Useful Animal Products

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Table of Contents

Introduction

Animal products are either produced by an animal or taken from the body of an animal. The term is primarily used in relation to diet, particularly for vegetarians, vegans and those concerned with maintaining a Kosher, Halaal, or raw food diet.

Although there is debate what constitutes an animal product, the term is generally not applied to products made from fossilized or decomposed animals, such as Petroleum which is formed from the ancient remains of marine animals. Crops grown in soil fertilized with animal remains are rarely characterized as animal products.

Common animal products used for food

- Blood, especially in the form of blood sausage
- Broths and stocks are often created with animal fat, bone, and connective tissue
- Carmine also known as cochineal (food dye)
- Casein (found in milk and cheese)
- Civet oil (food flavoring additive)
- Dairy products (e.g., milk, cheese, yoghurt, etc.)
- Eggs
- Gelatin
- Honey
- Honeydew (secretion)
- Isinglass (used in clarification of beer and wine)
- L-cysteine from human hair and pig bristles (used in the production of biscuits and bread)
- Lard
- Meat (including fish, poultry, and game)
- Rennet (commonly used in the production of cheese)
- Shellac
- Swiftlet's nest (made of saliva)
- Whey (found in cheese and added to many other products)

Non-food animal products

- Animal fiber
- Ambergris
- Beeswax
- Blood and some blood substitutes (blood used for transfusions is always human in origin, though some blood substitutes are made from animal sources. Many diagnostic laboratory tests use animal or human sourced reagents)
- Bone, including antlers, ivory, tusks, bone char, bone meal, etc.
- Casein (used in plastics, clothing, cosmetics, adhesives and paint)
- Castoreum (secretion of the beaver used in perfumes and possibly in food flavoring)
- Coral rock
- Down
- Ejaculate (used in artificial insemination)
- Feathers
- Foreskin (used to treat burns victims)
- Fur
- Gallstones (from livestock for Traditional Chinese Medicine)
- Ivory
- Lanolin
- Leather
- Manure
- Mink oil
- Musk
- Pearl or mother of pearl
- Shellac
- Silk
- Sponges
- Tallow, may be used in food and soap
- Tortoiseshell
- Urine
- Venom (used to produce human and veterinary antivenin)
- Whale oil
- Wool

Chapter 1

Animal Fiber

Animal fibers are natural fibers that consist largely of particular proteins. Instances are silk, hair/fur (including wool) and feathers. The animal fibers used most commonly both in the manufacturing world as well as by the hand spinners are wool from domestic sheep and silk. Also very popular are alpaca fiber and mohair from Angora goats. Unusual fibers such as Angora wool from rabbits and Chiengora from dogs also exist, but are rarely used for mass production.

Not all animal fibers have the same properties, and even within a species the fiber is not consistent. Merino is a very soft, fine wool, while Cotswold is coarser, and yet both merino and Cotswold are types of sheep. This comparison can be continued on the microscopic level, comparing the diameter and structure of the fiber. With animal fibers, and natural fibers in general, the individual fibers look different, whereas all synthetic fibers look the same. This provides an easy way to differentiate between natural and synthetic fibers under a microscope.

Silk

Silk is a "natural" protein fiber, some forms of which can be woven into textiles. The best-known type of silk is obtained from cocoons made by the larvae of the silkworm *Bombyx mori* reared in captivity (sericulture). Degummed fibers from *B. mori* are 5-10 μm in diameter. The shimmering appearance for which silk is prized comes from the fibers' triangular prism-like cross-sectional structure which allows silk cloth to refract incoming light at different angles. Silk is also the strongest natural fiber known.

The length of the silk fiber depends on how it has been prepared. Since the cocoon is made of one strand, if the cocoon is unwound carefully the fibers can be very long.

Wool

Wool is the fiber derived from the fur of animals of the Caprinae family, principally sheep, but the hair of certain species of other mammals such as goats, alpacas, and rabbits may also be called wool.

Alpaca

Alpaca fiber is that of an alpaca. It is warmer than sheep's wool and lighter in weight. It is soft, fine, glossy, and luxurious. The thickness of quality fiber is between 12-29 micrometres. Most alpaca fiber is white, but it also comes in various shades of brown and black.

