pot costs and weighs 60% as much as an appropriately sized pottery vessel.

Metal Pots (TL1). Compared to pottery, metal is far more resistant to repeated heating and cooling, transmits heat better, and reaches higher temperatures. Metal cooking pots could be held *over* the fire on a spit or a chain, making them easier to move than ceramic ones; they also made frying in oil possible. An uncovered metal pot costs and weighs 80% as much as a similarly sized metal vessel.

Pressure Cooker (TL4). A sealed metal cooking container with pressure-control valves, invented in France in 1679. Air pressure in the cooker increases with heat, raising water's boiling point. This cooks food in 1/4 of the usual time without burning. Low-tech valves are unreliable, however! Critical failure on Cooking or Housekeeping means the cooker *explodes,* doing fragmentation damage: 1d-1 cutting. Has 10× the cost and 5× the weight of an ordinary metal vessel of comparable capacity.

Heated Stone

A problem with direct heat is that it's a messy or impractical way to cook many foods without a heavy and/or expensive cooking pot. One workaround is to use heated stones. After 15 minutes in a fire, stones can reach temperatures approaching 1,000°F and, once dusted off, are clean enough to touch food.

Flat stones can serve as griddles. Late in TL0, bread ovens used the same principle in a more sophisticated fashion. Instead of putting a rock into a fire, a fire was built atop a fireproof surface that was enclosed to retain heat. When the oven was hot, the baker pushed aside the coals and put in loaves to bake.

A less obvious use is to cook soups and stews. A pit or a watertight container is filled with the dish's ingredients, and then hot rocks are added. Well-heated stones can boil three times their volume of water. California Indians used this method with watertight baskets, while Neolithic Celts used stone-lined, coffin-sized pits to cook entire feasts.

Heated rocks used as weapons inflict linked burning damage as a torch (p. B433). They *also* do 1d-3 burning damage per second to anyone holding them, however!

Temporary Containers

Instead of constructing heavy cooking pots, hunter-gatherers employed lightweight, disposable vessels for cooking. Many of their techniques continued to be used after the rise of agriculture. A skin bag or an animal's stomach, filled with food and placed over a fire, will scorch but not burn provided that its contents are wet; the water absorbs heat, keeping the vessel from burning. Ingredients might also be stuffed into a hollow branch, or wrapped in leaves and placed among hot coals to cook. As long as oxygen around the container is kept to a minimum, it chars slowly but keeps enough structural integrity to contain the food until cooked.

Temporary containers are usually free, made from leaves from nearby trees, entrails of the animal being cooked, convenient fallen branches, and so on. They weigh as much as a wicker basket of the same capacity – and, if they must be purchased, cost 10% as much.

Food Preservation

Food was preserved by making it an environment hostile to microbes. This might involve a combination of techniques, including depriving them of water, making the food very salty or acid, and adding ingredients with antimicrobial qualities.

Drying

Dried bean and grain products can remain edible for up to four years, provided that they're kept away from moisture and vermin. Foods whose water content is naturally higher – including meats and most fruits and vegetables – don't keep as well. Dried provisions are also easier to carry; reduce weight by 10% for most grains, or by 75% for moisture-rich foods. Such victuals must generally be rehydrated by soaking or boiling before eating, however.

Most foods were air-dried by being hung in an arid environment for a week. Deserts and steppes are ideal for this, but in temperate climates, winter air may be dry enough. While very water-rich foods don't dry well, a freeze-drying technique was practiced in the Peruvian highlands: potatoes were frozen overnight, trampled in the morning to crush out the moisture that collected internally, and then air-dried into a powder that could keep for up to four years.

Drying food requires a successful Housekeeping or Cooking roll. Roll against Housekeeping every six months to avoid spoilage.

Salting

Dried foods, particularly meats, may be cured with a thick coating of salt (using at least half the weight of the unsalted food). This provides an environment hostile to bacterial growth, draws out even more water than drying alone, and *halves* drying time. Salt-dried fish were a particularly important commodity in Europe during the Middle Ages. Salt-drying allowed Northern Atlantic fishermen to export their catch through Europe.

Like dried foods, salted foods should be rehydrated before eating. Salting gives +2 to rolls against spoilage in environments that aren't extremely dry.

Smoking

The primary benefits of smoking are that it kills microbes with heat and deposits a layer of chemicals with antimicrobial properties on the food's surface to slow future growth. Smoking itself has only lightly preservative properties, however, extending the life of food by just a few days; thus, it's most commonly an adjunct to other preservation techniques. In climates where simple air drying isn't an option, food is dried over a slow fire for about three days, and smoking is a side benefit of the process. Food is sometimes smoked simply to keep pests off as it dries.

Smoking gives an additional +1 to *other* preservation attempts.

Pickling

Water-rich plant foods are typically pickled, although this is also an option for meats. Foods are heat-sterilized and stored in brine, which may include vinegar. Many pickles slowly ferment, giving a distinctive sour taste. Pickled foods in sealed containers can last for several years, though the flavor may suffer after the first year or two. In many cases, the container's seal is likely to go bad before the pickles spoil. Even unsealed, pickles may last several weeks if treated carefully and fished out using only clean utensils.

Pickling requires half as much vinegar or salt as food to be preserved, as well as an appropriate-sized jar. Roll against Cooking or Housekeeping to prepare pickles. Make a Housekeeping roll every year to keep them preserved.

Spicing

Contrary to folklore, medieval Europeans didn't use pepper to hide the smell of rotting meat – anyone rich enough to afford pepper could easily afford *fresh* meat! However, many strongly flavored ingredients have antimicrobial properties, and thus can help prevent food from spoiling. Spices, herbs, and pungent vegetables believed to have such qualities include allspice, cinnamon, clove, garlic, mustard, onion, oregano, thyme, and turmeric.

Like smoking, cooking with spices doesn't provide long-term preservation. However, many preserved foods are *also* treated with spices, both for flavor and as an aid to real preservation techniques. If a cook uses a significant quantity of antimicrobial spices and herbs (at least 5% of the dish by weight), this gives +1 on rolls to avoid spoilage – or +2 if at least three *different* spices are used.

Fermentation

At TL1+, a number of foodstuffs were fermented as a means of preservation. Before refrigeration, this was often the easiest way to preserve food in the short term, and fermented flavors became highly prized. Examples include cheese, soy sauce, fish sauce (a wildly popular condiment in Rome and Southeast Asia), and aged butter (a prestigious condiment in Morocco). Most such things were simply cooked and left to age in cellars, caves, or sealed pots.

Preparing food for fermentation requires a successful Housekeeping or Cooking roll. To avoid spoilage, roll against Housekeeping every six months – or *weekly,* if the food is removed from a stable storage environment.

Freezing

Freezing is most easily practiced in arctic areas – where food will freeze unless precautions are taken to prevent it – but semi-arctic tundra also provides refrigeration. Such regions often have a layer of permafrost within a foot or two of the ground's surface. Chipping a hole into the permanently frozen layer of soil (permafrost is *very* hard; treat this as digging through solid rock) provides a natural deep freeze that can preserve food indefinitely. Food may suffer "freezer burn," but it can last for generations if protected from scavengers and climate change.

Chapter Two
Domesticated Animals

People surrounded themselves with animals for protection, transportation, food, and labor. Many of these changed over time.

Cattle

Although their ancestors were hunted through the Paleolithic, cattle were probably domesticated around 6500 B.C., in the Near East. The stats given here describe typical *historical* cattle. Those under *Oxen* (p. B460) reflect the results of modern ranching.

Live cattle provide both food and extremely useful labor. Effective plow harnesses for oxen (castrated bulls) are unsophisticated, allowing people to use these animals to help till fields starting in very early TL1. Cows produce milk, but significant milk production depends on exceptional pasturage or supplemental feed: 40 gallons per year on typical grazing alone, but up to 200 gallons with excellent grazing land or a supplement of $80 worth of grain per month. The best milkers might give up to 25% more (+1 CF per 5% increased production). Milk is typically turned into cheese at two pounds per gallon. The Maasai periodically bleed their cattle and consume the blood.

When slaughtered, cattle provide a great deal of meat (see *Butchering,* p. 6), plus 3-4 square yards of leather.

The drawback of cattle is their great size. Even the relatively small, underfed beasts of centuries past weighed close to half a ton apiece. As inefficient grazers, they required significant land for support. They also packed a great deal of value into a single animal, making them attractive targets for thieves.

ST 23; **DX** 8; **IQ** 3; **HT** 12.
Will 9; **Per** 10; **Speed** 5; **Dodge** 8; **Move** 5.
SM +1; 800-1,000 lbs.

Traits: Domestic Animal; Quadruped.
Cost: $1,200.

Dogs

Dogs were the first creatures to be domesticated, possibly as far back as 30,000 B.C. Already social hunters, they provided huntsmen with superior tracking and animal-driving capabilities. They could consume food waste and rubbish discarded by humans, making them surprisingly easy to keep. (A family can support a number of dogs from kitchen scraps equal to their Status squared, or one dog at Status 0 or below; additional dogs are $15 per month each.) They also served as an early warning system, hearing and smelling possible threats long before people could see them, and keeping more timid enemies at bay with impressive barking and snarling.

Over time, dogs were uniquely affected by selective breeding. They became highly susceptible to training and unusually capable of interpreting human voices, gestures, and facial expressions. Consequently, as agriculture gradually overshadowed hunting, dogs were kept into TL1 and beyond as guards and herding animals, patrolling the periphery of their charges' grazing range to run off or at least raise the alarm about predators.

While not specifically bred for combat, large dogs occasionally saw use in war. Dogs were bred to hunt vermin by the end of TL3. Toy breeds – purely pets – appeared first in China in TL3, and then in Europe by TL4. Dogs sometimes provided traction (mostly in northwestern North America) and occasionally meat (in East Asia and Mesoamerica), but neither was a major use.

ST 6; **DX** 11; **IQ** 4; **HT** 11.
Will 10; **Per** 12; **Speed** 5.5; **Dodge** 8; **Move** 9.
SM -1; 40 lbs.

Traits: Chummy; Discriminatory Smell; Domestic Animal; Quadruped; Sharp Teeth.
Skills: Brawling-11; Intimidation-10; Tracking-13.
Cost: $50.

Notes

These stats describe a *typical* mutt. Specialized breeds are available at +3 CF:

- *Herding* dogs have Animal Handling-8, which may only be used to direct herd animals. They can be trained to improve their Animal Handling skill.
- *Hunting* varieties have Brawling-12 and Tracking-15. Most are specialized for scent, but some are adapted for sight instead.
- *Toy* breeds have ST 3-4 and SM -3, and weigh no more than 10 lbs.
- *Traction* animals use the stats under *Large Guard Dog* (p. B457). Many such dogs are bred for near-arctic conditions, giving them Temperature Tolerance 2.

Less-common specialized breeds may have racial bonuses to skills such as Swimming or Climbing, or attributes limited to specific tasks, such as a higher ST only for dragging or digging.

Horses

The first domesticated horses appeared in western Asia around 3500 B.C., late in TL0 or very early in TL1. It's possible that they were independently domesticated elsewhere. These early horses were small by modern standards, but the remains of riding gear indicate that they were large enough to ride.

In addition to serving as beasts of burden, they provided some meat and milk. Specific breeds were slow to arise, though.

At TL0, the typical horse is relatively small; all horses use the saddle horse stats on p. B460, but have only ST 19. Better horses aren't impossible, but they're rare and – if for sale – expensive. *Double* prices for superior characteristics as determined on p. B457 and B459. The highest readily available ST for horses increases by one per TL until TL4; thus, ST 20 horses are available at no increased cost at TL1, rising to ST 21 at TL2 and ST 22 at TL3. As for the other horses on pp. B459-460, the cavalry horse becomes available at the listed price at TL2; the pony, by TL3; and the heavy warhorse and the racehorse, in TL4.

While versatile and capable, working horses are also expensive to keep. A common-quality horse that can be pastured regularly (e.g., one used for plowing or commercial carting) requires a ration of 0.75 lb. of grain a day, costing about $1 per pound. Between that and the requirements for additional care, notably shoeing, maintenance costs for a working horse can easily average $45 per month during the working season (plow horses often work for only part of the year, eating grass during the off season). Horses traveling through poor terrain that lacks suitable pasture, or simply quickly enough that they don't have time to forage, must be fed 3.5 lbs. of grain per day, plus 10 lbs. of hay at $0.25/lb. In particularly dry conditions, a horse might also need 5-8 gallons of water daily. Larger horses are even more expensive to keep; increase these costs and requirements by 10% per point of ST past 20.

Pigs

Pigs were most likely first domesticated in the Near East around 7000 B.C., and then separately in China not long after that. Unlike cattle, sheep, and goats, pigs produce no secondary products. They have the advantage of being cheap and easy to keep, however. They can forage for food in the woods, or consume kitchen scraps and other food waste; for pigs who can't forage, use the maintenance costs for dogs. If driven to a patch of wild land to forage, they're often tractable enough that the job of tending them can be given to children.

When slaughtered, a pig provides meat according to *Butchering* (p. 6), as well as 1 square yard of leather.

ST 10; **DX** 10; **IQ** 5; **HT** 12.
Will 11; **Per** 11; **Speed** 5.5; **Dodge** 8; **Move** 5.
SM 0; 120-180 lbs.

Traits: Domestic Animal; Quadruped.
Cost: $450.

Poultry

Domestic poultry first appeared in southern Asia in the eighth millennium B.C. They reached North Africa and China by 2500 B.C., and Europe perhaps a thousand years later. While impossible to train and difficult to lead, they can often be found in large numbers. In addition to providing meat, domestic fowl supply eggs, plus feathers for cushions and insulation. Most important, they're small enough to be inexpensive and can live mostly by scavenging, allowing even relatively poor families to have a few.

ST 3; **DX** 10; **IQ** 2; **HT** 10.
Will 10; **Per** 10; **Speed** 5; **Dodge** 8; **Move** 5.
SM -3; 3-7 lbs.

Traits: Domestic Animal; No Fine Manipulators; Peripheral Vision. Notoriously noisy geese have Penetrating Voice!
Cost: $25.

Sheep and Goats

Sheep and goats were the second animals to be domesticated, sometime around 9,000 B.C. in the Near East. Their bones are frequently indistinguishable, so archaeologists often refer to *ovicaprids* or *sheep-goats*. Domestic sheep appeared first, while the first unambiguous remains of domestic goats date to around 7500 B.C.

These animals are easily led and easy to feed, but they're very hard grazers. Left to their own devices, they can denude entire hillsides, exposing them to erosion. Herders must move their flocks frequently, although grazing land can be of low quality. Indeed, sheep and goats are popular in hilly areas where conventional agriculture is difficult. Goats are great climbers and can even go up small trees in pursuit of edible greenery.

While they're poor traction animals, sheep and goats provide a range of secondary products. Sheep and many breeds of goats provide wool, which was used at least as far back as 4000 B.C. Most sheep yield 1 lb. of wool a year, although some can provide more (+1 CF for 1.5 lbs./year, +3 CF for 2 lbs./year).

Certain breeds can be milked, too. Sheep and goat milks lack lactose, so they can be consumed where adult lactose intolerance is common (e.g., across most of Africa and Asia). Goat milk is closer to human milk than that produced by other animals, so it has been used medicinally. Goats produce 4 gallons of milk per year (usually turned into cheese, as with cow's milk) with grazing alone, but up to 10 gallons with a supplement of $20 worth of grain per month. Exceptional milkers might give up to 25% more (+1 CF per 5% increased production).

When slaughtered, a sheep or a goat provides meat according to *Butchering* (p. 6), as well as 1-1.5 square yards of lightweight leather.

ST 7; **DX** 9; **IQ** 3; **HT** 10.
Will 8; **Per** 10; **Speed** 4.75; **Dodge** 7; **Move** 5.
SM 0; 80-130 lbs.

Traits: Chummy; Domestic Animal; Quadruped; Temperature Tolerance 4.
Skills: Goats have Climbing-11.
Cost: $420.

Other Domestic Animals

Donkeys were domesticated in northern Africa by 4000 B.C., if not slightly earlier, and had spread through the Near and Middle East by 2500 B.C. The stats on p. B459 are generally suitable – although donkeys in early stages of domestication may have only ST 14, but also Reduced Consumption 1 (Water Only). *Mules* appeared in western Asia during the second millennium B.C. Being cheaper to keep than horses and oxen, donkeys and mules were popular beasts of burden. Donkeys used this way require about half as much pasture, food, and water as horses; mules, about 3/4 as much.

Camels were domesticated in western and central Asia around 2500 B.C. While primarily used for transport, they're sometimes used for meat and can produce some secondary products. They can provide about as much milk and hair as a goat.

Chapter Three
Heavy Equipment

At TL0-4, most work was done using hand tools. However, certain tasks could only be performed with larger machinery, from logs used as basic levers or rollers to complex cranes and mills. While some stats appear here, the real goal is to paint a picture of what a worksite might look like at a given TL – whether the project is building and bringing water to a single home or the Hanging Gardens of Babylon. For construction times and similar details, see Chapter 6.

Basic Machines

Basic machines are the simplest tools that can multiply or change the direction of force. The classical list of six was compiled by Renaissance philosophers, who included some relatively recent inventions. However, a few of them predate humanity.

Lever: A lever multiplies force by a factor equal to the length of the arm on which the force is exerted divided by the length of the arm on which the load rests. For example, a 100-lb. weight one yard from the fulcrum could be lifted with 50 lbs. of effort on the other end of the lever two yards away. While the philosopher Archimedes most elegantly *stated* the principles of levers, levers were certainly *used* in animal traps and some manufacturing by the late Paleolithic, if not earlier.

Pulley: A pulley allows the free movement of a cable over it, changing the direction of motion: pulling *down* on the cable moves the loaded end *up*. A single pulley is a reasonably effective tool for lifting light loads. Multi-pulley systems give greater mechanical advantage like a lever, with each additional pulley adding another factor to the multiplication of force.

Ramp: Ramps convert a portion of horizontal force into vertical force. Like a lever, a ramp makes it easier to raise an object, but at the cost of having to push it a long distance. See *Roads* (pp. 38-39) for details.

Screw: A screw is essentially a ramp wrapped around a cylinder. It converts torque into forward motion, and vice versa. Screws were the latest of the basic machines, employed as water-lifting devices in mid TL2, and as fasteners by TL3. Given the difficulty of manufacturing screws at low TLs, neither saw large-scale use.

Wedge: A wedge takes force applied to the end and exerts it perpendicular to the inclined sides. That is, if a V-shaped wedge is struck at the top of the V, the force of the blow is exerted outward from the sides. Wedges, in the form of hand axes, are among the earliest basic machines used by humanity.

Wheel: The wheel (technically, wheel and axle) provides mechanical advantage to torque by turning a wide wheel in order to rotate a narrower axle. The factor is similar to that afforded by a lever, equal to the proportion between the diameters of wheel and axle. Wheels and axles were invented at early TL1, but weren't widely used outside of transportation until waterwheels appeared late in TL2. Crank handles and winches – which use force exerted on the ends of spokes rather than on the rim of a wheel – were far more common, however.

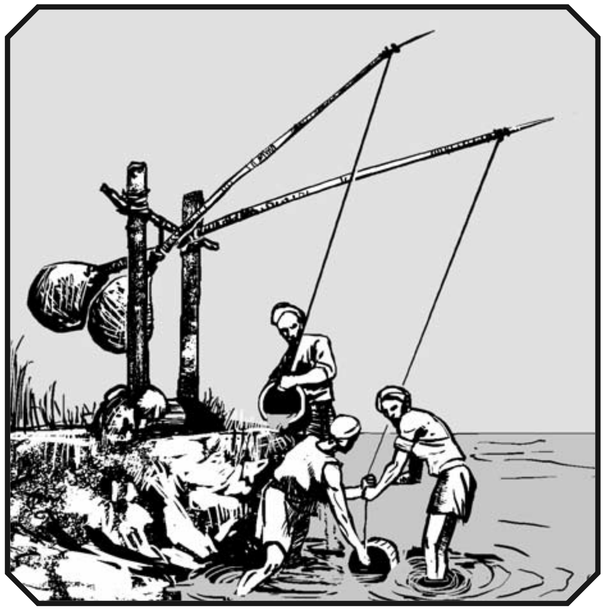
Construction Equipment

Unless otherwise noted, lifting devices can raise a load with an effective weight up to the user's two-handed lift (8×BL; see p. B353) at a rate of 1 yard/second divided by the divisor used to calculate effective load from actual load. For example, someone with ST 10 has BL 20 and a two-handed lift of 160 lbs. Using a block and tackle that divides effective load by 4, he could raise a load of up to 160 × 4 = 640 lbs. at 0.25 yard/second, or one yard every four seconds.

Basic machines predate humanity.

Lever (TL0). Levers can shift large weights easily, but can only move them a limited distance. The longest effective levers would be logs no more than 20' long. Allowing for the fulcrum and the load end, the maximum divisor is 10 (effective load is 1/10 of actual load). $50, 170 lbs.

Winch (TL1). An axle turned by a crank or long handles and supported over an open space, such as a well or a mineshaft, by posts on either end. When the winch is turned, a rope wraps or unwraps from the axle. A winch gives a divisor of up to 8 (effective load is 1/8 of actual load). At TL2, built-in catches prevent the load from dropping if the user lets go. Lightweight winch (maximum actual load 1,000 lbs.): $65, 75 lbs. Construction winch (maximum actual load 18 tons): $350, 400 lbs. These can be added to a crane for the listed weight and cost.



Block and Tackle (TL2). A set of compound pulleys for improved lifting. For $50, 30 lbs., the divisor is 2 (effective load is 1/2 of actual load), but the effective distance the load must be lifted is doubled. Each additional halving of the load, to a maximum divisor of 8, doubles cost and weight. This assumes a maximum actual load of 1,000 lbs. Heavy versions that can handle an actual load of up to 18 tons are available for +4 CF. A block and tackle may be added to a crane for the same cost and weight per line of cable.

Crane (TL2). The basic crane is a wooden triangle leaning slightly forward. Two long beams are fastened together at the top and set a few feet apart at the bottom, with shorter beams and guy ropes bracing the structure. Men at the bottom pull on a rope, which goes through a pulley at the top and lifts a load. Brackets in the vertical beams provide places to set the pulley assembly and serve as a ladder. Loads may be lifted one yard every four seconds. The basic crane provides no mechanical advantage. A 25' crane: $5,500, 6,500 lbs. A 50' crane: $22,000, 20,000 lbs. Maximum actual load for a basic crane is 6 tons, but up to three additional cable lines can be added for a 1.5% increase to cost and weight each, or 6% for additional lines for winches and treadles, which have a maximum load of 18 tons each.

Crane Treadle (TL2). A circular treadmill attached to an axle with a cable wrapped around it. Humans or draft animals step inside the wheel (8 yards in diameter, 4 yards wide) and walk on risers to rotate it, reeling in the cable at 1 yard/second. A treadle provides a divisor of 2 (effective load is 1/2 of actual load). Per line of cable: $5,800, 7,260 lbs.

Pile Driver (TL2). A one-ton weight used to pound logs into the ground for a firm foundation. A crane raises the weight and drops it to the ground, doing 23d crushing damage for a 25' crane or 33d for a 50' crane. $150, 2,000 lbs. (crane not included!).

Irrigation and Hydraulics

Hunter-gatherers can go to where the water is. Farmers and townsfolk don't have that luxury! As settlements grew and farms expanded, the water supply became a matter of vital importance.

The first question was where the water came from. Natural bodies of fresh water were preferred; rivers and lakes not only provided large volumes of water, but also fish and an easy means of transportation. Water sources often had to be created, though. Wells up to 100 yards deep had been dug by the end of the Bronze Age, although such heroic efforts were rarely needed. Underground *cisterns* – deep, covered pits lined with tile or stone, filled by streams or rain during wet seasons – were often used to store water. Unsurprisingly, cisterns were more common in dry regions, wells in wet climates.

As settlements outgrew local and seasonal water supplies, the next step was to bring water from elsewhere. Deliberate irrigation appeared late in TL0, not long after the beginning of intensive agriculture. Many early civilizations appeared in dry climates (Mesopotamia, Egypt, the Peruvian coast) and required extensive canal networks to support their growing size and complexity; it has been argued that the need to coordinate such construction led to more stratified societies and some of the first states. Most irrigation canals were simply ditches leading from a water source to the fields. While easy to build, these had to be dredged and weeded periodically to prevent them from becoming choked with silt and water plants.

Devices used to move water include:

Shadouf (TL0). This is a long pole with a bucket on one end and a counterweight on the other. The pole is set on a pivoting post near a water source. The operator dips the bucket into the water, lifts it up again (a task eased by the counterweight), and swings it over to a higher spot where it can be dumped out. The shadouf is simple to build and maintain, but time-consuming to use. It can move up to 1,000 gallons of water per hour to a height of up to three yards. $40, 30 lbs.

Archimedean Screw (TL1). This is a broad-bladed screw in an angled cylindrical shaft, turned by a crank at the top. Operating the crank causes the screw to draw up water from the bottom. An agricultural model, designed to irrigate fields from adjacent canals, can move up to 5,300 gallons per hour, but can lift it only 2' from its source: $80, 40 lbs. A model used to drain mineshafts moves only 400 gallons per hour, but has a 10' lift: $450, 120 lbs.

Saqiya (TL1). The saqiya is often regarded as a forerunner to the waterwheel, although it's essentially a waterwheel in reverse. A yoked animal attached to an axle is driven in a circular course to turn a wheel. The wheel has a series of buckets attached to the edge, with their open ends pointing in the direction of motion. As the wheel turns, the buckets are submerged and fill with water. When a bucket reaches the top of the wheel, the water pours out into an adjacent trough. A saqiya can move up to 3,900 gallons of water per hour, lifting it up to four yards. $3,000, 2,400 lbs.

Bucket Chain (TL2). A bucket chain is a ladder-like loop of connected buckets secured at the bottom by an axle and driven by an attached treadmill or waterwheel. The buckets in the chain dip into a body of water at the bottom and dump it out at the top. Bucket chains were occasionally used to move small quantities of materials on building sites, too. A bucket chain can move up to 4,800 gallons of water per hour, lifting it to a height of 10 yards. $6,200, 5,400 lbs.

Reg: And what have [the Romans] ever given us in return?
Xerxes: The aqueduct?
– Monty Python, ***Life of Brian***

Industrial Equipment

Unless otherwise indicated, these items are driven by a waterwheel or windmill that isn't included in cost and weight.

Large Saw (TL1). This 6'-long saw, with handles on both ends, *requires* two workers. Often, the log to be sawed is placed over a pit, with one man working from above and the other from below. Does sw-2(2) cutting damage per second; effective ST for damage purposes is the stronger user's ST plus 1/5 weaker user's score (round down). $400, 7 lbs.

Oil Press (TL1). Olives and other oil-rich materials were first crushed by mortar-and-pestle, specially adapted millstones, or edge crushers, and then put in coarse fiber bags and pressed to extract oils. The simplest presses, built by 5000 B.C. at the latest, had a shallow trough to hold paste. A heavy stone or wooden block placed atop this would slowly crush the oil out through a spout for collection; a wooden lever, a winch, or a turning screw might be added to press down on the weight and develop greater force. Presses could process up to 100 lbs. of material at a time, taking an hour at TL1 or half an hour with more sophisticated TL2 devices; additional pressings and treatment with hot water would eventually yield more oil of inferior character. It takes 6 lbs. of olives to produce 1 lb. of oil, total. Objects in the press take 1d+2 crushing damage per second. $500, 750 lbs.

Edge Crusher (TL2). A stone wheel up to 4' across, set on its edge on a circular track and attached to a pivoting axle. The wheel is rolled around its path using animal power, crushing material placed in the trough. Edge crushers are used for everything from olives to iron ore, processing about 30 lbs. an hour. A full rotation of the press takes at least 10 seconds and usually twice as long. Objects in the press take 2d crushing damage per pass. $850, 1,500 lbs.

Grain Mill (TL2). Although portable grain mills were used in the field, scaled-up rotary querns dominated everyday production. At TL2, mills using a single draft animal produced 25 lbs. of flour per hour: $750, 1,300 lbs. Larger mills using multiple animals turned out commensurately more. A one-horsepower *water*-powered mill could process 175 lbs. per hour: $1,200, 2,000 lbs.

Waterwheel (TL2). A waterwheel with ST 40 is 5' in diameter and costs $1,725, not including attached machinery (grain mill, sawmill, etc.). For a larger model, multiply diameter by the *square* of (desired ST)/40, and cost by the square of *that*. Horizontal wheels (TL2) have maximum ST 40 at TL2-4, and get only 90% of rated ST for useful work; however, they're the only option at TL2. Undershot and overshot wheels (TL3) have maximum ST 125 at TL3 and 175 at TL4. Undershot wheels have full rated ST; overshot wheels deliver 140% of rated ST, but require a mill race that isn't included in the above cost. Due to a lack of accurate measurements, the superiority of overshot wheels wasn't recognized until TL5, so builders tended to construct overshot wheels in hilly territory where falling water could be harnessed easily, and undershot mills in flat terrain.

Sawmill (TL3). Saws driven by water power were used for wood as early as the 13th century; near quarries, they were sometimes used to cut stone blocks as well. A powered saw does 4d(2) cutting damage per second per blade. $850, 150 lbs. *per blade,* up to eight blades.

Trip Hammer (TL3). These massive hammers used a see-saw arrangement: a waterwheel pushed the haft end of the hammer down, raising the head, and then released it, letting gravity take care of the rest. Small hammers weighing 150 lbs. could be driven as fast as 200 strokes per minute (4d crushing damage/strike), while bigger hammers of up to three tons could strike every other second (14d crushing); intermediate sizes struck faster the smaller they were. In metallurgy, hammers were used to pound slag out of iron blooms – starting with larger, slower hammers and moving on to smaller, faster ones – and to produce sheet metal. Lighter hammers were also used to process textiles. Small hammer: $280, 250 lbs. Large hammer: $8,000, 6,500 lbs.

Windmill (TL3). A windmill with ST 40 is 9' in diameter and costs $1,725, not including attached machinery (e.g., a grain mill or sawmill). For a larger mill, multiply diameter by the *square* of (desired ST)/40, and cost by the square of *that*. Maximum ST is 125 at TL3, 175 at TL4. Horizontal windmills deliver only 70% of rated ST, but are no smaller or cheaper.

Wire Mill (TL3). Wire mills created a back-and-forth motion, which pulled on a set of tongs at the end of a shaft or a rope. A metalworker would grasp the wire being pulled through a draw plate to draw out more wire as the tongs moved back, then release it as he leaned forward again to grasp the wire closer to the plate. Some wire mills put the worker on a swing, moving him back and forth through a broader arc, thereby enabling him to draw more wire per cycle than if he were standing on solid ground and leaning back and forth. $650, 520 lbs.

Wire Drum (TL4). This Chinese invention was a crank-driven rotating drum around which wire could be wrapped, connected to a ratchet that ensured that the drum turned only in one direction. It was used to make wire from softer metals. $300, 220 lbs.

"Well, the heart of it all is this cam shaft," said Simnel, gratified at the interest. "The power comes up via the pulley ***here,*** *and the cams move the swaging arms – that's these things – and the combing gate, which is operated by the reciprocating mechanism, comes down just as the gripping shutter drops in this slot* ***here,*** *and of course at the same time the two brass balls go around and around and the fletching sheets carry off the straw while the grain drops with the aid of gravity down the riffling screw and into the hopper. Simple."*

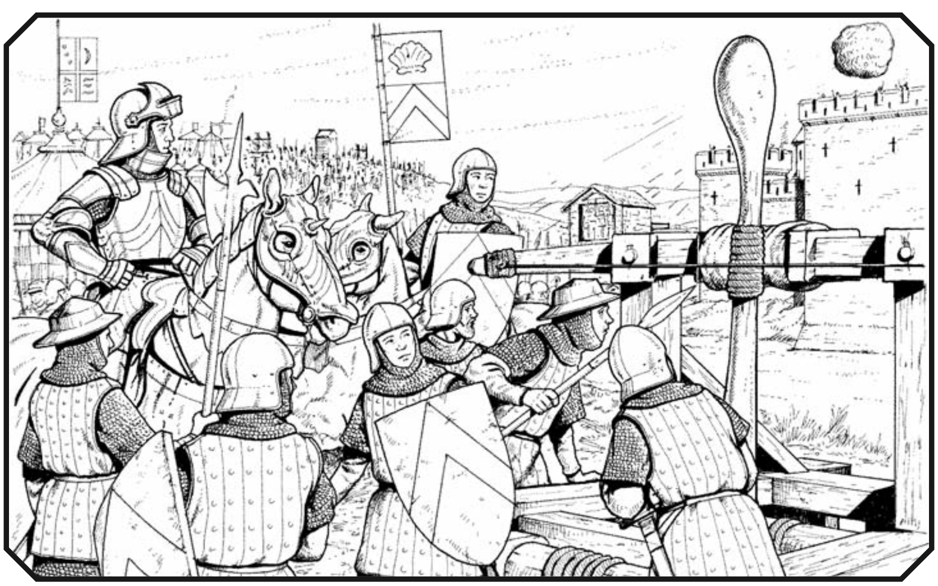
– Terry Pratchett, ***Reaper Man***

Energy Storage and Power Transmission

Before TL5, there were few ways to store energy, and those that existed were limited in scope. For example, crossbows (TL2), onager-style catapults (TL2), and a small range of counterweight-driven machines such as clocks and trebuchets (TL3) stored energy in the form of the tension on bent wood and twisted ropes, or the gravitational potential of suspended weights. However, most of those didn't store it for long, and expended what they *did* store in a single use; e.g., a weapon discharged all of its energy in one shot. For the most part, "energy storage" meant laying in supplies of wood, charcoal, and food.

Power transmission was slightly more sophisticated. As early as TL1, power could be transmitted via shafts, pulleys, and other basic machines. Wagon axles appeared by 3500 B.C. However, *bearings* were primitive – a collar around the axle or a cap into which the axle's end fit – and while they might be lined with smooth bone or lubricated using grease, friction was high, making them inefficient. Log rollers lubricated with water or oil were used at least as far back as the construction of the Pyramids, but the principle wasn't adapted to smaller-scale applications until much later. Ball or roller bearings were invented in about the third century B.C. in China, and shortly thereafter around the Mediterranean. Instead of smooth sides, bearings had a groove around the inner surface holding balls or short shafts, producing less friction.

Gearing also appeared almost simultaneously in China and around the Mediterranean, shortly before 200 B.C. It enabled devices where a wheel's motion was transmitted to other parts of a machine – but sped up, slowed down, changed into a different plane, or even converted to back-and-forth movement. However, while ancient engineers understood the relationships of gears, there were subtleties of tooth shape and materials engineering that they hadn't mastered, leading to inefficient gear trains that jammed easily. And while gears, shafts, and belts could be used to transmit power, no one had discovered how to regulate the speed of motion; a machine moved with the same force as its power source. Power regulation was a TL3 invention, in the form of clock escapements.



Chapter Four

Mining and Excavation

The earliest methods of obtaining metals and metal ores hardly qualified as mining. Dense minerals eroded away from their source by moving water tend to collect in places where the flow slows: where a stream's slope becomes shallower, at a bend in a river, beneath a waterfall, etc. Such accumulations of heavy particles, called *placer deposits,* could be carted away by anyone with a shovel and a bucket. While gold placers are best-known in the modern era, deposits of iron ore – which have a distinctive glossy, black appearance – supplied many early civilizations with significant quantities of metal.

Iron deposits might in fact be found in almost any terrain, including muddy alluvial plains where other minerals – even stone – are rare. Some early Iron Age civilizations, particularly in northern Europe, used *bog iron,* a form of oxide iron ore that can form in wet conditions. It required somewhat more processing than many other iron ores, but it was available near the surface, and more often covered with dirt and mud than with rock.

For a few centuries at the beginning of the Bronze Age, surface deposits sufficed to meet the light demand for metal. The pattern repeated itself in the early Iron Age, with societies getting by on easily gathered iron sands and bog iron. As demand rose and surface and near-surface deposits were depleted, though, miners had to tunnel through solid rock. The first challenge was figuring out *where* to dig.

Locating Minerals

Prospectors looked for any number of surface signs. Eroded hillsides could reveal veins of ore – but in any terrain, surface minerals and even changes in vegetation could indicate deposits. For example, blue or green minerals suggest copper ores, shiny black or grey may indicate iron, and vegetation is sparse in pyrite-rich soil near iron sources.

The utility of the Prospecting skill depends on TL. At TL0, it can be used to find useful clays and minerals – e.g., stones suitable for tool use – but *not* metal ores. While a prospector might discover some attractively colored minerals that happen to be ores, he wouldn't be able to evaluate them properly. At TL1, it can also turn up native metals, and ores of copper, silver, tin, and lead, but not iron. At TL2+, it can locate iron, too.

Excavating Mines

After locating a likely spot, low-tech peoples took two approaches to mining. Labor-rich societies (e.g., the Roman Empire) dug large, open pits, avoiding the problems of lighting and ventilation. This method was also used for most building stone, which was typically found over wide areas rather than in small veins. Where labor was at a premium and valuable deposits were tightly concentrated, smaller mineshafts were dug, creating sometimes vast tunnel networks.

The simplest excavation method was to bang away at a stone face with another rock until the target crumbled. Chisels were used to cut grooves into stone. Crowbars in the grooves then split off sections of rock. Mining implements were made of the hardest materials available, and the basics varied little from one time and place to the next – everywhere, the miner's tool kit consisted mainly of hammers (often with a flat end and a pointed one, much like modern rock hammers), chisels of various sizes, and crowbars.

> *. . . let [farmers] leave to miners the gloomy valleys and sterile mountains, that they may draw forth from these, gems and metals which can buy, not only the crops, but all things that are sold.*
>
> *– Georgius Agricola,* ***De re metallica***

Wedges also saw use. These were thin but wide. Some were accompanied by slim metal shims on either side so that they would touch more metal, not the stone itself. Striking the wedge with a heavy hammer drove it down and split the stone along the groove.

For larger chunks, miners might drill a series of holes several feet deep around the desired block. Then they would insert a wooden pole into each hole and pour water over the poles. As the water-soaked wood expanded, it split the stone.

Fire was used, too. Miners built a fire on the area of rock to be excavated and then allowed it to cool. Heating and cooling cycles caused the rock to crack and crumble; dousing the heated area with water sped cooling and increased cracking. Rubble was carried away where it came off naturally and was easier to break off where it didn't. However, not all societies favored this technique, as it filled the mines with smoke, making them difficult to work for a long time after the fire was out.

Explosives – a fixture of modern mining – were rarely employed. Engineers were quite aware that gunpowder could be used for blasting rock. However, its high cost prevented widespread use until the 17th century.

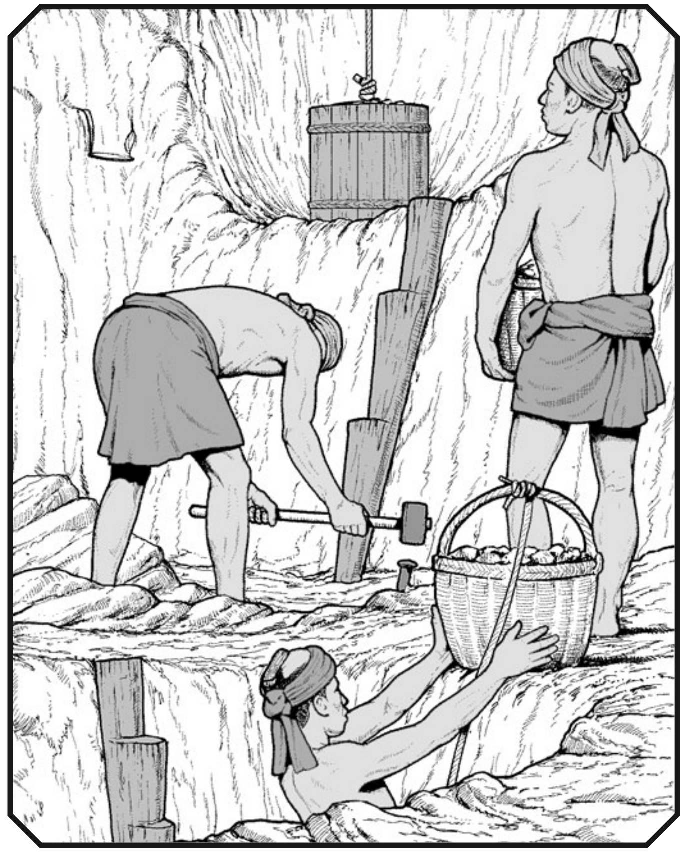
Where shafts were needed, classical miners frequently sank them in parallel pairs. This improved ventilation and provided clear "in" and "out" paths. Most shafts were large enough to admit a single person carrying a load, but no wider. Typical mineshafts were at most a little less than two yards square; the Romans often dug them narrower at the bottom than at the top, reflecting the profile of a man carrying a heavy load on his back. Some were even narrower, with a cross section as small as three square feet!