Angora

Angora wool or Angora fiber refers to the down coat produced by the Angora rabbit.There are many types of Angora rabbits - English, French, German and Giant. Angora is prized for its softness, thin fibers of around 12-16 micrometres for quality fiber, and what knitters refer to as a halo (fluffiness). The fiber felts very easily. Angora fiber comes in white, black, and various shades of brown.

Bison Down

Bison Down is the soft undercoat of the American Bison. The coat of the bison contains two different types of fiber. The main coat is made up of coarse fibers (average 59 micrometres) called guard hairs, and the downy undercoat (average 18.5 micrometres). This undercoat is shed annually and consists of fine, soft fibers which are very warm and protect the animal from harsh winter conditions.

Cashmere

Cashmere wool is wool obtained from the Cashmere goat. Cashmere is characterized by its luxuriously soft fibers, with high napability and loft. In order for a natural goat fiber to be considered Cashmere, it must be under 18.5 micrometers in diameter and be at least 3.175 centimeters long. It is noted as providing a natural light-weight insulation without bulk. Fibers are highly adaptable and are easily constructed into fine or thick yarns, and light to heavy-weight fabrics.

Mohair

Mohair is a silk-like fabric or yarn made from the hair of the Angora goat. It is both durable and resilient. It is notable for its high luster and sheen, and is often used in fiber blends to add these qualities to a textile. Mohair also takes dye exceptionally well.

Sheep's wool

Wool has two qualities that distinguish it from hair or fur: it has scales which overlap like shingles on a roof and it is crimped; in some fleeces the wool fibers have more than 20 bends per inch. Wool varies in diameter from below 17 micrometres to over 35 micrometres. The finer the wool, the softer it will be, while coarser grades are more durable and less prone to pilling.

Qiviut

Qiviut is the fine underwool of the muskox. Qiviut fibres are long (about 5 to 8 cm), fine (between 15 and 20 micrometers in diameter), and relatively smooth. It is approximately eight times warmer than sheep's wool and does not felt or shrink.

Fibre from other animals

Hand spinners also use fibre from animals such as llamas, camels, yak, and possums. These fibres are generally used in clothing.

Hair from animals such as horses is also an animal fibre. Horsehair is used for brushes, the bows of musical instruments and many other things. Chiengora is dog hair.

Chapter 2

Beeswax

Beeswax cake

Uncapping beeswax honeycombs

Fresh wax scales (in the middle of the lower row)

Beeswax is a natural wax produced in the bee hive of honey bees of the genus *Apis*. It is mainly esters of fatty acids and various long chain alcohols. Typically, for a honey bee keeper, 10 pounds of honey yields 1 pound of wax.

Anatomy and production

Worker bees (the females) have eight wax-producing mirror glands on the inner sides of the sternites (the ventral shield or plate of each segment of the body) on abdominal segments 4 to 7. The size of these wax glands depends on the age of the worker and after daily flights begin these glands gradually atrophy. The new wax scales are initially glass-clear and colorless, becoming opaque after mastication by the worker bee. The wax of honeycomb is nearly white, but becomes progressively more yellow or brown by incorporation of pollen oils and propolis. The wax scales are about 3 millimetres (0.12 in) across and 0.1 millimetres (0.0039 in) thick, and about 1100 are required to make a gram of wax.

Honey bees use the beeswax to build honeycomb cells in which their young are raised and honey and pollen are stored. For the wax-making bees to secrete wax, the ambient temperature in the hive has to be 33 to 36 °C (91 to 97 °F). To produce their wax, bees must consume about eight times as much honey by mass. It is estimated that bees fly 150,000 miles, roughly six times around the earth, to yield one pound of beeswax (530,000 km/kg). When beekeepers extract the honey, they cut off the wax caps from each honeycomb cell with an uncapping knife or machine. Its color varies from nearly white to brownish, but most often a shade of yellow, depending on purity and the type of flowers gathered by the bees. Wax from the brood comb of the honey bee hive tends to be darker than wax from the honeycomb. Impurities accumulate more quickly in the brood comb. Due to the impurities, the wax has to be rendered before further use. The leftovers are called slumgum.