Using metal tools, as miners usually did, excavators can dig as much as BL×10 cubic feet of mineshaft per day through soil (about 16' of typical 5'×2.5' shaft) – but no more than BL/2 feet per day through stone (just under a 1' length of shaft). Divide the volume of tunnel that can be dug per man-day by the excavation's depth in yards; e.g., digging a shaft through soil 10 yards down would go at a rate of 1.6' per man-day. Mining should be supervised by someone with the Engineer (Mining) skill. Roll weekly when digging mineshafts, monthly for an open pit. Failure means a cave-in or a collapse threatens the miners; any miner who fails a Dodge roll suffers 2d+3 crushing damage. On a critical failure, Dodge is at -1 and damage is 3d+3.

Instead of digging tunnels, narrow shafts a few inches across – often for wells – could be drilled using metal bits and long series of poles and cables. Typically, shafts up to 1' in diameter were dug with a pounding technique. A derrick similar to a pile driver (p. 17) pounded a pointed bit into the ground, loosening soil and rock to be pulled up by a bucket at the end of a rope. Deep Chinese wells of the first century B.C. could reach several hundred feet underground – although at a rate of a yard to as little as an inch of excavation a day, they could take *years* of work to reach their final depth.

Ventilation

For shallow mines, natural ventilation provided air circulation – but greater depths called for forced air. The most frequent solution was flapping fans, sometimes driven by water power starting in the Middle Ages. The Greeks occasionally used fire to improve ventilation: A small additional shaft was dug along with the one the miners used, and intersecting it near the bottom. This had a small shelf near the bottom on which a fire could be built. The heat of the fire sped exhaust through that shaft, increasing the rate at which air was drawn in elsewhere.



Drainage

One of the greatest obstacles to mining was water. Experts observed sadly that many mines contained valuable minerals but couldn't be mined below a certain depth before being flooded by groundwater. Water-lifting devices were thus crucial to mining and employed at all significant mines. The practical height limitations of early water-lifting gear meant that such machines had to be set up in series, each pulling water from a pool filled by the one below. The need to pump water was such that the first industrial steam engines – which appeared late in TL4 – were used to drive mine pumps, not vehicles!

I was born one mornin' and the sun didn't shine
I picked up my shovel and I walked to the mine
– Merle Travis, "Sixteen Tons"

Chapter Five

Manufacturing

Anyone with appropriate tools and skills can turn raw materials into finished goods. Job rolls cover the routine output of such craftsmen. However, it's sometimes useful to know how much time and material are required to make individual articles.

Material Costs

An item's cost has two components: *materials* and *labor.* For equipment with a listed weight, consult the "Cost" column of the *Raw Materials Table* (below) to find the cost of the necessary weight of raw materials from the item's weight. The "Production" column indicates the weight of material (in lbs.) that workers can produce on an average day. For new goods that PC craftsmen come up with, the GM should make approximations based on existing equipment.

All prices on the table assume ready access to the natural resources from which the materials are processed. In practice, scarcity and transport costs can drive up prices. For example, compared to iron, most metals take much less labor and fuel to produce, but are also at least an order of magnitude less abundant on Earth; thus, they were historically more expensive. The cost of copper in the Classical Mediterranean was $18/lb., while tin was over $122/lb.!

Raw Materials Table

Material	Cost ($/lb.)	Production (lbs./day)	Notes
Animal Products			
Bone/Horn/Shell	$3.55	4	
Leather	$3.00	6	[1]
Fiber			
Cloth	$1.15	15	[2]
Raw Fiber	$0.10	160	
Thread/Yarn	$0.30	63	[3]
Metals			
Iron	$6.90	3	
Soft Metals	$4.30	6	[4]
Stone and Ceramic			
Earthenware Pottery	$0.40	43	
Glass	$2.10	11	
Porcelain	$1.25	19	
Raw Clay	$0.20	80	
Rubble	$0.25	64	[5]
Shaped Stone	$0.75	32	[6]
Stoneware Pottery	$0.80	30	
Wood and Wicker			
1/2" Plank	$5.20	3	[7]
1" Plank	$2.70	6	[7]
2" Plank	$1.45	12	[7]
4" Wood Post	$0.85	20	[7]
8" Wood Post	$0.40	43	[7]
Pitch	$4.00	4.5	[8]
Raw Wood	$0.25	64	[9]
Wicker	$0.80	20	

Notes

[1] Armor-weight leather (DR 2) weighs 0.5 lb./square foot. Heavy jacket leather (DR 1) weighs 0.25 lb./square foot. Wallets, tents, and other leather items may be made from much lighter leather, as little as 1-2 oz./ square foot.

[2] Price is for very rough cloth, suitable for sacks and coarse cloaks; 1 lb. is equal to about 10 square feet. Finer fabric using thinner but more tightly woven thread can easily be several times as expensive but much lighter per square foot. See *Clothworking* (p. 30) for more technical details. The *Luxury Pricing* rules in ***GURPS Low-Tech*** may apply to grades of cloth.

[3] Price is for coarse, undyed thread; 1 lb. is equal to about 640 yards.

[4] Includes copper, zinc, lead, and other metals available at TL1.

[5] Raw stone picked up from the ground or rapidly excavated with pick and shovel.

[6] Stone intentionally cut or ground to a particular form – whether for sculpture, a building, or a tool. *Halve* price for particularly soft stones (e.g., gypsum and sandstone), but *double* it for very hard stones (e.g., jadeite and marble).

[7] Before complex sawmills were invented, lumber costs more per pound for thinner pieces. When buying wood, calculate price per pound by its *thinnest* dimension.

[8] Use the same price for other organic adhesives.

[9] Includes roughly chopped trees, dismembered branches, and other essentially unprocessed bits of wood. Double price for charcoal.

Skills for Preparing Materials

Most materials are prepared using a Professional Skill; e.g., Professional Skill (Clothmaker) for cloth. Those listed below involve other skills or special defaults. In either case, assume that preparing a material and producing items from it use the *same* skill, in the absence of specific rules.

Bone, horn, and shell: Machinist at TL0-2.
Charcoal, pitch, and tar: Professional Skill (Charcoal-Burner).
Clay: Artist (Pottery).
Fibers: Professional Skill (Sericulturist) for silk; appropriate Animal Handling specialty for animal fibers; Farming for plant fibers; or Professional Skill (Clothmaker) for any fiber.
Food (preserved): Cooking or Housekeeping.
Leather and fur: Professional Skill (Tanner), defaults to Leatherworking-3.
Metals and alloys: Metallurgy.
Paints: Artist (Painting).
Stone and mortar (for building): Masonry.
Stone tools: Machinist/TL0.
Thread: Professional Skill (Clothmaker).
Wood: Professional Skill (Forester), defaults to Carpentry-3.

Labor Costs

An item's labor cost is its list price minus the materials cost. For novel goods, the GM must again extrapolate a cost based on existing articles. Labor costs are *typically* one to four times materials costs, depending on how much work the craftsman must do to turn the materials into a finished product.

However, some artifacts – e.g., sword blades – are *exceptionally* labor-intensive, with labor costs many, many times material costs. Conversely, the more expensive decorative embellishments usually have a greater proportion of their cost in materials; it takes about the same amount of effort to decorate something with beads whether they're made from semiprecious stones or common shells, but the former cost more. For goods made mostly of silver, materials account for 80% of the finished item price. For anything made largely of gold and/or gems, materials cost is 98% of the final price.

To determine how much active work time an item takes to manufacture, divide the labor portion of its cost by the labor pay rate. Most craftwork is carried out at workshops employing a mixture of craftsmen, apprentices, and unskilled workers. Thus, the actual rate will be lower than the pay of the appropriate craft professional (see *Occupations,* pp. 45-49):

- *Routine work, including production of most undecorated, utilitarian goods.* Less-skilled workers do the majority of the labor under a master's supervision. Monthly labor rate is (craftsman's monthly pay) × 0.55.
- *Artistic or high-performance work, including arms manufacture and the decorative options from* ***GURPS Low-Tech.*** This requires more involvement by a master. Monthly labor rate is (craftsman's monthly pay) × 0.75.

Divide monthly rates by 25 for *daily* rates, by 200 for *hourly* rates.

Active time isn't necessarily the total start-to-finish manufacturing time, though. Most items are produced by workers doing tasks in concert with one another – that is, an item that takes two days of work is probably made not by one person working for two days but by two people working together for a day. To find actual manufacturing time, divide active time by the number of craftsmen and assistants involved, to a maximum of six people.

Example: A carpenter makes a 9' ladder. According to ***GURPS Low-Tech,*** this costs $90 and weighs 22.5 lbs. The GM decides that the wood involved is closest to 1" planks at $2.70/lb. (the wood is certainly thicker than 1" at its thinnest, but probably thinner than 2", so he uses the cost for thinner lumber). Total materials cost is therefore $60.75. This means the labor costs $29.25. A carpenter at TL4 makes $790, so the *hourly* rate for basic carpentry is ($790 × 0.55)/200 = $2.17. Thus, the ladder calls for $29.25/$2.17 = 13.5 man-hours of effort. A carpenter and five assistants could make one from lumber in just over two hours.

However, many processes *also* require long delays while heated items cool down, wet items dry out, or organic substances ferment. Add *at least* a day for anything that's heated, or soaked and dried, regardless of how many work hours are involved. The sections on specific crafts (pp. 25-32) note timescales and complications for several important industries.

Crafting Rolls

After the labor has been expended, make a skill roll to determine the work's quality, using the *highest* craft skill among the workers involved. Apply *Equipment Modifiers* (p. B345), where relevant. Faster or slower work gives the modifiers under *Time Spent* (p. B346), but haste only reduces *active* time; e.g., a potter or a glassblower can roll at -5 to produce an item in half the usual time, but it will still take a day to cool down enough to be usable. Roll separately for each decorative embellishment.

• Failure by 4+ gives junk! At least half of the raw materials are lost.

• Failure by 1-3 indicates a functional-but-flawed finished piece – a pot is misshapen, a cabinet lid is askew, etc. Tools will give users the penalties for *improvised* equipment. Weapons and armor are *cheap*. The article will sell for at most half price. For attempts at decorative embellishments, this outcome reduces the piece's value (-0.5 CF) but doesn't destroy it.

• Success by 0-11 yields an article of *basic* quality. For armor or a weapon, this means *good* quality.

• Success by 12-17 means that non-combat gear is of *good* quality. Armor is *fine*. A weapon is *either* fine *or* balanced – craftsman's choice. For decorative work, this result *doubles* the embellishment's CF; e.g., if an artist attempted a complex painted decoration for +5 CF, his unusually skilled work gives +10 CF.

• Success by 18+ gives a *fine*-quality example of most items. Armor is *very fine*. A weapon is *either* both fine and balanced, *or* very fine, where applicable – craftsman's choice. For decorative work, this outcome *quadruples* the embellishment's CF.

The *Crafting Table* (below) summarizes these details. Critical success *doesn't* impact quality beyond margin of success. Some craftsmen may know craft secrets that make it easier to produce high-quality equipment; see *Craft Secret Perks* (below).

Crafting Table

Margin	*Armor/Weapon Quality*	*Tool Quality**	*Decoration Quality*
Failure by 1-3	Cheap	Poor/Improvised	-0.5 CF
Success by 0-11	Good	Basic	–
Success by 12-17	Fine	Good	CF×2
Success by 18+	Very Fine	Fine	CF×4

* See *Equipment Modifiers* (p. B345). Fine-quality tools *are* the "best equipment possible" at TL0-4.

CRAFT SECRET PERKS

Perks (pp. B100-101) can represent specialized bodies of knowledge associated with broader craft skills. Craftsmen may buy one such *Craft Secret Perk* per 20 points total in related craft skills. An individual who holds a craft job (see *Occupations*, pp. 45-49) – or with a suitable craftsman or craft guild as his Ally or Patron – may purchase one *further* perk per 10 points in job skills.

Craft Secret Perks most often cover knowledge of how to make special materials or work in styles limited to particular geographical regions. Some examples by trade:

Alchemists: Greek fire.
Glassblowers: crown glass.
Masons and architects: concrete; Gothic construction; quarrying (this required specialized expertise beyond that of the typical mason, and particularly poor regions occasionally lacked qualified quarrymen); vaulting.
Potters: luster glazing; porcelain; tin glazing.

Such perks were often jealously guarded secrets, and someone who learned a single, particularly prized craft secret in one region could make a vast fortune if he practiced it elsewhere. Historically, Crucible Steel (below) would have been immensely lucrative if practiced in medieval Europe. Perks for making Greek fire, luster glazes, and porcelain likewise would have been worth a huge amount of money. Thus, the GM may want to restrict access to Craft Secret Perks. Entire campaigns could be built on their pursuit!

EXAMPLE: METALWORKING PERKS

Eligible craft skills for these sample perks include Armoury (Body Armor or Melee Weapons), Jeweler, Metallurgy, and Smith (any). Every 20 points in skills allows a perk. Anyone actually working as a smith or an armorer may buy one *additional* perk per 10 points in skills.

Crucible Steel

The smith can produce a small quantity of high-quality steel that may subsequently be used to craft any metal object. The process requires $20 worth of materials per pound of steel to be produced. It demands five man-days per batch; there's no bonus for taking additional time. Make a Smith roll to manufacture the steel, at -1 per full 3 lbs. of steel in the batch. Success yields an ingot that, if *successfully* used to craft something, improves margin of success by 5 when determining that item's quality.

Everything has its limit – iron ore cannot be educated into gold.
– Mark Twain

Graceful Blade

The armorer carefully controls the weight and shape of all parts of a weapon during production, using a working knowledge of human anatomy to arrive at a well-balanced blade that fits well in the user's hand. Using Graceful Blade gives -4 to skill and *doubles* base crafting time. Any success produces a blade with which one individual – whom the armorer must study for a day before starting work – may buy a Weapon Bond (+1 to skill for him). Success by 5+ yields a balanced weapon (+1 to skill for anyone). Success by 9+ means the blade is balanced *and* suitable for Weapon Bond.

Masterwork Blade

The armorer knows subtle, difficult techniques for producing a sword that combines hardness with resiliency. Using Masterwork Blade gives -5 to skill and *doubles* base crafting time, but gives a fine-quality sword on any success – or a very fine weapon on success by 12+. This perk is available for TL2-4 smiths; at TL5, methods of producing homogenously high-quality steel appear, rendering it obsolete.

Arms and Armor

Weapons and protective gear cost more per pound than almost anything else a low-tech society produces – and with good reason! Lives depend on them, and they place high demands on both raw materials and craftsmen.

Weapon Composition

Many weapons are composite, combining a wooden shaft with a head of a different material. Some 1/3 to 1/4 of the weight of an axe or similar weapon is wood, as is about 3/4 of the weight of a spear or an arrow. The rest is metal or, particularly at TL0, stone.

Most other weapons are entirely wood or entirely metal – or nearly so. They're made from a single material with negligible quantities of others; e.g., sinew for the string of an otherwise wooden bow. As long as any incidental materials are accessible, assume that their costs are accounted for in the overall cost.

Superior arms and armor often require higher-quality – and thus costlier – materials:

- *Bows.* The best designs require superior wood and other materials; *double* raw materials costs for longbows and crossbows, *triple* them for composite bows.
- *Swords and plate armor.* These require extensive working; *double* raw materials costs to account for the large quantities of additional charcoal necessary.

The GM may allow use of particularly fine materials – e.g., select pieces of wood for bows, or high-quality iron ores for steel weapons – to add up to 5 to effective margin of success on the roll to produce armor or a weapon, *if* the roll succeeds. See *Crucible Steel* (p. 24) for an example. It's entirely realistic for the GM set extreme costs for superior materials (see *Luxury Pricing* in ***GURPS Low-Tech***), or even to have materials become unavailable as their sources are consumed (e.g., wood must be expertly cut and seasoned long before use, so supplies are likely to vanish quickly if demand is high) or cut off by war, political conflict, and natural disasters.

Weapon-Making

Craftsmen producing weaponry nearly always roll against Armoury (p. B178), but different items use different specialties, which in turn may have different defaults:

Cannon: Armoury (Heavy Weapons) at TL3+.
Guns: Armoury (Small Arms).
Melee and thrown weapons: Armoury (Melee Weapons).
Missile weapons, including bows, crossbows, slings, and their variants: Armoury (Missile Weapons).
Siege engines: Armoury (Heavy Weapons).
Siege equipment other than missile-firing engines (e.g., siege towers and rams): Engineer (Combat).

The GM may allow a -3 default to the non-Armoury craft skill(s) usually used to work the weapon's material(s): Carpentry-3 to make bows, Leatherworking-3 for whips, etc.

Armor-Making

Armor-making requires the Armoury (Body Armor) skill. Each type of armor calls for different raw materials and tools, and allows different defaults:

- *Textile armor.* Made either by stuffing padding between two layers of cloth or by quilting together multiple layers of textiles. Manufacture defaults to Sewing-3.
- *Leather armor.* Made by shaping thick pieces of leather to conform to various body shapes, and then treating the leather for stiffness. Production defaults to Leatherworking-3.
- *Metal armor.* Mail consists of thousands of metal links made from coiled wire and linked into a mesh. Segmented plate is quicker to make; narrow bands of plate are laced together or riveted to leather straps. Making either defaults to Smith-3.
- *Scale armor.* Made by lacing or wiring small plates (metal, leather, horn, etc.) into a row and then attaching the rows to a textile or leather foundation garment. Making it and other composite armors could default to any of several skills – notably Leatherworking-3, Sewing-3, or Smith-3 – depending on the component materials. Choose the *lowest* applicable default.
- *Plate armor.* A special case of metal armor that must also be shaped to conform to the body. The basics of its manufacture are straightforward: fashion metal plates, cut and hammer them into the appropriate shape, and then rivet them together. This process is extremely complex, though, and demands a *very* skilled armorer. Craftsmen roll at -1 per Armoury skill level below 14; thus, skill 14+ is unaffected, but skill 13 works as 12, 12 as 10, and so on. Unlike simpler metal armor, such as mail or scale, plate armorers need a workshop full of specialized tools, including an array of anvils in different sizes and shapes.

In theory, metal armor involving large plates *could* be handmade by a single armorer and his assistants. In practice, this proved impractical; most such work was distributed between specialists. In many sophisticated cultures, metal armor-making was regulated, if not directly controlled, by the state.

The preparatory stage involves taking detailed measurements of the intended wearer. Next, a pattern is marked onto a sheet of plate. The armorer doesn't usually produce such sheets himself, but purchases them from specialty dealers known as *platers,* who mass-produce sheet plate with the assistance of water-powered trip hammers.

Once the pattern is marked, the armorer cuts out the piece with shears. Careful filing, bending, and hot and cold hammer work force the metal into shape. Hammers are kept polished to present the smoothest face while working a piece.

To prevent cracking during this process, the steel is *annealed* (softened with heat). Throughout these steps, the armorer must ensure that the armor is of the appropriate thickness, which varies depending on the body part being covered.

At this stage, the customer is often called back in for a final fitting, after which minor adjustments are made. When the pieces are completed, the edges are cropped with shears and usually rolled over a wire to prevent weapons from glancing into a vulnerable area. Individual sections are riveted together, and then straps and buckles are attached. Once lined with padding, the armor is serviceable but ugly, covered with hammer marks and black from the forge. Munitions armor may be shipped out in this "unfinished" condition, but better-quality armor is polished and decorated.

Furnaces

Even with charcoal, open fires can heat objects to perhaps 1,000°F at most – and that assumes an item buried in smoldering coals. For higher temperatures, heat must be contained and focused.

Early pottery was produced by covering it with fuel and a thin layer of dirt as an insulator. This developed temperatures sufficient to make earthenware and melt some metals. It was ultimately just a well-organized bonfire, however, and provided inadequate temperatures and airflow control for more serious work.

Early in TL1, smiths and potters began to build dedicated furnaces from brick, stone, and earth. These had three essential parts: an *airway* near the bottom, a *firing chamber,* and *exhaust holes* at the top. In pottery kilns, the airway was at ground level or in a ditch; the central chamber had a perforated platform above the fuel, or shelves around the sides, to hold unfired pieces. In metalworking furnaces, the airway was often above the furnace's floor. Melted metal settled in the bottom, or was drawn away through a separate drain.

Both types of furnace saw use for millennia, with variations. Longer chimneys increased airflow, while sophisticated airways allowed the craftsman to control the amount of oxygen reaching the interior. Most furnaces were at least partly built and torn down with every use. More sophisticated designs became more permanent, evolving from a V-shaped wall or a half-excavated pit to a permanent brick or stone chamber with doors.

In TL4, airflow developed to the point where furnaces could melt iron. In most places, this was accomplished by water-driven bellows pushing air through the furnace. However, in 13th-century Sub-Saharan Africa, small furnaces using hand-driven bellows reached similar temperatures. The process required the assistance of several men, and produced very little iron, but the furnaces weren't tied to large, expensive waterwheels.

Smelting

Like most things, turning ore into metal is easier in theory than in practice. Smelting was a specialized task practiced by a minority of smiths, who should know Metallurgy (p. B209) as well as Smith. While ores *do* turn into metal when sufficiently heated in an appropriate environment (usually surrounded by charcoal), they're rarely very pure – or in a state that makes for efficient smelting – when extracted from the ground. Therefore, they're processed extensively.

A first step in ore processing is *crushing* or *grinding.* Reducing ore to a powder exposes more of it to whatever processes it will be subjected to later. Through TL1, it was crushed with hammers or ground with a mortar and pestle. Purpose-built crushers appeared at TL2. At TL3, water-driven equipment replaced muscle.

Washing to remove lightweight components, concentrating the ore, is common. This is done in a sloped trough with a ridged bottom. Ore is placed in the trough and water run over it. Heavier metal ores sink to the bottom, while lighter particles are rinsed away.

The next step is typically *roasting:* heating the ore to a point below the desired metal's smelting temperature. This dries the ore for serious smelting, drives off volatile materials, and sometimes removes small quantities of other metals with lower smelting and melting temperatures. Again, this concentrates the ore and prepares it for more efficient smelting. It also makes the ore more friable for subsequent rounds of crushing and washing.

After preparation, the ore is loaded into a furnace with charcoal – taking about a day per 200 lbs. – and fired for 12-24 hours. This time might also include the construction or partial reconstruction of the furnace itself, from excavated slopes, stacked stones, and piled earth. During and immediately after firing, metal must be separated from *slag,* a leftover mass of other minerals. Slag with a lower melting point might simply run off, but the addition of a *flux,* such as lime or silica, can help the process. However, flux often takes some of the desired metal with it.

Some ores must be smelted twice, in effect – or at least in a two-stage process. Many metals have oxide and sulfide ores. Oxide ores are simply heated in a low-oxygen atmosphere, drawing the oxygen out of the ore and leaving pure metal behind. Sulfide ores, however, can't be converted directly into metal. They have to be cooked first in an oxygen-rich atmosphere to draw out the sulfur, replacing it with oxygen. After that, the converted ore is smelted normally. This process is more costly and time-consuming, but as sulfide ores are much more common than oxides, its invention unlocked large quantities of metal.

Purity of the finished metal and efficiency of smelting are often opposed. Classical smiths could produce 99%-pure silver from ore, but the resulting slag contained 5-10% of the ore's original silver content. Slag left behind by fifth-century B.C. Greek miners at the mines at Laurion contained so much silver that Imperial Roman miners worked them over profitably for half of their silver content . . . and 18th-century miners worked over *those* tailings gainfully! By the Renaissance, silver could profitably be extracted at a rate of 0.5 lb. per ton of ore.

Once smelted, metals are formed into ingots for transport. Historically, copper ingots were 40-80 lbs. – as large as a laborer could reasonably carry. Iron, which couldn't be combined in large pieces so easily, ended up in blocks of 10-15 lbs., still more than large enough to make all but the largest iron items.

Fine Metalwork

Metals are exceptionally malleable, and a number of techniques developed to take advantage of that property.

Depletion Gilding (TL1). This process, historically restricted to South America, uses an alloy of copper and gold (sometimes with silver added) called *tumbaga.* The untreated alloy might resemble gold or copper, or be reddish-silver, depending on its exact composition. However, treatment with vinegar or salt water oxidizes the copper and silver, which can then be polished off to leave a surface of pure gold. Depletion gilding may be a Craft Secret Perk (p. 24) related to the Jeweler skill.

Gilding (TL1). Metal leaf was made by pounding small ingots with a hammer. When the metal became too thin to strike without tearing, it was placed between layers of leather to spread out the impact. A single ounce of gold could be pounded out to nearly 80 square feet; assume that a jeweler can produce Jeweler skill × 4 square feet from an ounce of precious metal. Any solid object can be brushed with glue and covered with leaf.

Hammered Wire (TL1). Wire appeared early in TL1, first produced by hammering on a grooved anvil or using a hammer with a thin groove. Most early wire was made from softer metals such as gold and silver, and was for decorative use. A smith can hammer Jeweler skill × 1.5 yards/day of wire from precious metals or Smith skill × 0.5 yards/day of iron wire.

Soldering (TL1). Early soldering was done in a furnace. Metal parts were placed together with metal shavings and a flux. In the furnace, the shavings melted and bound the solid pieces together. The ancient Egyptians and Mesopotamians used gold and silver as solder, making it expensive. At TL2, tin-lead solder was developed.

Drawn Wire (TL2). Drawing was practiced with softer metals early in TL2 and with iron by the time of Imperial Rome; while still arduous, it was faster than hammering. A metal ingot, the thinner the better, was filed to a long point at one end; the tip was pushed into a hole drilled through a stone block; and the end was grasped with pliers and pulled through the hole, stretching it to greater length and narrower diameter. The wire was drawn through progressively smaller holes until it reached the desired size. Drawn wire could be several yards long, but between small inclusions causing weak spots and the clumsiness of dealing with great lengths, it was rarely produced in large spools like modern wire. At TL4, water mills were turned to the task, yielding both longer and cheaper wire. Wire made from industrial metals such as iron and bronze was manufactured for applications where stiffness was valued: mail, sewing needles, fishhooks, and cards for processing fibers. The thinnest wire for mail was just under a millimeter thick, in the range of piano wire (wire strong and flexible enough for a garrote didn't arrive until late TL4, with the invention of brass-wrapped silk strings for musical instruments); gold and silver wire could be much thinner, but wasn't particularly strong. Drawing increases wire-making speed by 50%; industrial tools double wire-making speed.

Amalgam Gilding (TL3). Gold and silver become so soft in *amalgams* (mercury alloys) that they can be pressed and even spread like butter onto an object's surface. Heating the item removes the mercury, leaving a layer of precious metal stuck to the surface.

Etching (TL3). Etching provided a fast, easy way of making a design on metal. Iron and copper alloys were prepared for etching by covering them with wax or varnish. The artist scratched a design into the surface and then treated the item with an acid, which lightly corroded the exposed metal. Almost any metal object could be etched for decoration. By TL4, flat etched plates were used for printing images.

Screws (TL3). Early screws were made from thick wire, cut into sections. A smith had to cut a groove around the screw by hand using a file. Screws weren't pointed at the end until early in the modern era; at TL3-4, they could as easily be called "bolts," although nuts to thread onto the end didn't yet exist.

Pottery

The raw material of pottery is *clay,* which is available almost everywhere. In some areas, the soil is so clay-rich that it can be made into pottery without processing. In most places, though, it must be refined. Soil is mixed with a large quantity of water in a pit and left to settle. The larger, heavier particles of sand and silt precipitate out first; the tiny particles of clay, last. After a day or two of settling, the potter can scrape a layer of pure clay off the top. Unskilled laborers with shovels can do most of this work, although a craftsman with Artist (Pottery) should supervise them.

Low-fired pottery doesn't need anything mixed into it, but the potter may add *sizing* for particular purposes. The inclusion of sand and crushed bits of previously fired pottery makes the fabric of the pottery more difficult to work and harder on the fingers, which is a particular problem when using faster wheels. It renders the piece rougher and harder to decorate, too, possibly limiting its suitability for anything but utility purposes.

However, those same ingredients impart resistance to high heat and rapid changes in temperature, making the resulting wares suitable for cooking, lab work, and other high-temperature applications.

Feldspar- and quartz-derived clays are more resistant to slumping when fired at high temperatures. Such good clays are relatively rare and valuable; finding them would be a suitable use of the Prospecting skill. Sizing can be beneficial for these, too. However, high-fired pottery is often produced for luxury trade, and rough sand would ruin the appearance. Thus, sizing is likely to be a finer material such as ground glass or alabaster.

At TL0 and well into TL1, pottery was formed entirely by hand – the potter shaped a lump of clay as a whole piece, built up his work from slabs, or rolled clay into long strings and coiled them. The pottery wheel was invented around 2700 B.C., and even then it was a "slow wheel" resembling a tabletop Lazy Susan: an unpowered revolving platform that helped the user form a symmetrical piece. The earliest wheels were simply stuck into the ground on a post, with later models developing more elaborate pivots. Faster kick-wheels, which turned with sufficient speed to actively help shape the piece, didn't emerge until the 16th century A.D. Factories producing pottery on an industrial scale appeared in large empires by mid-TL2. Many used stamps and forms to mass-produce standardized vessels; such tools grant from +1 to +4 to Artist (Pottery), but only to make vessels of the size, shape, and decoration for which the equipment was made.

Once formed, a clay vessel could be decorated using a dizzying variety of techniques. Historical examples included painting; incising with a pointed tool or comb; burnishing; impressing figures with carved stamps; impressing textures with basketry, cloth, or other objects; appliqué with separately formed figures; and piercing for function or decoration.

Clay is available almost everywhere.

For long-term liquid storage, earthenware can be treated to retain water. A thick layer of *slip* (a liquid solution of very fine clay) or vigorous polishing before the piece is fired can reduce water loss. More effective, though, is a *glaze*.

Glazes made with wood ash first appeared in Mesopotamia around 1600 B.C. Painted onto the surface of an unbaked pot, potassium in the ash lowered the melting point of silica in the clay and made the surface vitrify when fired; trace iron and copper provided blue and green colors. Later glazes used other elements, such as lead and sodium, which provided more durable or more attractive finishes. Tin glazes, yielding an opaque white finish, came to be used in imitations of Chinese porcelain, and by 800 A.D., Egyptian potters had developed complex methods for including metallic ores in glazes to give pottery surfaces a thin layer of gold, silver, or copper. Muslim and Chinese potters also developed "hidden" decorations – subtle applications of special glazes, metallic lusters, or shallow incisions under layers of other decoration – that were visible only from certain angles. The preparation of glazes falls under Artist (Pottery) skill, and the most valuable processes might qualify as Craft Secret Perks (p. 24).

Once the piece has been formed and decorated, it's left to dry; usually, a day or two will do. Then it may be fired. The simplest pottery kiln is a shallow pit, which provides insulation and shelter from the wind. After initial warming to reduce thermal shock, pieces are placed on a layer of coals and covered with fuel and earth. Such piles can reach sufficiently high temperatures to fire earthenware pottery within an hour, although they may be left to sit for several hours until the pieces cool down enough to handle. Open-hearth pottery requires about four times its own weight in firewood or half that much charcoal. More sophisticated kiln designs reduce the required fuel to about the same weight in wood as the pottery itself.

Stoneware and porcelain require much more time and fuel to fire. They also call for purpose-built kilns, and their vitrified structure means that the vessels must cool down slowly to avoid cracking the glassy parts. The earliest high-fired pottery demands up to eight times its weight in firewood or four times its weight in charcoal, reduced by three quarters by the end of TL4. The firing cycle takes two to three days.

Firing is sometimes a more complex process than that, though. Most pottery is fired in a low-oxygen atmosphere, which prevents blackening, but potters who *want* a blackened surface might let more air through. Glazed pots may be fired at a low temperature to bake the clay, cooled, treated with a glaze, and then fired a second time at a higher temperature for long enough to vitrify the glaze but not so long as to melt the clay. Particularly complex pieces may have yet another layer of surface treatment and require a third firing.

Around 4000 B.C., potters from Egypt to India started making an intermediate material between pottery and glass: *faience*. Made from crushed quartz, this could be formed like clay (though not very well – it was suited to pressing into forms or cutting into slabs, but not to hand- or wheel-shaping) but fired to a colorful, glassy finish. It was used to produce attractive yet relatively inexpensive ornaments and vessels. Faience started to lose popularity after the development of pottery glazes, and vanished not long after the development of blown glass. *Fritware,* a similar ceramic, appeared in the 11th century A.D. in Egypt and Iran. With small quantities of clay and ground glass added to crushed quartz, very thin vessels could be translucent.

Woodworking

Carpentry starts with wood. For the serious carpenter, woods *aren't* interchangeable. Species widely used through history include:

Bamboo: Technically a grass, bamboo is fast-growing, strong, and flexible, but very light (22 lbs./cubic foot). It's also *hollow,* making it useful for piping. Bamboo's major drawback is its poor durability; structural members made from it may need replacement every few years, where harder woods last for decades or even centuries.

Cedar: A softwood (23.5 lbs./cubic foot), cedar is faintly and pleasantly aromatic – with insect-repelling properties – making it popular for furniture.

Cypress: Cypress is a harder wood (32 lbs./cubic foot) and a good structural material. It's particularly resistant to water, making it excellent for ships. However, it grows best in wet, even swampy areas, so it might not be available in drier regions.

Ebony: Exceptionally dense (65 lbs./cubic foot; ebony sinks in water!), this attractive, black tropical wood is used primarily for furniture and decorative inlay. It has rarely been plentiful enough for architectural use.

Fir: The tall, straight trunks of firs (*many* species, around 33 lbs./cubic foot) are prized for ships' masts.

Oak: One of the more common hardwoods (47.5 lbs./cubic foot), oak is widely valued as a structural material. In addition, hunter-gatherer societies often use its acorns as a food source.

Pine: While less desirable than hardwoods for most uses, pines grow quickly and in dense stands, are more durable than many other softwoods, and may be found throughout the northern hemisphere, even into near-arctic regions. Many species are also good sources of pitch. Pines have a wide range of densities, from 23 to 41 lbs./cubic foot.

Teak: Comparable to oak in density, teak has superior natural resistance to weather and insects. Historically, teak was found only in tropical regions of Asia.

Willow: While relatively light (26 lbs./cubic foot), willow grows very straight, making it a good light-duty structural material. It's also an excellent source of pitch, its ash has chemical uses, and the bark is medicinal.

Yew: Yew's short, twisted trunks yield poor building lumber, but the internal structure of the relatively dense wood (48 lbs./cubic foot) makes carefully cut sections remarkably springy and resilient, and thus exceptional for bows.

Many carpentry and woodworking techniques go back to the Bronze Age, if not before. The tools used to carry them out have improved tremendously, however.

A primary carpentry task is turning felled trees into useful pieces of wood. For simple construction, little work is needed beyond stripping off protruding branches and cutting the trunk into suitable lengths. Naturally, more sophisticated carpentry requires more sophisticated techniques.

To produce boards and posts, a trunk may be split while still green and flexible, using a tool as simple as a polished stone axe. Rough planks might be finished with an adze or more axe-splitting to square the sides, and then "sanded" with a series of stones that grow progressively less rough. But most shaping is done after the wood is *seasoned:* left to dry for weeks or months. As wood dries, it shrinks and can warp, so woodworkers usually wait until it reaches a stable, dry condition. Some shaping is done as part of the drying process; e.g., curved handles for tools might be bent and clamped to a form while still green, and left to dry for up to a year, during which time they become more rigid in the desired shape. Seasoned lumber is also easier to transport, weighing 20-30% less than green wood.

The *Raw Materials Table* (p. 22) gives nominal rates for lumber production. If the laborers aren't supervised by someone with Professional Skill (Forester) or Carpentry at 12+ (at least one supervisor for every six workers), work will go more slowly. Find the highest supervisory skill in the group – which might well be a default – and reduce daily production by 10% per skill level under 12.

Many approaches were taken to fitting together pieces of wood. Lightweight wooden furniture and even architecture could be secured by *tying:* wrapping multiple lengths of cord around a joint to keep two crossing members stable. Most work, however, required more elaborate joining techniques – *dovetails, lap joints, mortise and tenon, tongue and groove,* etc. In the era before readily available screws and metal nails, joints were usually made by cutting members so that they would fit closely together and lock one another in place with only a bare minimum of glue or other reinforcement. When drills were used, wooden pegs could be inserted through pilot holes as a means of fastening, particularly when held in place with glue, although cut joints remained a primary method of joining.

While many of these techniques were used as far back as the Mesolithic, metal tools introduced during the Bronze Age sped the work considerably and provided room for greater elaboration. Most notably, metal saws made it much easier to produce boards of even size and thickness. Metal staples and nails made from drawn wire slowly came into use, particularly during TL2 when iron nails became possible. In TL3, water-driven sawmills sped the initial processing of logs enormously where water power was available.

Functional woodworking (making furniture, barrels, boxes, etc.) requires a Carpentry roll. Artistic embellishments call for Artist (Woodworking). The two skills default to one another at -3, though, so a good carpenter can do competent decoration, while a capable artist can produce reasonably useful wooden items.

Glassmaking

Although glass is made from sand, not just any sand will do. Low-tech glass requires silica, but coral atolls and most Mediterranean beaches consist of calcium-rich minerals with almost no silica. Glass may also contain minute quantities (less than 1% by weight) of other substances to provide clarity or color. Copper gives light blue; cobalt, dark blue; iron compounds, greens; gold dissolved in acid, red; tin, milky white; and iron and sulfur, yellow and brown. Since none of the historical sources of raw materials were particularly pure, the resulting glass was almost always colored or cloudy. Finding high-quality sand for glass production is yet another use for the Prospecting skill.

Glassmaking was often a two-step process. First, the mixture was heated to cook off volatile compounds and create an unformed *frit.* Then the frit was melted down to be formed into a desired shape. Early glassmakers were limited to a few pounds per batch, but by the Middle Ages, glass factories equipped with large furnaces similar to those used for smelting might produce several tons of colored frit at a time.

Standard glassblowing tools and techniques developed in the first century B.C. have changed little since their introduction. The basic tool is a metal tube about 6' long. Glass kept molten in a crucible is gathered onto one end, and then the glassblower blows through the pipe to produce a glass bubble.

The bubble may be returned to the crucible for another coating or two of glass as the piece grows.

Most of the work, though, is in turning and shaping the piece. It needs to be moved close to the furnace frequently so that it remains pliable, yet it must not get so hot that it slumps. It also has to be turned steadily over the heat so that it maintains an even temperature. Shaping is done with dampened wooden paddles and fabric, tongs, and specially designed shears. The bubble is sometimes blown inside a form, pressing up against the sides to take on elaborate figurative shapes. Finally, the shaped piece may have other glass parts – e.g., handles and decorations – applied to it while still hot.

Late TL2 saw the invention of techniques to produce flat plates. Glass was molded into cylinders that were cut open and laid flat, or the end of the bubble was cut off and carefully spun to open it into a disk. By the ninth century A.D., flat plates of colored glass were being used in stained-glass windows.

However it was shaped, blown glass, once formed, would be left in a furnace for several days to cool slowly to prevent cracking. To distribute heat more efficiently, a common furnace design had three chambers, stacked vertically. The lowest contained a fire, the next contained melted glass, and the top was used for annealing. The cooled glass might be further polished or engraved using a rotating stone or metal wheel.

Glassblowing wasn't the only method of producing glass objects. Even after that art was developed, glass beads were produced by cutting bits of glass from rods and firing them until they melted and took on a round shape. *Tesserae* for Roman and Byzantine mosaics were probably produced by cutting blocks of colored glass.

Fortune is like glass –
the brighter the glitter,
the more easily broken.
– Publilius Syrus,
Maxim 280

Roll against Professional Skill (Glassblower) to make a glass item. For convenience, use the same skill name for TL1 core formation (described under *Glass* in ***GURPS Low-Tech***). However, artistic arrangements of glass – stained-glass windows, mosaics, etc. – call for Artist (Glassblowing).

Clothworking

Custom has it that it takes four spinners to supply one weaver. In many settings, this means that a spinner produces from 300 (for very fine thread) to 400 (for coarser yarn) yards of thread per day. Since length rather than weight is the limiting factor, this could correspond to anywhere from two to 10 ounces of thread daily. Historically, spinning thread was a traditional bit of household labor. Using a drop spindle to make thread could be done one-handed and often was, while the user carried out other household tasks for at least part of the day; thus, a weaver might be supplied by a far larger number of part-time spinners. The spinning wheel (TL3) reduced the ratio to about one spinner per weaver, but also made spinning a dedicated occupation instead of something done part-time by the members of any household.

The size of pieces of cloth is limited by loom size. Since most looms were set up so that the weaver could work while seated, pieces wider than a person's arm span and longer than a seated individual's reach would be special projects. Thus, most cloth was at most two yards wide and often no more than 1.5 yards long. Width limitations persisted though TL4, but horizontal loom designs – which limited length only to that of the available thread – appeared by 5000 B.C. Even then, pieces of cloth were rarely more than 10-20 yards long; longer pieces could be woven for special purposes, but they would be more difficult to set up on the loom and harder to transport once finished.

Decorative variations are endless on even the simplest looms. Many texture and color patterns can be created by using contrasting colors or thread dyed in sections, or by modifying the in-front/behind alternation while passing the weft through the warp. Shorter segments of thread might be woven into sections of the weft to produce complex geometric or figurative patterns.

Cloth quality is typically associated with the thickness of the threads and how closely they're woven. The base cloth on the *Raw Materials Table* (p. 22) uses 640 yards of thick thread (weighing 1 lb.) for 10 square feet of fabric – or 9,600 yards of thick thread for a 15-lb., 5'×30' bolt of cloth – at eight threads per inch (that is, each square inch of cloth has eight warp threads and eight weft threads). It would take four to six days to set up and weave on a loom.

A mid-grade fabric might incorporate twice the length of thread (around 18,000 yards), but since it would use finer, thinner thread, it would end up weighing half as much per unit area: 1 lb. per 20 square feet, or 7.5 lbs. for a standard bolt. It would also take about twice as long to set up and weave. The finer thread would be more expensive – four or more times basic cost per pound, since it requires more labor and superior raw materials. Such a fabric would cost at least $2.64 per pound or 20 square feet.

Highest-quality fabric would take nearly three times the length of thread (26,400 yards of vastly more expensive thread), but weigh a *quarter* as much and require *triple* the production time (18 to 20 days). Final cost would be $7.16 per pound or 40 square feet. Finer cloths are far more likely to be dyed, further increasing their value.

Most operations with fibers require Professional Skill (Clothmaker). Since making thread and cloth was, historically, such a common household task, the GM may allow this skill to default to Housekeeping at -4.

PAINTING, DYEING, AND PIGMENTATION

When graphic arts appeared around 30,000 B.C., artists had a limited palette to work with. Pigments were derived mainly from mineral sources, which unsurprisingly offered earth tones. *Sienna, umber,* and *ochre* – all containing iron oxides – provided a range of yellows, reds, and browns. Charcoal and other iron oxides yielded black. While common and inexpensive, these TL0 pigments were rather dull. Many colors were absent, outside of a few extremely short-lived vegetable dyes. Dyers went to considerable trouble and expense in the ensuing millennia to find blues, greens, and purples, and superior reds and yellows.

Red: Cinnabar (mercury sulfide), popular in Egypt and Central America, was one of the earliest improved reds. In addition to its vivid color, it has a high refractive index, giving it a distinctive appearance. Other red pigments came from organic sources. One of the most popular – appearing in late TL1 or early TL2 – was derived from shellfish of genus *Murex.* The resulting color was called purple, although it would look more like burgundy to modern eyes. The Mayans (TL1) developed *carmine* or *cochineal,* a high-quality red pigment processed from several cactus-dwelling insects. The root of the *madder* plant provided a relatively inexpensive red dye during the Middle Ages.

Yellow: Orpiment (arsenic sulfide) was another Egyptian development. It makes a good yellow, but it's also toxic. *Saffron* was exploited as a superior yellow dye by 1000 B.C., and may have been used in paint even earlier. *Turmeric* entered use at some point thereafter, predominantly in eastern Asia; it isn't a great pigment because it fades quickly in light, but it's inexpensive enough to make re-dying fading cloth feasible.

Blue: The first blue pigment, appearing around 5000 B.C. in Egypt, was ground blue glass. This couldn't be used as a dye material, though, and when used in painting had to be sprinkled over a wet paint or adhesive so that it stuck to the surface. Ground *lapis lazuli* and *azurite,* more amenable to use in paints, were also employed as blue pigments; azurite is easier to obtain but takes on a greenish cast in paint. The Egyptians created the first artificial pigment by mixing copper and silicon compounds to get a vivid turquoise. *Indigo,* a blue dye produced in various concentrations by many different plants and even a few mollusks, was developed by several different societies early in TL2. The best indigo came from India, but specially processed murex yielded a high-quality indigo, and the early Britons processed a pale, dilute indigo dye from *woad.*

Green: Green pigments were derived from copper compounds. *Terre vert,* a pale green copper salt, was lightly used in prehistory. Ground *malachite,* which provides a vivid deep green, entered use by TL1. *Verdigris,* obtained from corroded copper, yielded green and blue-green pigments. In most media, though, the color fades or turns a brownish green quickly unless given a varnish topcoat to protect it from air.

In many cases, pigments could be combined to give other colors. For example, green cloth might be made by dyeing fabric first yellow and then blue. Mixing different paints yielded any number of hues.

The first paints were simply wet pigments. Early artists mixed pigments with protein-containing binders such as blood or egg whites (late TL0), or milk (TL1). Watercolor and egg-based tempera paints predominated for millennia. In Europe at late TL2, they were challenged briefly by *encaustic* painting, which used pigments mixed with hot wax. This produced vivid colors and interesting textures, but the wax-based "paints" solidified quickly when removed from heated vessels, making the technique laborious.

Vegetable oils appeared as binders for paints as early as 500 A.D. in Central Asia. Linseed oil boiled with pine resin and pigment, developed around 1100 A.D. in Europe, produced a fleshier, shinier paint. This became the dominant European painting medium by the middle of TL4.

Dyes with superior colors often make up for their cost by requiring very little dye to be effective; e.g., indigo dyes four times its weight a deep blue, cheaper madder dyes twice its weight a deep red, and inexpensive (near its source, anyway) turmeric dyes just a third of its weight yellow. For most pigments used as dyes, fibers are simply soaked in a dye solution for a few hours. From at least as far back as TL2, many fibers are treated with *mordants:* chemicals that make fibers absorb and hold dyes better, including plant ashes, urine, vinegars, and alum. Cloth – or, more often, unwoven fiber – is added to simmer briefly, and then lifted out to dry. It might be immersed multiple times for deeper colors.

With dying, as with many processes, there are exceptions. For example, brown dye made from walnut shells needs no mordant; that and the cheapness of the raw material made it a popular color for the poor. On the other hand, indigo needs more than just a mordant. It must be isolated from oxygen to dissolve in water – a goal often achieved by using urine or ammonia. The resulting indigo solution is yellow, but dyed cloth slowly turns blue once exposed to air.

Cinnabar, indigo, malachite, ochre . . .

Locating and obtaining pigments can involve many different skills:

- *Gardening* to grow dye plants amenable to cultivation, such as woad and madder.
- *Naturalist* to find plants and animals in the wild that can be used to produce dyes.
- *Professional Skill (Glassblower)* to make colored glasses to grind for pigments.
- *Prospecting* to locate mineral pigments.

Processing the raw materials calls for Professional Skill (Dyer) for fabric dyes or Artist (Painting) for paints. Pigment production has always been an important part of the chemical industry, so any pigment-making skill may default to Chemistry at -4.

Brewing and Distilling

The fermentation of fruit juice into alcohol occurs naturally. Indeed, animals are sometimes observed getting drunk from eating overripe fruit! Crushing fruit into juice and letting it ferment into wine is simply organizing the process. Fruit produces half its weight in juice – that is, one needs about 1 lb. of raw fruit per cup of juice, or 16 lbs. per gallon.

Fruit juices are by far the best historically accessible sources of fermentable sugars, but it's possible to ferment any sugar-rich solution to produce alcohol. Where bees are exploited, honey can be turned into *mead,* its alcohol content similar to that of beers and wines. Several cultures of horse-riding nomads – from Hungary to Mongolia – fermented mare's milk, which is unusually high in sugar, into *kumis,* a mildly alcoholic beverage (perhaps 2% alcohol).

Brewing grain into alcohol was a significant economic development. Instead of putting considerable labor into growing inessential fruit to turn into wine, any surplus in the grain harvest could be made into a fermented beverage such as beer, ale, or sake (for brevity, such drinks are collectively referred to as "beer" hereafter). Grain needs help to ferment, however – alcohol-producing microbes can't consume starches. When exposed to appropriate enzymes, though, starches are converted into sugars, which the microbes *can* work with.

In most of the Old World, barley was allowed to sprout, which naturally produced starch-breaking enzymes. In the simplest processes, *malt* (sprouted grain) was left to ferment, yielding a thick, cloudy, mildly alcoholic brew (at most 3% alcohol). More complex recipes involved filtering an extract from the malt and adding yeast from a previous brewing to the sterilized extract.

In some of the New World, enzymes were introduced by chewing (saliva contains the same starch-converting enzyme found in malt). This process was simple but labor-intensive. In other parts of the New World, sprouted maize provided the same catalyst as malted barley, leading to maize beer. In Japan, a mold that produced appropriate enzymes was discovered. This was used to make rice wine, and kept between batches like a yeast starter.

Each gallon of beer requires 1-3 lbs. of raw grain; the more grain used, the stronger and better-tasting the beer. Low-quality beer – such as a peasant might make for his own consumption – requires 1 lb. per gallon and may be manufactured in batches of up to four gallons at a time. Total active time for malting the grain, preparing the mash, and setting it aside for fermentation is about a day, although it's spread out over several weeks. Taking greater care with the water and grain, and adding other ingredients (herbs are often included for flavor or preservative qualities), can increase working time to 2-3 days or more. Using larger vessels, practical for the professional brewer, allows batch sizes of 50-60 gallons.

Starting in TL3, beer and wine can be distilled to produce whiskey and brandy. Basic distilling requires about half of the undistilled liquid's weight in wood, an alembic, and a few hours of careful attention – or the undistilled liquid's full weight in fuel and a whole day for double distillation. Few alembics can hold more than a gallon, so batch sizes are very small, but batches of 5-6 gallons were possible by late TL4. Double-distilled liquor has 1/3 of the original volume.

Alcoholic beverages are often consumed as soon as they produce as much alcohol as possible – after a week or two of brewing for beer, within a month for wine. Longer aging in well-sealed containers can improve flavor, but poor seals or the presence of unwanted microbes can quickly turn the drink to vinegar. Higher alcohol concentrations allow longer storage times but require more fruit or grain, making them more expensive. One notable development was the introduction of *hops*. In addition to giving beer a bitter taste, hops preserve it for several weeks, enabling the possibility of long-distance beer trade. Hopped beers are first attested to in early TL2 (around 400 B.C. in Mesopotamia), but don't come to predominate until the 15th century A.D.

Roll against Professional Skill (Brewer) to ferment basic alcoholic beverages. Handle differences in fermentable stock (barley, grape juice, honey, maize, etc.) with *Familiarity* (p. B169). Distilling alcohol requires Chemistry at TL2-3, Professional Skill (Distiller) at TL4. The latter skill also covers fermenting appropriate materials into alcoholic solutions suitable for distilling.

Pollution

Pollution and environmental hazards date to the dawn of civilization. With the high population densities and poor sanitation of the earliest permanent settlements, communicable diseases caused life expectancies to *decrease* from hunter-gatherer levels. Well into the Renaissance, cities were net consumers of people, with populations kept up by constant immigration from the countryside.

In addition to disease, indoor air quality was terrible. For most of history, indoor fires were set in a fireproof hearth, but there was no way of channeling the smoke out of the house. The roof had a hole where it eventually escaped, but chimneys weren't invented until TL2 and didn't become widespread until TL5.

As industries burned more wood and charcoal, there was also a recognizable impact on *outdoor* air quality. As early as TL2, some societies required that potters place their kilns outside city walls to reduce smoke. By the end of the Middle Ages, several cities suffered from visible smog.

Industrial processes even produced toxic waste. Anyone who smelted silver from ore was invariably exposed to lead, and numerous activities associated with fine metalwork involved contact with lead and mercury. Pigments often contained poisonous chemicals as well. Long-term work with alchemy, painting, dyeing, jewelry, or smelting lead-bearing ores could lead to symptoms such as reduced DX or IQ from several varieties of neurological damage, lowered HT or FP, or seizures with symptoms similar to epilepsy. Historically, many societies showed limited awareness of the problems of industrial toxicity – but most noticed only relatively severe cases in workers who had suffered particularly heavy, long-term exposure.

Chapter Six
Shelter and Architecture

Humanity's earliest shelters were temporary: tents, lean-tos, and so forth. As people gave up the nomadic life, however, they invested considerable effort into permanent dwellings. The PCs might likewise want to settle down and build homes – from simple houses to palaces and strongholds – or even monuments, temples, and roads.

Below are rules for working out the requirements, costs, and characteristics of TL0-4 construction. To use them, start with a general idea of what the structure is like: layout (or at least general dimensions), materials, and any special attributes (e.g., heated rooms, structural reinforcements, or plumbing). These parameters will determine cost, DR, HP, and other stats and traits.

Building Materials

At TL0-4, permanent architecture involves a very short list of materials:

Hard Earth (TL0). Mud brick (mud put in wooden forms and left to dry for several months), rammed earth (dirt shoveled into forms and forcibly compressed), and sod (blocks of dirt cut directly from the earth, held together by grass roots) are extremely cheap, fire-resistant, and surprisingly durable, even in temperate areas.

Rubble (TL0). Stone is by far the most durable of building materials (Jericho has a partial tower around 10,000 years old!), but also the most expensive. Early stone construction, and a great deal of cheaper stone construction thereafter, was made from *rubble:* unshaped or lightly shaped stone that wasn't so much fitted as piled up.

Thatch (TL0). Bundles of reeds and grasses, or thin wooden slats woven into wicker panels, make poor structural materials but can be attached to a wooden frame to provide inexpensive walls and roofs. In many societies, these materials were covered with mud to give windproof-but-inexpensive walls. Wicker is flammable and flimsy – in medieval Europe, a thief could literally *break* into a poor man's wattle-and-daub house by forcing an opening in the wall!

Wood (TL0). Wood can be used for any part of a structure. Important drawbacks are flammability and – in less-fertile or more-developed areas – cost. However, historical builders had little choice but to use it, even if supplies were scarce, to provide the basic structure of roofs and upper floors. Long after vaulted masonry (p. 35) appeared, wood remained far cheaper for internal frames, floors, and auxiliary structural members, which is why stone and brick buildings remain somewhat susceptible to flame.

Ashlar (TL1). Metal tools led to the use of *ashlar:* neatly squared-off, polished stone that could be laid more tightly than rubble. Ashlar is extremely expensive, but it's also attractive, very sturdy, and required for the most sophisticated architectural techniques. It's often used as a facing on cheaper earth or rubble cores.

Structural Limitations

Into TL2, *wooden* roofs can span up to 20' without additional support. Wider buildings are possible, but have support posts at most 20' apart. By around 200 B.C., trusses are developed that permit unsupported spans of up to 50'. By the beginning of TL3, spans as great as 90' are achievable, although anything over 50' requires the masterful labor option (see *Construction Quality,* p. 35).

Several options under *Construction Variants* (pp. 35-36) allow larger structures. *Corbelled* buildings can span up to 30'; unlike wooden roofs, wider spans cannot be supported by posts. By late TL2, *vaults* can span up to 140', although it's rare to see even half that distance – anything greater than 70' demands the masterful labor option. *Gothic* buildings are subject to the same width restrictions.

A structure made from *hard earth, rubble, ashlar, brick,* or *concrete* can't accommodate many openings. Without structural modifications, only 5% of the building's surface may be taken up with windows and doors.

Brick (TL1). Cheaper than stone yet more durable than hard earth, thatch, or wood, brick takes mud brick a step farther by firing it to become a ceramic. It may then be laid just like stone. Even where brick construction is prohibitively expensive, brick facings can be used to cover less-desirable materials. To modern eyes, most ancient bricks look more like thick tiles, longer and wider than they are thick.

Concrete (TL2). This development is sometimes derided as the natural consequence of sloppy rubble filling between sturdier walls. Regardless, it allows rapid construction of durable buildings, and is comparable to stone but cheaper.

The physician can bury his mistakes, but the architect can only advise his clients to plant vines.
– Frank Lloyd Wright

Cost and Weight

To build a barrier – fence, curtain wall, etc. – multiply its total length by its height, both in feet, and then multiply the resulting area by the cost and weight of the desired material on the *Building Materials Table* (below). For barriers thicker than 1", further multiply by the desired thickness in inches.

For enclosed buildings, first find the structure's volume in cubic feet – usually height × width × length, although buildings with unusual shapes will require different formulas. Multiply volume by average wall thickness in inches and then by the *partition factor* (below). Multiply this result by the cost and weight of the desired material on the table.

Costs on the *Building Materials Table* assume that raw materials are available on or near the site. The way most societies build – mud brick where clay is plentiful, wooden stockades near forests, straw huts on farms, etc. – this will usually be true. However, that's definitely *not* the case for buildings that place greater demands on their building materials, notably brick, stone, and sometimes wooden structures. Good building stone, particularly high-quality marble and limestone for facings, was frequently mined at a few quarries and shipped many miles to its destination. The price of imported high-quality materials is likely to be subject to *Transport Costs* (p. 42) or the *Luxury Pricing* rules in ***GURPS Low-Tech.***

Partition Factor

Partition factor is a numerical rating of the extent of a structure's interior walls. For a building with a few large rooms (e.g., theater or Greek temple), it may be as low as 0.25, representing a box with floors and a ceiling, but no internal walls. For a structure with many small rooms (apartment building, monastic dormitory, enclosed market containing many small shops, etc.) it can be as high as 0.25 + (1/average wall thickness in inches); with thin wood and thatch walls, this might be as great as 1.25, but for a 6" stone wall, it's unlikely to rise above 0.42. Buildings with a mix of room sizes (such as palaces or mansions with both large public rooms and small private ones), should have partition factors somewhere between 0.25 and the maximum.

HP, HT, DR

HP: Calculate building HP from weight: 100 × cube root of (building weight in tons). The HP of 10-square-foot sections – roughly 1 hex on a battle map – is 80 × cube root of (material weight from table × thickness in inches/100).

HT: Unless changed by structural modifications under *Building Options* (pp. 35-36), a building has HT 12. Except as noted, all buildings have *some* wooden structural members – wooden or thatched roofs, and wooden internal floors – all of which are combustible.

DR: For buildings and sections, DR is that given on the table multiplied by thickness in inches. For all of the materials discussed here, repeated *impaling, piercing,* or *large piercing* attacks against a specific point lower DR *at that spot* as though it were semi-ablative. Repeated *burning, corrosion, crushing, cutting,* or *huge piercing* attacks on one point reduce DR *at that spot* as though it were ablative. DR never falls below 1 for wood and thatch, or 3 for other materials.

Building Materials Table

All figures assume a 1" thickness of wall. Remember to multiply by thickness in inches. *Hard earth, rubble, ashlar, brick,* or *concrete* structures must be at least 6" thick.

TL	*Material*	*Cost*	*Weight*	*DR*
0	Hard Earth	$0.85	3.75	1
0	Rubble	$3.82	14	12
0	Thatch	$0.74	1.3	0.5
0	Wood	*	2.67	1
1	Ashlar	$11.72	15.5	13
1	Brick	$3.34	7.7	8
2	Concrete	$9.98	15.5	9

* Thinner planks are harder to make, so the base price of wood construction depends on wall thickness:

Thickness	*Cost*	*Thickness*	*Cost*
1"	$7.75	5"	$1.99
2"	$4.14	6"	$1.66
3"	$3.10	7"	$1.43
4"	$2.47	8" or thicker	$1.26

Construction Examples

A castle has 600' of curtain wall made from rubble 12' high and 8' (that's 96") thick. This costs 600 × 12 × $3.82 × 96 = $2,640,384 and weighs 600 × 12 × 14 lbs. × 96 = 9,676,800 lbs., or 4,838 tons. It has DR 96 × 12 = 1,152 and HP 100 × cube root (4,838) = 1,691.

A small stone keep stands 40' tall (three stories of just over 13'), covers 500 square feet, has walls 1' thick (12"), and has almost no internal partitions (partition factor 0.25). It costs 40 × 500 × 12 × 0.25 × $3.82 = $229,200 and weighs 40 × 500 × 12 × 0.25 × 14 lbs. = 840,000 lbs., or 420 tons. It has DR 12 × 12 = 144 and HP 100 × cube root (420) = 748.

Building Options

Like other technology, architecture comes in many quality grades and variants. These differ from those described for personal gear in ***GURPS Low-Tech,*** however.

Construction Quality

A building's HT is normally 12, but the builders' skill and building materials' quality may modify this, and possibly DR and HP as well:

Unskilled Labor: Most members of the work crew have appropriate skills below 12. This is typical of the homes that peasants and poor city-folk build for themselves. Gives -1 to HT, and -5% to DR and HP. CF is -0.2.

Masterful Labor: The work crew contains predominantly master craftsmen with skill 14+. Gives +1 to HT. CF is +0.25.

Cheap Materials: The building is made from inadequately dried mud, splintering wood, crumbling stone, etc. Builders unable to import good-quality materials may be forced to use cheap ones! Gives -1 to HT, and -5% to DR and HP. CF is -0.2.

Fine Materials: The building is made from top-quality materials. Gives +1 to HT. CF is +0.25, *not* including additional transport costs (p. 42).

Mortar

For *stone* and *brick* buildings, mortar quality varies by TL, affecting HP (see *Mortars and Mineral Adhesives* in ***GURPS Low-Tech***). At TL0, stonework uses either no mortar or mud, giving another -5% to HP. In early TL1, stone and brick structures are mortared with plaster, giving -2% to HP. Stone and brick buildings with lime mortar (mid-TL1 on) have full HP.

Construction Variants

Many structural options can affect a building's durability and characteristics. Unless otherwise noted, these modifications are mutually exclusive. Calculate building HP *after* adjusting weight for construction variants.

Corbelled Masonry (TL1). This is the most primitive method of constructing all-stone buildings. Each course of masonry extends slightly farther over the space beneath it than the course under it, making a beehive-shaped roof. Corbelled vaults require thick walls to support the weight properly, and can have very few windows and doors. Single-story corbelled buildings require no wooden structural members, although additional internal floors are wooden. *Stone* or *brick* buildings only; gives -1 to HT and +5% to weight. CF is +0.2.

Cribwork (TL1). Cribworked walls consist of different materials layered together for increased resiliency. They may be primarily stone but with courses of brick tying them together, or hard earth walls may have an internal wooden framework. Only *hard earth, stone,* or *brick* walls at least 1' thick may be cribworked; gives +1 to HT, and +5% to the weight of hard earth or brick walls, but -5% to the weight of stone walls. CF is +0.1.

Hypocaust (TL1). The structure has a false floor with an airspace underneath. The exhaust of an attached furnace flows under the floor on its way to a chimney, heating the floor from beneath. Though used most spectacularly to heat Roman baths, homes in northern China use a similar system even today. To be heated by a hypocaust, a building must be made from *hard earth, stone, brick,* or *concrete*. This *can* be combined with options other than water cooling. Costs $8 per square foot heated, and consumes 1 lb. of charcoal per hour per 90 square feet.

Tiling (TL1). Less-attractive or -durable surfaces are replaced or covered by ceramic tiles, stone flags, or lead sheeting. This has no direct effect on building HT, but any flammable members are covered by fireproof materials. This *can* be combined with other options. Tile facings have a basic cost of $3.15 and weight of 5.5 lbs. To tile over floors and roofs, multiply cost and weight by the building's floor area: length × width × number of floors. To *completely* tile over a building, multiply cost and weight by the building's area, height, and partition factor instead.

Embossing (TL2). Large stones project at intervals from the wall. These transmit the force of blows to the wall's interior, spreading out the impact and increasing resistance to battering. This option also provides convenient handholds for anyone who wants to climb the wall (+3 to Climbing skill). Only *stone* or *brick* walls at least 1' thick may be embossed; gives +5% to DR vs. crushing damage. CF is +0.1.

Vaulted Masonry (TL2). This is a "true" arch that directs all the downward pressure of a semicircular (or nearly so) vault through the walls and into the foundation, resulting in a durable, all-masonry structure. The drawback of such vaults is that, as with corbelled vaults, it's difficult to leave any holes in the walls. Vaulted buildings don't require wooden structural members. They must be made from *ashlar, brick,* or *concrete.* Gives +5% to weight. CF is +0.15.

Why do they call them buildings when they're done building them? They ought to call them "builts."

– Gallagher

Gothic Masonry (TL3). Gothic construction combined two innovations: the *broken arch* and the *flying buttress*. The former development allowed arches with pointed tops (and led to elaborate arch designs, such as the scalloped "multifoliate" arches of Muslim architecture) and more symmetrical intersections between vaults. The latter was a pier supporting a half-arch that helped reinforce another wall. Flying buttresses let architects replace walls with a system of piers, leaving most of the space in between for windows and doors. Up to 75% of the building's walls may be used for windows, doors, and other openings. Gothic buildings must be made from *ashlar* or *brick*. CF is +0.5.

Water Cooling (TL4). Sufficiently expensive to be used only in a handful of palaces in the hottest climates, rooms can be cooled by a system structurally resembling a hypocaust (p. 35). Instead of running hot air through the hollow walls and floors, a steady flow of water trickles through the empty spaces, cooling the room as it evaporates. Water-cooled structures must be made of *brick* or *stone*. Water cooling *can* be combined with options other than a hypocaust. Costs $16 per square foot cooled, *not* including connections to water sources.

Civil Engineering

Not all construction is enclosed buildings:

Monumental Earthworks (TL0). Earth piled into mounds isn't used to construct buildings, but it can serve as a platform for building, a rapidly prepared fortification, or a monument in its own right. Earthworks cannot exceed twice the height of their shortest horizontal dimension. Piled earthen walls have DR 0.8/inch, cost $0.25/cubic foot, and weigh 80 lbs./cubic foot.

Roads (TL0). Basic road-clearing costs $0.2 per square foot over firm, even ground; $0.4 per square foot for particularly rocky ground; or $1 per square foot to clear forest or especially tough vegetation. This simply creates a path that will quickly become muddy in the rain, although it can last for decades in near-desert conditions. Treat such a road as Average terrain, becoming Very Bad in damp conditions (for definitions and effects, see p. B351). Once cleared, it may be paved. *Rubble, ashlar, brick,* and *concrete* are the most common materials – but *wood* has been used for at least short stretches in heavily forested regions. Treat paving as constructing a wall of the same length; use road width in place of height and road bed depth instead of thickness. Roads paved at least 1' deep typically remain Average in damp conditions; roads paved at least 3' deep, at least 1' of which is ashlar, brick, or concrete, count as Good.

Tunneling (TL0). Cutting tunnels costs $0.4 per cubic foot through ordinary soil, or $0.8 per cubic foot through rock or loose soil.

Plumbing (TL1). Underground water pipes and sewage pipes suitable for supplying individual buildings cost $98 per person worth of capacity.

Construction Time

The time required for a building or engineering project can be calculated as explained in *Labor Costs* (p. 23). Since materials costs are essentially the labor costs of obtaining the materials, the total time involved can be approximated by dividing the total cost by the labor rate. Generally, construction involves a small number of craftsmen who do the detail work plus a large number of less-skilled helpers who do the heavy lifting.

The bulk of the cost in any construction resides in obtaining and preparing materials. Building stone was often recycled and might be shipped long distances due to the high cost of cutting new stone. In the unlikely event that ready-made materials are at hand (e.g., an architect is building a new temple from the ruins of an old one), consult the *Construction Labor Cost Table* (p. 37) to determine the percentage of the total cost that's devoted to construction labor.

Example: The castle in *Construction Examples* (p. 34) has a total cost of $2,869,584. Since a mason (p. 47) has a salary of $900/month, the average labor rate is $900 × 0.55 = $495/month. Thus, it takes about 5,797 man-months to dig up rock and assemble it into a castle. With an average crew of 100 builders, that comes to around 58 months, or five years. The *Construction Labor Cost Table* indicates that the labor to pile up that rubble is only 5% of the total cost, or $143,479. This translates into just shy of 290 man-months – or, with that 100-man crew, a quick three months if the builder starts on a site deeply covered with rubble.

Construction Labor Cost Table

Material	*Labor Cost*
Hard Earth	10%
Rubble	5%
Thatch	30%
Wood	20%
Ashlar	1%
Brick	2%
Concrete	5%

Environmental Concerns

Given the limited range of materials and techniques at TL0-4, buildings are shaped largely by responses to the environment. For example, rooms without windows are rare because they can't get natural light, and artificial light sources are both too dim and too expensive to be practical. Mansions and palaces often have a fairly small built area but are constructed around courtyards that provide illumination through the day. One of the innovations enabled by Gothic architecture was the *clerestory:* a raised section of walls and roof near a building's center, with windows piercing the upper walls to let light into parts of the building far from the lower levels' windows.

It's nice to be indoors.
– Emo Phillips

Warm-weather buildings, from African family compounds to Italian villas to homes in southern China, are very open. They have rooms for storage and sleeping, but most household work is done in courtyards. Walled-in courtyards serve as reservoirs of cool air, cooling at night and providing shade during the day. A larger building might employ courtyards divided into eastern and western halves by a high-roofed covered walkway. In the morning, the courtyard to the east warms faster than the more-shaded one to the west. The temperature differential creates a breeze between the two. In the afternoon, the eastern courtyard cools while the western one warms up, reversing the breeze.

Buildings built for cold climates, on the other hand, are as enclosed as possible. Courtyards may exist for work in warmer seasons, but cold-weather buildings provide more indoor work space. They also tend to be taller, to use rising heat more effectively. Rather than putting animals into separate barns, a number of societies (e.g., Bhutanese farmers, and medieval English and Germans) keep livestock indoors in separate rooms or on a lower floor. The animals' body heat makes the house more comfortable for the human inhabitants.

Damp climates are hard on the cheapest architectural materials. Thatch and wood decay quickly, while hard earth is difficult to stabilize. Builders working with organic materials in damp areas must either perform frequent maintenance (often the case for bamboo structures), use particularly moisture-resistant woods (such as cypress; see *Woodworking,* pp. 28-29), or minimize contact with the ground. In parts of southern Asia, wooden homes are built on wooden posts that keep most of the building well clear of the damp ground. Earthen buildings are likewise kept from moisture, by building a stone foundation and starting earthen construction a bit above ground level.

Bathing and Bath-Houses

Warm baths are both hygienic and physically pleasurable, but before the invention of automatic temperature regulation and the development of ample, inexpensive water supplies, the physical infrastructure to provide warm water on demand was quite expensive. Therefore, several societies developed public bathing facilities.

Despite some Greek forerunners, large public bathhouses were essentially a Roman innovation, appearing by the second century B.C. Roman baths heated water over a large central furnace, which also used a hypocaust system (p. 35) to warm parts of the building. Public baths appeared later in India and China, spreading to Japan by the eighth century A.D. Roman and, later, Muslim baths provided several temperatures of water in different pools; Scandinavian and Central and East Asian bathing facilities concentrated on hot water or just steam. Smaller baths, such as Scandinavian steam baths and medieval European "stewes" (tubs large enough for two or three rather than swimming-pool-sized Roman-style baths) often relied on transporting kettles of hot water or heating water with stones.

Baths themselves were rarely used as the sole method of cleaning. Romans used oil and strigils before bathing, and Asian bathing etiquette demanded that one wash before entering a communal tub. Because their purpose was as much recreation as cleanliness, public baths became centers of social activity and shopping. Medieval stewes became notorious for prostitution.

Chapter Seven
Transportation

Improvements in transportation from TL0 to TL4 opened up new possibilities to those who achieved them. Early Paleolithic societies traveled on foot and had no political unit larger than a nomad band. By contrast, kingdoms of the Age of Sail circumnavigated the Earth and conquered huge overseas empires! Both more elaborate infrastructure and better vehicles contributed to these advances.

Infrastructure

Like other land animals, humans trample soil and vegetation on the move, creating paths. But unlike most creatures, humans often *deliberately* modify the environment to make travel and transportation easier. While mainly a TL1 development, a few TL0 societies did this on a smaller scale.

The resulting transportation networks influence settlement patterns. It's common for cities to grow up at points where two networks are linked; e.g., a bridge over a river, the upper end of a river's navigable waters, a river's outlet into the sea, or a safe harbor. Such settlements house travelers, vehicles, and goods, and provide laborers to load and unload goods. These circumstances attract merchants, and the concentration of wealth and population brings government officials. All of this fuels an urban economy that can support specialized artisans and servants.

Roads

Roads (p. B351) are made by clearing and leveling the ground to widths from several feet to a number of yards. Some TL0 societies do this, most often in connection with the construction of monuments; e.g., the megalithic architecture of Stonehenge, or the huge sculptured heads on Easter Island. However, large-scale road-building becomes more common at TL1, when roads are also required for wheeled vehicles, caravans of pack animals, and marching armies. Cities at TL1 have streets within their walls and local road networks outside them.

By TL2, empires regularly build elaborate highways for their armies and messengers. Persia's Royal Road extended 1,600 miles from end to end. China contained an estimated 4,250 miles of Imperial highway by 200 B.C., growing to almost 20,000 miles by 200 A.D. Yet both systems were dwarfed by the roads of the Roman Empire. Over six centuries, the Romans constructed more than 50,000 miles of roads, with pavement 16' wide and 3' deep. These roads required about 24,000 man-days of labor per mile to build, and around 8,000 man-days per century to maintain.

Hauling heavy loads at TL0 – and often at higher TLs – requires gangs of men with ropes. ***GURPS Low-Tech*** describes various types of rope and their strength. A good-quality low-tech rope (e.g., hemp) 1" in diameter can support 2,000 lbs. Since a rope can handle a load proportional to the square of its diameter, the weight in tons that such a rope can manage is simply the square of its diameter in inches. The thickest rope used in antiquity was 2 1/2", sufficient to haul about six tons (roughly 80 cubic feet of stone). Heavier loads required multiple ropes.

To move a six-ton object at all requires a minimum BL of 800; see *Pulling and Dragging* (p. B353). This corresponds to 40 men with ST10 hauling a rope. Spacing them at one-yard intervals calls for at least 120' of rope. Comfortable hauling, at no worse than Medium encumbrance, demands a minimum BL of 4,000, equivalent to 200 men, and at least 600' of rope. Hauling is easier on smooth, level ground, such as a cleared road; there, *halve* effective weight.

Loads can be made more manageable with rollers made from logs. Divide effective weight by 5 in that case; rollers work better than a sledge (which halves weight), but not as well as a wheeled vehicle (which divides weight by 10 or 20). The laborers must periodically stop and move the rollers in front of their load, or else extra men must be available to do so continuously – although a few TL0 cultures laid rollers along the *entire length* of a frequently used roadway!

Roads can't always be made level, though. Sometimes they slope uphill, increasing the effort required to haul a load. Smooth surfaces – and runners, rollers, or wheels – make it easier to drag a load over the road surface but don't help lift it; thus, loads hauled uphill are divided by smaller numbers than those pulled on the level. Look up the usual (level-ground) divisor in the first column of the *Slope Table* (p. 39), and then read across to the column that corresponds to the slope (expressed in degrees or as a height-to-distance ratio) to find the applicable divisor.

For controlled *descent* of a slope, use the same divisors; the force needed to hold a load back from sliding or rolling downhill is comparable to that needed to push it uphill. For uncontrolled descent, use an approach similar to that for skis in ***GURPS Low-Tech:*** descending 1 yard adds 1 yard/second to velocity. The highest speed attainable this way is cruising speed × 1.6 (see *Ground Travel,* p. B466). If this exceeds normal Top Speed, make a control roll (p. B469). To decelerate, steer onto level ground, which kills 1 yard/second of velocity each second. Decelerating or turning requires an *additional* control roll.

Slope Table

Less than 5° *Less than 1:12*	*Less than 10°* *Less than 1:6*	*Less than 15°* *Less than 1:4*	*Less than 30°* *Less than 4:7*	*Less than 45°* *Less than 1:1*	*45° or greater* *1:1 or greater*
1.5	1.5	1.5	1.5	1.5	1
2	2	2	2	2	1
3	3	3	2	2	1
4	4	3	3	2	1
5	5	4	3	2	1
8	7	5	4	2	1
10	8	5	4	2	1
12	8	5	4	2	1
20	10	6	4	2	1
40	11	6	4	2	1

Bridges

Bridges enable traffic to cross rivers without swimming and with no need for a ford or a ferry. The earliest examples are TL0 *suspension bridges* made from ropes and boards; see *Rope Bridges* (below). At TL1, more durable designs appear, with solid frames supported at the ends or from below, by pillars. The Romans, at TL2, are major bridge builders, using the new architectural form of the *arch* to negotiate wider gaps and raise spans higher above the water they traverse.

Rope Bridges

The simplest bridge is a single rope across a gap, from one tree, riverbank, or building to another. Such a rope must be longer than the gap is wide, because it can't be drawn perfectly straight. A fairly taut rope, with its midpoint lower than its ends by 10% of the gap width, needs 2% extra length; e.g., 102' for a 100' gap.

A rope must support its weight and that of the man crossing it, however he moves (hand-over-hand, walking, etc.). As his weight pulls the rope taut, though, the horizontal force along the rope is equal to *five times* the total weight, half of which acts on each end. The rope will break if this force exceeds its maximum load (see *Rope, String, and Thread* in ***GURPS Low-Tech***).

A similar computation can be done for a rope bridge. Total the weight of the ropes, any planks they support, and the bridge's load. Multiply this by 5 to find the force along the ropes. Divide by twice the number of ropes to get the force acting on either end of each rope. Finally, compare this to the rope's maximum load.

Example: A bridge over a100' gap uses two hemp ropes, each 102' long, 1" in diameter, and weighing 30.6 lbs. These support a walkway of boards 3' long and 1/2" thick, which weighs a little over 400 lbs. Thus, the bridge weighs about 462 lbs. Six men, each weighing 200 lbs., are on the bridge, bringing the total weight to 1,662 lbs. The horizontal force is thus 8,310 lbs. With two ropes, we divide by 4, giving 2,077.5 lbs. on each half of each rope. A 1" rope can support only 2,000 lbs., so the ropes break under the load, dropping the party into the chasm below!

Portages

Portages let watercraft cross land, much as bridges enable land traffic to cross water. A stretch of rough water can make a portage necessary for boats traveling along a river. A more common application, however, is to transport a vessel between rivers that pass close to each other, or across a narrow isthmus between arms of the sea.

Any society that builds boats may carry them over natural portages, if the craft are light enough. At TL0, societies improve trails at natural portages, sometimes even laying down rollers that make it possible to drag heavier vessels (see *Roads,* p. 38). At higher TLs, advances in road construction allow more sophisticated portages.

At TL2, the ancient Greek city of Corinth constructed a particularly elaborate portage, the Diolkos, across the Isthmus of Corinth. Built around 600 B.C., it has been described as a kind of early railway, with two grooves cut into the stone 5'3" apart – the standard spacing for cart wheels. Ships could be loaded onto carts and dragged over the isthmus' four-mile width, avoiding a long, dangerous sea voyage around the Peloponnese. The Diolkos' average slope was 1:70. It was probably used mostly for boats, or to transship cargo to a new vessel, but apparently saw some use for warships (120' long, and 5 tons at the lightest).

Canals and Aqueducts

A canal provides an alternative to a portage by connecting two rivers with an artificial channel. Canal-building goes back to ancient Mesopotamia (TL1), where the Tigris and Euphrates flow roughly side by side for many miles. In China at TL2-3, a network of canals linked together various rivers, providing many of the empire's major trade routes. The same happened in Europe at TL3-4, but on a smaller scale within individual nations.

Canal boats and ships can gain motive power from a source that isn't available on the open ocean: towlines pulled by men or draft animals. For such a load, divide effective weight by 8 for a raft or a squared-off barge, by 10 for a craft with round lines, and by 12 for anything with long lines (e.g., a canoe or a warship). A boat can also be towed along a river, if the bank provides adequate footing; in that case, add the river's flow speed to the vessel's speed for movement downstream, but subtract it for movement upstream. A typical flow speed in level terrain is 5 miles/day.

Canals also are useful for irrigation, carrying water to fields where it's needed; this was their primary function in Mesopotamia, and just about their sole purpose in Egypt, which had only one major river. At TL2, the Romans developed a different technology for transporting water, the *aqueduct:* an artificial channel running straight over uneven ground, partly below the ground and partly above it, held up in the same way as a bridge. Eleven different aqueducts brought water to Rome from as far as 59 miles away, supplying 300 million gallons daily for drinking and bathing. Rome's aqueducts mostly fell into disuse at TL3, but many were restored at TL4.

Starting at around 1000 A.D. (TL3) in China and Europe, canals are built with *locks*. These divide canals into segments between which the flow of water can be blocked off. Opening a lock lets the water level in two segments equalize, allowing a ship to move forward; then the lock behind the vessel can be closed and the lock in front of it opened, permitting the water to equalize at a new level. This enables canal craft to travel uphill or downhill between bodies of water at different levels.

Bilbo: It's a dangerous business, Frodo, going out of your door. You step into the Road, and if you don't keep your feet, there is no knowing where you might be swept off to.

– J.R.R. Tolkien,
The Lord of the Rings

Harbors

At TL0, boats simply pull up onto any conveniently flat beach. But starting at TL1, port settlements take steps to provide better harbors for watercraft – and especially for large ships.

A major TL1 development is *docks:* wooden platforms extending out over the water, supported by wooden pilings sunk into the sea bottom. A ship can pull up alongside a dock without needing to be beached, facilitating its departure. Moreover, the reduced height difference between its decks and the dock makes loading and unloading easier. This is enhanced by the use of counterweighted levers – similar to the *shadouf* (see *Irrigation and Hydraulics,* pp. 17-18) – to raise cargos out of the ship and swing them onto the dock, a TL1 invention that comes back into use in Europe after 1000 A.D. (TL3), when dock-building resumes. Cranes (see *Construction Equipment,* pp. 16-17) enter use at TL2, and reappear in Europe after 1175 A.D. However, a ship tied up next to a dock needs sturdier sides to withstand bumping into the dock, particularly during rough weather.

To keep their harbors navigable, TL2 societies develop *dredging,* removing rocks and silt from harbor bottoms. Another TL2 improvement is the *breakwater:* a barrier extending out from the shore to enclose part of the water, blocking incoming waves and giving ships a smoother anchorage. This type of construction is expensive; breakwaters are normally built to separate natural bays from the open sea, taking advantage of the shore's curve to shorten the length of the required wall. By late TL2, some Roman designs have arched foundations below the waterline, letting water through to scour the harbor and reduce the need for dredging.

Some TL2 societies built artificial landmarks adjacent to harbors; e.g., the Colossus of Rhodes (100' tall on a 50' pedestal) and the Pharos of Alexandria (over 375' tall). The Pharos was eventually transformed into the first lighthouse by having a beacon fire set up on top of it, providing ships with a point of light to steer for after dark. The use of *lighthouses* to warn ships away from rocks was a later development, which spread to Persia and as far as China at TL3. These were revived in Europe at TL4, with the first British lighthouse built in 1619. For the range at which a landmark or a lighthouse can be seen, see *Visual Signals* and the *Horizon Table* in ***GURPS Low-Tech.***

Cargo Ships

Cargo ships include many of the largest vehicles at TL0-4. They're typically *too* large to count as personal gear, and too costly for most adventurers. Still, such a vessel can provide a mobile base of operations for a party of merchants. The PCs may constitute the entire crew of a smaller craft or be the owners and/or officers of a larger one, making the decisions that earn a profit.

Dhow (TL3)

The dhow is the characteristic ship of Indian Ocean trade, as conducted by Muslim merchants such as the legendary Sinbad. It's not a single class of vessel but a general style of construction. There are names for specific sizes and designs of dhow.

Dhow construction is shell-first, with planks closely fitted together to give the vessel its shape. Lighter models derive all their structural strength from the outer hull; heavier ones have framing timbers added. The shell is sewn together with cords passing back and forth between upper and lower planks, somewhat like shoelaces. Most dhows have open cargo spaces, but larger craft may be decked over, and might even have superstructures fore or aft.

Dhows normally have a single mast with fore-and-aft sails. However, they don't use this to beat upwind – the typical dhow has a high mast that bears large sails, and cannot carry sufficient crew to handle these as required for tacking. Instead, the ship sails east during part of the monsoon cycle, and then west during the other part. Its substantial sail area and low drag let it make good speed on such voyages.

Badan (TL3). A small craft, less than 50' long, pointed at both ends, with a single mast and a fore-and-aft sail.

Boum (TL3). A larger craft, starting at 50' long, again pointed at both ends. It may have one or two masts with fore-and-aft sails.

Baghlah (TL4). A later dhow – influenced by contact with Portuguese sailing ships – with a high, square stern and five windows. A typical baghlah has two masts with fore-and-aft sails, the mainmast much higher than the mizzenmast.

Hulks and Cogs (TL3)

As trade revived in Europe after 1000 A.D., two types of vessels dominated Northern European shipping: *hulks* and *cogs*. Both were initially developed by Frisian traders but later came into general use.

The hulk was a keelless, flat-bottomed ship whose timbers curved upward at the bow and the stern, giving them a "U" shape. The hull was curved at both ends, like half an eggshell. The hulk's flat bottom meant that it could navigate shallow river waters and be beached easily; however, it was extremely stable, and could also travel on the high seas. A hulk had a single large, square sail near the prow, and two side rudders for steering. Its rounded shape gave it a substantial cargo capacity.

Cogs started out keelless and flat-bottomed, too. After 1000 A.D., though, they were built with keels, in a design borrowed from Anglo-Saxon *ceols* (whence the word "keel") and Scandinavian *knarrs*. Both versions had slanted stem and stern posts, and their timbers curved sideways to meet at the posts, giving them sharper prows that could cut through the water. The cog wasn't designed to be beached; early cogs anchored on tidal flats, came to rest on the bottom at low tide, and then floated out again at high tide, while later ones used docks. Cogs grew larger over the centuries. Like hulks, they had just one large, square sail – but after 1250, they added a bowsprit, and lines stretching back from this offered better control of the sail for beating upwind. A single rudder was fixed to the sternpost.

The gradual improvements to cogs turned them into ocean-going vessels, while hulks became specialized river ships. During the 1300s, hulks grew larger, to rival cogs. After 1380, the two designs merged into a combined form, which remained in use until full-rigged ships appeared at the very end of the Middle Ages.

Junk (TL4)

"Junk," like "dhow," is a generic term describing a variety of vessels. These sailing ships developed fairly late in Chinese history, and had a number of advanced features, some of which didn't appear in the West until TL5. A fleet of over 300 junks, including examples far larger than Columbus' flagship, departed from China in 1405 and traveled as far as Africa's eastern shores, under the command of the eunuch admiral Cheng Ho. Chinese maritime expansion was stopped not by technological shortcomings but by the mandarins' decision that China had no need to explore barbarian lands or trade for their goods.

Junks were originally developed to navigate China's coasts, rivers, and canals. To avoid problems with shallow water, northern junks tended to be flat-bottomed and keelless, with deep rudders that could be raised using windlasses to let the ship pass over obstacles. Southern junks were typically ocean-going, V-shaped craft, often with keels.

Following a pattern first established in *sampans* (see ***GURPS Low-Tech***), junks had bulkheads that provided internal compartmentalization, making them nearly impossible to sink. The forward compartment was sometimes deliberately left open to the sea for improved stability (this gives +1 to SR). Junks made on classic patterns in recent times were recorded to be essentially watertight, and carried no pumps.

Junks carried multiple masts, like advanced European sailing ships at TL3-4. Their sails had a distinctive design similar to rice-paper blinds, with horizontal strips that could be raised or lowered according to wind conditions, making them easy to handle. Sails were lowered from the top down, so it was it unnecessary for the crew to go aloft. Despite their square shape, these sails were as efficient at sailing upwind as the best fore-and-aft designs. Some of a junk's masts weren't placed on the midline, but to one side, and were anchored to one of the ship's bulkheads.

Fishing Junk: This is a small, one-family craft of the sort used by Chinese "boat people." The design has a square stern but a sharply pointed prow, and only two masts. In addition to the very deep movable rudder, it features a keel with a daggerboard that can be lowered at the front for improved stability. Hatches make up most of the deck, and give access to seven hull compartments.

Cargo Ships Table

All of these ships are sailing craft. Terms and notation are as defined in *Vehicle Statistics* (pp. B462-463).

TL	*Vehicle*	*ST/HP*	*Hnd/SR*	*HT*	*Move*	*LWt.*	*Load*	*SM*	*Occ.*	*DR*	*Range*	*Cost*	*Locations*	*Draft*	*Notes*
SHIPHANDLING/TL (SHIP)															
3	Badan, 30'	73†	-1/2	10c	0.2/3	15	12	+5	9	2	–	$5.6K	M	6	[1, 2]
3	Boum, 60'	137†	-2/3	10c	0.15/4	80	60	+7	12	2	–	$37K	2M	10	[1, 2]
3	Cog, 60'	147†	-3/4	12c	0.1/4	85	60	+7	18	5	–	$140K	M	13	[1]
3	Hulk, 60'	157†	-4/5	12c	0.05/4	105	75	+7	18	5	–	$170K	M	11	[1]
4	Baghlah, 120'	208†	-4/4	11c	0.1/6	350	280	+9	15	2	–	$130K	2MS	15	[1, 2]
4	Fishing Junk, 33'	77†	-1/3	13c	0.15/3	12	8.5	+5	6	3	–	$33K	2M	2	[1, 3]
4	Pole Junk, 140'	252†	-5/6	13c	0.05/5	300	175	+9	25	5	–	$1.2M	3MS	10	[3]
4	Trade Junk, 70'	96†	-3/4	13c	0.1/4	23	16	+7	12	4	–	$65K	3M	4	[3]

Notes

[1] Unreinforced decks; can't mount cannon.

[2] Sailing against the wind, suffers -2 to Hnd and has Top Speed 1.

[3] Use full HT for rolls to avoid sinking, leaking, etc. Complex sails and rudders give -2 to HT rolls to avoid *mechanical* failure, and might count as unfamiliar (-2 to Seamanship or maintenance rolls).

Pole Junk: A large cargo ship – between 120' and 180' – with 15 internal bulkheads, designed to carry lumber or building stone. Three large masts support the sails. The hull is squared-off at the stern and rounded at the prow. There's a shelter for the owner at the rear.

Trade Junk: A small cargo carrier, scaled up from Amoy fishing craft, squared-off at both ends. It has three masts and a flat bottom, and a small keel in addition to the rudder. Hatches in the decked-over body lead into 10 compartments. Historically, such junks were considered exceptionally seaworthy and maneuverable.

My ship is built of spice-wood
and has a rudder of ***mulan.***
– Li Po, "On the Ship of Spice-Wood"

In the Air

Ships and roads are well and good, but seem less important if you can take to the air! Human beings have imagined flying for a long time; stories about aerial vehicles are as old as civilization, if not older. While flight was usually regarded as magic, Greek legend had the master craftsman Daedalus making artificial wings from feathers and wax, which was at least an attempt to envision a physically plausible contrivance for flying. Leonardo da Vinci's notebooks contain many sketches of such devices, although none would actually have worked – being dependent on human physical effort for power, they couldn't generate enough lift to support their own weight. His design for a hang glider wouldn't have needed power, but a recent test model inspired by it had severe stability problems: -4 to Handling, if a TL(4+1) gadgeteer manages to build one.

There has been recent speculation about the use of hot air balloons in pre-Columbian Peru, based largely on the observation that the elaborate designs cut into the Nazca Plain aren't visible from the ground. Balloonist Jim Woodman built a hot air balloon from local materials to support this conjecture. Archaeologists haven't accepted this idea. Still, an early balloon made with thin leather or tightly woven cloth could achieve TL(1+1) manned flight. (Chinese "lantern balloons," described in ***GURPS Low-Tech,*** were too small for human riders.)

Transport Costs

An important consequence of improved transport capabilities is lower transportation costs. In low-tech societies, hauling goods even short distances substantially increases their cost. For example, a cart pulled by two oxen can hold about 1,200 lbs. of grain, but the oxen need to eat 100 lbs. of food a day. If they take three days to travel from a village to a town, and three days to return, they'll eat half the load – so the farmer must sell 600 lbs. of grain in town for as much as he could get for 1,200 lbs. back in his village. Oxen travel at 2 mph for no more than 5 hours a day, or 30 miles in three days; thus, a 30-mile journey is enough to double the price of grain!

As a general rule, hauling goods over land costs five times as much as moving them on a river, which costs five times as much as shipping them by sea. This ratio applied from the empires of the ancient world until the end of the 18th century, just before the invention of railroads and steamships. Because of this, cities tend to grow up on rivers and harbors, where they can bring in food from farther away. *Huge* cities may import food from hundreds of miles away; Athens was fed by grain from the north shore of the Black Sea, and Rome by grain from the Nile Valley. Most such metropolises ship grain by sea, but in China, canals linked different rivers into a single shipping network that could feed the imperial capital.

The effects of transport costs vary with the goods, though. Suppose that dried fruit costs five times as much per pound as grain. If the cart in our earlier example carries 600 lbs. of grain to feed the oxen and a 600-lb. cargo of dried fruit that sells for as much as 3,000 lbs. of grain, then shipping dried fruit 30 miles adds just 20% to its cost, where it added 100% to the price of grain. Thus, dried fruit could profitably be brought in from much farther away. Inexpensive goods, including most necessities, are traded only locally; expensive goods, especially luxuries, dominate long-distance trade. The longest trade routes are defined by the luxuries they carry; e.g., the Silk Road brought silk from China to the Near East and the Roman Empire.

Chapter Eight

Trade

Trade is a characteristic activity of towns and cities, and one of the principal uses for transportation systems. Someone who earns a living from trade is a "merchant." In game terms, this is a job – or rather, a category of jobs – for which one prerequisite is having money to invest in goods. Each class of goods has a *turnover time:* the average length of time that the merchant has to hold them before reselling them and (he hopes!) making a profit. Use these rules to quantify the relationship between invested wealth, turnover time, income, and profit margin.

First, determine the merchant's starting money. Begin with the amount of cash usual for his TL, as given in *Tech Level and Starting Wealth* (p. B27), and modify this for his personal Wealth (p. B25), which can be anything from Struggling to several levels of Multimillionaire. Of this, 20% can normally buy adventuring gear (see *Starting Wealth,* p. B26); the other 80% goes into fixed assets. A merchant pays for his stock out of this 80%. While it's technically "movable," he isn't free to use it up adventuring – not if he wants to stay in business! (Note that he may have *other* fixed assets, such as a house or furniture, which will limit what he can spend on stock.)

As a rule, a merchant will have typical Status for his Wealth (p. B517). Look up his Status on the *Cost of Living Table* (p. B265) to find his monthly cost of living. He must make that much profit each month to maintain his Status.

If the merchant's average turnover time is one month, divide the required profit by his investment in stock; this is the margin of profit he needs to keep operating. If turnover is faster, divide his margin by the number of turnovers in a month; if it's slower, multiply his margin by the number of months in a turnover cycle. This calculation determines how big a markup the merchant needs to make the trade worthwhile. The markup must cover his margin of profit, plus operating expenses and the costs of maintaining his equipment.

Example: Avram is a street vendor selling cooked food in a medieval (TL3) Near Eastern city. His Wealth is Struggling, so his starting money is $500. Of this, 20% goes into "gear," including cooking equipment, bags, and trays; the other 80%, or $400, goes into merchandise: food. Struggling implies Status -1, and supporting a Status -1 lifestyle costs $300/month. Avram has a one-day turnover and does business six days a week, or 25 days a month, so he needs $300/25 = $12 profit a day. His only significant operating expense is charcoal for fuel, which costs $24 a day. Each day, then, he must gross $436 on food that cost him $400, or a 9% markup; each week, his sales must total $2,616 to stay in business.

This example is intentionally simplified! Realistically, Avram will want a higher markup as insurance against days with bad sales. He may take other self-protective measures, too, such as setting aside money for emergencies.

By the nature of the job, being a merchant involves risk. Goods may sell for less than expected, go unsold, or be stolen! Such considerations are abstracted in monthly job rolls (p. B516), the rules for which depend on turnover time.

Short Turnover

Merchants with *short turnover* sell through their stock in a few days – for the sake of these rules, in less than a week. They have enough turnovers each month that good and bad days average out. Treat them as having a fixed income, even if they're actually self-employed. They only suffer serious losses on a critical failure on their job roll.

These sorts of merchants normally operate in a single settlement, usually a town or a city. Even a large community can only provide a limited number of customers, however, especially for expensive goods; thus, high-turnover merchandise is typically fairly inexpensive. If the goods are light – e.g., sewing equipment or snacks – the seller may personally carry them through the streets. Heavier wares might be sold in a market stall or over a shop counter facing the street. If the merchant doesn't own the space, he'll probably have to pay rent. He may also have incidental expenses (like Avram's charcoal for cooking).

During this interval, Aladdin frequented the shops of the principal merchants, where they sold cloth of gold and silver, linens, silk stuffs, and jewelry, and, oftentimes joining in their conversation, acquired a knowledge of the world, and a desire to improve himself.

– One Thousand and One Nights

Long Turnover

Merchants with *long turnover* take an average of a month to sell through their stock; this can vary down to a week or up to a few months. In any case, they sell some of their goods every month and have a monthly income – but they can have good or bad months. A successful job roll nets 10% more than monthly pay per point of success, while failure means 10% less per point of failure. Critical successes or failures have more drastic effects.

Merchants at this level have more goods than they can carry personally, so they need somewhere to keep them. Most have a shop, store, or warehouse; treat a substantial stall in an open-air marketplace, set up in a fixed location, as equivalent to a building. If they don't own the premises, they must pay rent. Those with employees or apprentices have to pay their staff or cover their living expenses. Some merchants instead travel around a sales territory, visiting towns and even villages, often in a cycle based on when each village has market days (see ***GURPS Fantasy,*** pp. 93-94); their expenses include upkeep for vehicles or draft animals, or pay for human porters. A businessman who owns a building, vehicle, draft animal, or slave counts its value as part of his fixed assets. Of course, this reduces the amount he can invest in merchandise.

Very Long Turnover

Some merchants make *no* sales – or only very small ones – every month. Their turnover is longer than a month, maybe longer than a year. Instead of making monthly job rolls for such businessmen, wait until they make their big sale to determine their earnings. One way to approach this is to make a single job roll for the *entire period,* its results affecting the total sum of their sales. For PC merchants, however, it's more fun to handle success or failure through roleplaying one or several transactions as they seek buyers for their goods. At the GM's discretion, they may still have to make monthly job rolls during their journey, but these don't affect income. Rather, severe failures indicate surprises similar to those faced by salaried workers who roll badly for jobs where trouble is likely: bad weather, employees running off, banditry, or whatever seems entertaining.

As this implies, the GM can treat this kind of merchant as the hero of an adventure story, traveling from city to distant city. Such an operation often requires an investment in riding, pack, or draft animals, or in vehicles. These count as adventuring gear rather than as fixed assets. Expenses include fodder for animals, and food and drink for guards and laborers.

Currency

Trade in very low-tech societies is conducted by *barter,* but there's a problem with this: *coincidence of wants.* For example, suppose that a fisherman wants some apples. He could go to an orchard-keeper and offer him fish. But what if the orchard-keeper has all the fish he needs, or doesn't like fish? In that case, the fisherman must find out what the orchard-keeper does want, and hunt for someone who will trade him that in exchange for some of his fish. Such searches can cost a lot of time – and this expense increases with the variety of goods a society produces.

At TL1 – even TL0, in some places – an alternative emerges: *money.* Early forms of money are physical goods that members of a society are willing to take in trade; in economic language, these goods have *liquidity.* One common example is livestock, with men paying so many cattle or goats as a bride-price; another is luxury items, like cacao beans, cowry shells, furs, or tobacco. But at TL1+, the goods most widely used as money are gold and silver.

Money provides three distinct benefits to societies that use it:

1. A *medium of exchange,* avoiding barter's inconvenience.
2. A *store of value,* making it possible to accumulate wealth.
3. A *unit of account,* enabling merchants and governments to record their income and expenses (see *Accounting* in ***GURPS Low-Tech Companion 1***).

To perform these functions, money is ideally:

- *Divisible* into pieces of standard size.
- *Homogenous,* so these units can be treated as equivalent.
- *Durable,* so that it doesn't get used up, suffer damage from handling, or decay.
- *Valuable for its weight,* making it easy to carry and to conceal.

Precious metals have all of these qualities. Any other good that possesses most or all of them might serve a society as money, however.

At TL2, many societies develop *coins,* pieces of precious metal of a standard size, weight, and purity, stamped with a mark guaranteeing their value, and usually issued by the ruler of a city, country, or empire. At TL3, block printing enables *paper money,* redeemable for a specified amount of precious metal, as in China under the Mongols. Both are more convenient than metal ingots, nuggets, or dust. However, they also invite *counterfeiting:* the manufacture of fake coins or notes. Coins might be under weight or debased with cheap metals; notes may be forged by someone who isn't authorized to produce them. Rulers who issue money often impose harsh punishments for these acts!

On the other hand, rulers themselves may be tempted into debasing their own coins, or issuing notes they can't afford to redeem. This leads to rising prices, or *inflation.* Prices can also be driven upward by a sudden influx of more monetary goods, as when Spain conquered the Aztecs and Incas, and carried back huge amounts of gold and silver, disrupting its own economic growth.

Whoever said money can't buy happiness simply didn't know where to go shopping.

– Bo Derek

Chapter Nine
Occupations

These are primarily jobs for NPCs, but adventurers might take them during downtime, or start out working regular jobs before more interesting events overtake them. See *Jobs* (pp. B516-517) for rules and terminology. Monthly pay is appropriate to TL4. At lower TLs, multiply by the appropriate factor (derived from the average incomes on p. B517):

TL	0	1	2	3
Income Multiplier	×0.78	×0.81	×0.84	×0.88

Big Man (TL0)

Although this occupation is typical of TL0 tribes, political "fixers" who make a living by trading favors can be found in higher-tech societies, using the same skills.

Prerequisites: Finance-12; Merchant-12; Politics-12.
Job Roll: Worst prerequisite skill.
Monthly Pay: $1,600, adjusted for margin of success or failure.
Wealth Level: Comfortable. Supports Status 1.

Brewer (TL0)

Brewing beer and wine has been a popular job since the rise of agriculture, if not slightly earlier.

Prerequisite: Professional Skill (Brewer)-12.
Job Roll: Professional Skill (Brewer).
Monthly Pay: $820, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.

Fisherman (TL0)

This is appropriate for a subsistence fisherman or someone who fishes primarily for sale to others.

Prerequisite: Fishing-12.
Job Roll: Fishing.
Monthly Pay: $410, adjusted for margin of success or failure.
Wealth Level: Struggling. Supports Status -1.

Gatherer (TL0)

Largely a TL0 job, a few can still make a living on the fringes of high-tech societies by gathering and selling wild resources such as mushrooms, herbs, and small game.

Prerequisites: Area Knowledge-12; Survival (appropriate environment)-12.
Job Roll: Worse prerequisite skill.
Monthly Pay: $400, adjusted for margin of success or failure.
Wealth Level: Struggling. Supports Status -1.

Hunter (TL0)

This is another TL0 job that can survive on the fringes into later eras.

Prerequisites: Tracking-12; Traps *or* any ranged weapon skill at 12.
Job Roll: Worse prerequisite skill.
Monthly Pay: $400, adjusted for margin of success or failure using *double* the margin.
Wealth Level: Struggling. Supports Status -1.

Tribal Chief (TL0)

This represents a high tribal chief. A sub-chief would have Status 1, Comfortable wealth, and a monthly income of $1,600.

Prerequisites: Any *three* of Administration-12, Diplomacy-12, Leadership-12, or Politics-12; Status 2.
Job Roll: Worst prerequisite skill.
Monthly Pay: $3,800, adjusted for margin of success or failure.
Wealth Level: Wealthy. Supports Status 2.

Animal Driver (TL1)

A wagon-driver has Teamster. A member of a caravan using pack animals rather than vehicles has Packing.

Prerequisites: Animal Handling (Equines)-12; Packing-12 *or* Teamster-12.
Job Roll: Worse prerequisite skill.
Monthly Pay: $500, adjusted for margin of success or failure.
Wealth Level: Struggling. Supports Status -1.

Architect (TL1)

The historical master builder wasn't trained primarily in design. He "came up through the ranks" as a building craftsman – a mason or a carpenter – and eventually became sufficiently skilled and prominent to coordinate large-scale building projects.

Prerequisites: Administration-12; Architecture-12; Carpentry-14 *or* Masonry-14.
Job Roll: Architecture. On a critical failure, gain a -1 Reputation for poor work.
Monthly Pay: $4,000, adjusted for margin of success or failure.
Wealth Level: Wealthy. Supports Status 2.

Armorer (TL1)

Arms and armor production was a highly skilled, well-paid trade concentrated in cities and towns.

Prerequisites: ST 11; Armoury (Body Armor, Melee Weapons, Missile Weapons, *or* Small Arms) -14; Jeweler-11.
Job Roll: Armoury.
Monthly Pay: $1,900, adjusted for margin of success or failure.
Wealth Level: Comfortable. Supports Status 1.

Building Laborer (TL1)

Without powered equipment, builders need a lot of workers with strong backs and some idea of what they're doing.

Prerequisites: ST 11; Carpentry-10 *or* Masonry-10.
Job Roll: Prerequisite skill.
Monthly Pay: $400.
Wealth Level: Struggling. Supports Status -1.

Bureaucrat (TL1)

This is a government functionary with at least a bit of power and discretion in how to carry out his job. He may personally employ a few clerks (below) as assistants, but they ultimately work for him, not the government.

Prerequisites: Any *three* of Administration-14, Diplomacy-14, Law-14, or Writing-14; Native fluency in at least one written language.
Job Roll: Worst prerequisite skill.
Monthly Pay: $4,100, adjusted for margin of success or failure.
Wealth Level: Wealthy. Supports Status 2.

Carpenter (TL1)

Carpentry *existed* at TL0 but, like many crafts, didn't become its own trade until TL1. Common specialties include construction (architectural carpentry), joinery (furniture), and, at TL2+, cooperage (barrel-making). These require the Carpentry skill. A carpenter moving between them rolls at -2 for the first month at his new job; see *Familiarity* (p. B169). Artistic carpentry, however, uses Artist (Woodworking). Industrial and vehicular carpentry use Mechanic, with specialties such as Looms or Mill Equipment.

Prerequisite: Artist (Woodworking)-12, Carpentry-12, *or* Mechanic (appropriate specialty)-12.
Job Roll: Prerequisite skill.
Monthly Pay: $790, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.

Charcoal-Burner (TL1)

Charcoal producers are known for living solitary lives in the forest. In addition to making charcoal, they have to take care of themselves.

Prerequisites: Professional Skill (Charcoal-Burner)-12; Survival (Woodlands)-12.
Job Roll: Professional Skill (Charcoal-Burner).
Monthly Pay: $425, adjusted for margin of success or failure.
Wealth Level: Struggling. Supports Status -1.

Clerk (TL1)

This is a minor functionary who works for someone like an official or an important merchant.

Prerequisites: Any *two* of Accounting-12, Administration-12, or Writing-12; Native fluency in at least one written language.
Job Roll: Worse prerequisite skill.
Monthly Pay: $760, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.

Clothworker (TL1)

This is a craftsman who makes cloth from fiber or yarn, but *doesn't* necessarily make clothing out of the finished cloth.

Prerequisite: Professional Skill (Clothmaker *or* Dyer)-12.
Job Roll: Better prerequisite skill.
Monthly Pay: $800, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.

Courier (TL1)

Some messengers run; others ride horse relays.

Prerequisites: Riding (Horse)-14 *or* both Hiking-12 and Running-12.
Job Roll: Worse prerequisite skill.
Monthly Pay: $375, adjusted for margin of success or failure.
Wealth Level: Struggling. Supports Status -1.

Farmer (TL1)

A relatively well-to-do free farmer who owns the land he works and possibly employs a farmhand or two.

Prerequisite: Farming-12.
Job Roll: Farming.
Monthly Pay: $750, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.

Forester/Gamekeeper (TL1)

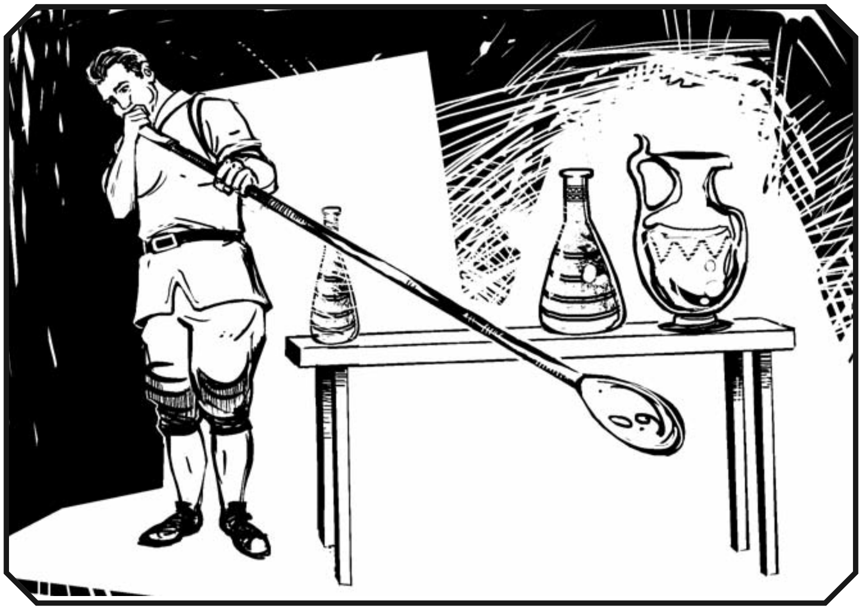
Aristocrats who owned forest land often employed specialists to look after it, keeping an eye on important forest resources (if a building or a ship required specialized lumber, foresters had to find it) and protecting the animals from poachers.

Prerequisites: Area Knowledge-12; Professional Skill (Forester)-12; any weapon skill at 12.
Job Roll: Worst prerequisite skill.
Monthly Pay: $775, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.

Glassblower (TL1)

This is appropriate for producers of glass and glass vessels. As noted in *Glassmaking* (pp. 29-30), making mosaics and stained glass windows demands other skills, but craftsmen who make art from glass often do have Professional Skill (Glassblower).

Prerequisite: Professional Skill (Glassblower)-12.
Job Roll: Professional Skill (Glassblower).
Monthly Pay: $610, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.



Herdsman (TL1)

Appropriate Animal Handling specialties include Cattle and Sheep/Goats.

Prerequisite: Animal Handling (herd animals)-12.
Job Roll: Animal Handling.
Monthly Pay: $440, adjusted for margin of success or failure.
Wealth Level: Struggling. Supports Status -1.

Illuminator (TL1)

Different from a common scribe, who simply writes, an illuminator produces highly decorative texts.

Prerequisites: Artist (Calligraphy)-12; Artist (Illumination)-12.
Job Roll: Worse prerequisite skill.
Monthly Pay: $830, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.

Jeweler (TL1)

Personal decoration takes off as a profession with the rise of wealthy elites who can support full-time craftsmen.

Prerequisite: Jeweler-14.
Job Roll: Jeweler. On a critical failure, roll vs. HT; if that roll fails, gain a disadvantage listed under *Pollution* (p. 32).
Monthly Pay: $1,800, adjusted for margin of success or failure.
Wealth Level: Comfortable. Supports Status 1.

Judge (TL1)

In many societies, trusted elders and scholars were hired by arguing parties to settle disputes, making it essentially a freelance job.

Prerequisites: Diplomacy-12; Law-12; Social Regard 2 *or* Status 2.
Job Roll: Worse prerequisite skill. On a critical failure, gain a -1 Reputation for flawed decisions.
Monthly Pay: $4,000, adjusted for margin of success or failure.
Wealth Level: Wealthy. Supports Status 2.

Mason (TL1)

Skilled stoneworking and bricklaying was a relatively lucrative trade. Masons were also more mobile than most, moving from one job site to the next.

Prerequisite: Masonry-12.
Job Roll: Masonry. On a critical failure, take 1d crushing damage to a random hit location.
Monthly Pay: $900, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.

Miller (TL1)

At TL1 and most of TL2, a miller runs an animal-powered mill. At late TL2, water- and wind-powered grinding machines become available.

Prerequisites: Animal Handling (draft animal)-12 *or* Mechanic (Mill Equipment)-12; Professional Skill (Miller)-12.
Job Roll: Professional Skill (Miller).
Monthly Pay: $830.
Wealth Level: Average. Supports Status 0.

Miner (TL1)

This is a relatively unskilled miner, digging up ores and other valuable minerals. Treat a worker in a stone quarry as a building laborer (p. 46); he must be more skilled, because the form in which material is excavated is important.

Prerequisite: ST 12.
Job Roll: ST. On a critical failure, take 2d crushing damage to a random hit location.
Monthly Pay: $420.
Wealth Level: Struggling. Supports Status -1.

Pilot (TL1)

Originally, a pilot was a guide for ships. Employed only near harbors, the pilot came on board ships to direct them around submerged rocks and sandbars.

Prerequisites: Area Knowledge (body of water)-12; Seamanship-12.
Job Roll: Worse prerequisite skill.
Monthly Pay: $810.
Wealth Level: Average. Supports Status 0.

Porter (TL1)

The porter carries small burdens, sedan chairs, and the like, making this primarily an urban profession. In areas where beast of burden are rare (e.g., Sub-Saharan Africa and most of the New World), though, porters may carry goods long distances.

Prerequisites: ST 10; HT 10; Savoir-Faire (Servant)-10.
Job Roll: Savoir-Faire.
Monthly Pay: $160.
Wealth Level: Poor. Supports Status -2.

Potter (TL1)

Yet another example of a craft that was widely practiced before it became a dedicated profession.

Prerequisite: Artist (Pottery)-12.
Job Roll: Artist.
Monthly Pay: $800, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.

Without work there is no play.
– Winston Churchill

Sailor (TL1)

In addition to their regular pay, sailors may be allowed to ship *small* quantities of goods – no more than they can carry – to trade in foreign ports.

Prerequisite: Seamanship-12.
Job Roll: Seamanship. On a critical failure, take 1d crushing damage to a random hit location.
Monthly Pay: $390, adjusted for margin of success or failure. On a success, if the GM rules that the ship lands at a trading port, the sailor may opt to make a Merchant roll and increase that month's pay by 2% times the margin of success.
Wealth Level: Struggling. Supports Status -1.

Scribe (TL1)

A freelance writer who produces letters and other documents as dictated to him.

Prerequisites: Professional Skill (Scribe)-12; Writing-12; Native fluency in at least one written language.
Job Roll: Worse prerequisite skill.
Monthly Pay: $800, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.

Serf/Sharecropper (TL1)

Many farmers made a living working someone else's land, giving up a large part of their harvest as tribute or their due to an employer in exchange for that individual's legal protection. This category includes farmhands and medieval serfs.

Prerequisite: Farming-12.
Job Roll: Farming.
Monthly Pay: $375, adjusted for margin of success or failure.
Wealth Level: Struggling. Supports Status -1.

Servant (TL1)

A household servant who cleans, cooks, and otherwise looks after an employer and his household.

Prerequisites: Housekeeping-12 *or* Savoir-Faire (Servant)-12.
Job Roll: Better prerequisite skill.
Monthly Pay: $180.
Wealth Level: Poor. Supports Status -2.

Shipwright (TL1)

Similar to the architect (p. 46), but works with boats rather than buildings.

Prerequisites: Engineer (Ships)-12; Mechanic (Ships)-12.
Job Roll: Engineer.
Monthly Pay: $850, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.

Smith (TL1)

A full-time professional smith, making utilitarian metal vessels, hardware (such as hinges), metal tools, etc., but who isn't involved in the specialized craft of making arms. A smith *may* have Metallurgy to smelt metal, but many did not.

Prerequisites: ST 11; Smith-12.
Job Roll: Smith.
Monthly Pay: $900, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.

Tailor (TL1)

Tailoring tended to be a lower-middle-class profession, but it required very little capital investment.

Prerequisite: Leatherworking-12 *or* Sewing-12.
Job Roll: Better prerequisite skill.
Monthly Pay: $750, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.

Tanner (TL1)

Tanning was historically an extremely smelly profession, so tanners often found themselves *working* outside city walls even if they *lived* inside the city.

Prerequisite: Professional Skill (Tanner)-12.
Job Roll: Professional Skill.
Monthly Pay: $800, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.

Teacher (TL1)

This represents a professional teacher – usually a freelance tutor. The upper classes in some societies owned educated slaves to teach their children.

Prerequisites: Teaching-12; at least *one* of History-12, Literature-12, Mathematics-12, Poetry-12, Public Speaking-12, or Writing-12; Native fluency in at least one written language.
Job Roll: Teaching.
Monthly Pay: $720 plus 5% per prerequisite skill at 12+, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.

Village Blacksmith (TL1)

Most smiths were part-time craftsmen who repaired farm tools. Though respected for their vital work, they were of only local importance.

Prerequisites: ST 11; Farming-11; Smith-11.
Job Roll: Worse prerequisite skill.
Monthly Pay: $440, adjusted for margin of success or failure.
Wealth Level: Struggling. Supports Status -1.

Alchemist (TL2)

A mundane, low-tech chemist – although dealing with mystical terminology is part of the job. Alchemical vessels are sufficiently specialized that alchemists must make their own.

Prerequisites: Chemistry-12; Occultism-12; Professional Skill (Glassblower)-11 *or* Artist (Pottery)-11.
Job Roll: Chemistry. On a critical failure, roll vs. HT; if that roll fails, gain a disadvantage listed under *Pollution* (p. 32).
Monthly Pay: $750, adjusted for margin of success or failure.
Wealth Level: Average. Supports Status 0.

Money-Lender (TL2)

Although money-lending is frequently lucrative enough to support high Status, professional money-lenders often have a precarious position in their community.

Prerequisites: Accounting-14; Merchant-14 *or* Streetwise-14.
Job Roll: Worse prerequisite skill. On a critical failure, gain a -1 Reputation.
Monthly Pay: $4,200, adjusted for margin of success or failure.
Wealth Level: Wealthy. Supports Status 2.

Clockmaker (TL4)

Clocks were produced far earlier, but clock-making wasn't common enough to appear as a distinct profession until the beginning of TL4.

Prerequisites: Machinist-12; Mechanic (Clockwork)-12.
Job Roll: Worse prerequisite skill.
Monthly Pay: $1,700, adjusted for margin of success or failure.
Wealth Level: Comfortable. Supports Status 1.

Apprentices and Masters

Most craftsmen start as unskilled apprentices. After some time learning on the job, they become working professionals. A few eventually develop into masters of their trade, with both demonstrated skill and enhanced social and political standing.

For any craft profession, apprentices have prerequisite skills below the listed level. Very young ones might only have defaults! Apprentices also have one step lower Wealth than professional craftsmen (e.g., Struggling instead of Average), with proportionately lower monthly income.

Masters have prerequisite skills two levels *higher* than the minimum in the job description. They get an extra level of Status. Wealth, too, is a step higher (e.g., Comfortable, for an Average job), with a corresponding increase in monthly pay.

Professional Skills

Professional Skills are explained on pp. B215-216. Below are some examples crucial to mundane technology and everyday work at TL0-4.

Brewer

IQ/Average

Defaults: IQ-5, Cooking-3, or Professional Skill (Distiller)-4.

This is the skill of producing alcoholic beverages through fermentation. *Familiarity* (p. B169) applies to different processes for converting starches into fermentable sugars; e.g., using sprouted grain vs. using starter cultures.

It ain't what you do; it's the way that you do it.

– Melvin Oliver and James Young

Brickmaker

IQ/Average

Defaults: IQ-5 or Artist (Pottery)-4.

This skill covers refining and mixing clays, building forms, drying earthen blocks, and firing bricks.

Butcher

DX/Average

Defaults: DX-5, Cooking-3, or Housekeeping-4.

This is the skill of dismembering animals and separating parts for different uses; e.g., cutting meat from skin and connective tissue that will be put to industrial use.

Charcoal-Burner

IQ/Easy

Defaults: IQ-4 or Professional Skill (Forester)-5.

The skill of producing charcoal and pitch from wood.

Clothmaker

DX/Average

Default: DX-5.

This skill deals with turning fiber into fabric, including processing raw material into clean, finished fiber, and spinning thread and yarn. Handle different means of producing cloth – weaving, felting, and knitting – using *Familiarity* (p. B169).

Courtesan

IQ/Average

Defaults: IQ-5, Carousing-3, or Streetwise-3.

This skill covers the business and basic practical aspects of exchanging sex and/or companionship for money. It may be used to find and solicit potential customers; dress properly or locate appropriate venues for transactions (often, courtesans and prostitutes were legal in low-tech societies, but sumptuary laws required them to wear distinctive garments or restrict their activities to particular districts); avoid pregnancies; and identify potential legal difficulties.

The Fine Arts are five in number: Painting, Sculpture, Poetry, Music, and Architecture – whereof the principal branch is Confectionery.

– Antonin Carême

Distiller

IQ/Average

Defaults: IQ-5, Chemistry, or Professional Skill (Brewer)-4.

This is the craft of producing alcoholic beverages through distilling a weaker alcohol solution. It covers operation and routine maintenance of large-scale distillation equipment. This skill is unavailable before TL4.

Dyer

IQ/Average

Defaults: IQ-5, Chemistry-4, or Naturalist-3.

This is the skill of producing pigments – including identifying natural mineral and vegetable sources, processing them, and using them to color raw materials.

Forester

IQ/Average

Defaults: IQ-5 or Carpentry-3.

The skill of locating desirable trees and cutting them safely. It includes coppicing, ground-clearing, and other forest-management techniques.

Glassblower

IQ/Average

Default: IQ-5.

This skill covers identifying raw glassmaking materials, producing glass, and making glass objects, including both vessels and flat shapes (windowpanes, mosaic tesserae, etc.).

Masseur

IQ/Average

Defaults: IQ-5 or Esoteric Medicine.

This is the skill of manipulating the body for muscular relaxation. It may include rubdowns, stretching limbs, and treating the body with heat, cold, and ointments or oils.

Midwife

IQ/Average

Defaults: IQ-5 or Diagnosis-4.

This is the skill of providing medical advice and assistance to pregnant women, particularly during childbirth. A successful skill roll identifies complications during pregnancy and assists the birthing process (see ***GURPS Low-Tech Companion 1***).

Miller

IQ/Average

Defaults: IQ-5 or Mechanic (Mill Equipment)-3.

This skill covers operating large-scale milling equipment, and includes minor repairs and routine maintenance, such as sharpening and replacing millstones. Handle different types of mills – animal-driven mills, water mills, and windmills – using *Familiarity* (p. B169).

Scribe

IQ/Average

Defaults: IQ-5 or Artist (Calligraphy)-3.
Prerequisite: Accented or Native fluency in a written language.

The skill of preparing documents. It encompasses legible handwriting, use of writing materials, and knowledge of appropriate polite language and formulas for letters, proclamations, petitions to government officials, etc.

Sericulturist

IQ/Average

Defaults: IQ-5 or Gardening-5.

The art of cultivating silkworms and producing silk fiber, which includes basic care of mulberry trees.

Tanner

IQ/Average

Defaults: IQ-5 or Leatherworking-3.

The skill of turning an animal hide into treated leather or fur.

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