The wax may further be clarified by heating in water and may then be used for candles or as a lubricant for drawers and windows or as a wood polish. As with petroleum waxes, it may be softened by dilution with vegetable oil to make it more workable at room temperature.

Physical characteristics

Beeswax is a tough wax formed from a mixture of several compounds.

Wax Content Type	Percent
hydrocarbons	14%
monoesters	35%
diesters	14%
triesters	3%
hydroxy monoesters	4%
hydroxy polyesters	8%
acid esters	1%
acid polyesters	2%
free acids	12%

free alcohols	1%
unidentified	6%

An approximate chemical formula for beeswax is $C_{15}H_{31}COOC_{30}H_{61}$. Its main components are palmitate, palmitoleate, hydroxypalmitate and oleate esters of long-chain (30-32 carbons) aliphatic alcohols, with the ratio of triacontanylpalmitate $CH_3(CH_2)_{29}O$-CO-$(CH_2)_{14}CH_3$ to cerotic acid $CH_3(CH_2)_{24}COOH$, the two principal components, being 6:1. Beeswax can be classified generally into European and Oriental types. The ratio of saponification value is lower (3-5) for European beeswax, and higher (8-9) for Oriental types.

Beeswax has a high melting point range, of 62 to 64 °C (144 to 147 °F). If beeswax is heated above 85 °C (185 °F) discoloration occurs. The flash point of beeswax is 204.4 °C (399.9 °F). Density at 15 °C is 0.958 to 0.970 g/cm³.

Uses as a product

Beeswax candles and figures

- Beeswax is mainly used to make honeycomb foundation for reuse by the bees.
- Purified and bleached beeswax is used in the production of food, cosmetics, and pharmaceuticals:

  - Beeswax is used as a coating for cheese, to protect the food as it ages. As a food additive, beeswax is known as E901 (glazing agent).
  - As a skin care product, a German study found beeswax to be superior to similar "barrier creams" (usually mineral oil based creams, such as petroleum jelly), when used according to its protocol.
  - Beeswax is an ingredient in moustache wax, as well as hair pomades.
  - Beeswax is an ingredient in surgical bone wax.

- Candles
  - Beeswax candles are preferred in churches because they burn cleanly, with little or no wax dripping down the sides and little visible smoke. Beeswax is also prescribed as the material (or at least a significant part of the material) for the Paschal candle ("Easter Candle") and is recommended for other candles used in the liturgy of the Roman Catholic Church.
  - Beeswax is used commercially to make fine candles.

- Although only about 10,000 tons are produced annually, a variety of niche uses exist:
  - As a component of Shoe polish
  - As a component of Furniture polish, dissolved in turpentine, sometimes blended with linseed or tung oil
  - As a component of modelling waxes.
  - As a blended with pine rosin, beeswax serves as an adhesive to attach reed plates to the structure inside a squeezebox.
  - Used to make Cutler's resin.
  - Used in Eastern Europe in egg decoration. It is used for writing on batik eggs (as in pysanky) and for making beaded eggs.
  - Formerly used in the manufacturing of the cylinders used by the earliest phonographs.
  - Used by percussionists to make a surface on tambourines for thumb rolls.

Historical use

- Beeswax was ancient man's first plastic, and for thousands of years has been used as a modeling material, to create sculpture and jewelry molds for use in the lost-wax casting process, or *cire perdue*. Lost-wax casting of metals involved coating of a wax model with plaster, melting the wax out of the resulting mould and filling the space with molten metal. The technique is still used today by jewellers, goldsmiths and sculptors, in dentistry and even in the industrial manufacture of complex components by investment casting of metals.
- Wax tablets were used for a variety of writing purposes, from taking down students' or secretaries' notes to recording business accounts.
- Traces of beeswax were found in the paintings in the Lascaux cave.
- Traces of beeswax were found in Egyptian mummies.
- Egyptians used beeswax in shipbuilding.

- In the Roman period, beeswax was used as waterproofing agent for painted walls and as a medium for the Fayum mummy portraits.
- Nations subjugated by Rome sometimes paid tribute or taxes in beeswax.
- In the Middle Ages beeswax was considered valuable enough to become a form of currency.
- Used in bow making.
- Used to strengthen and preserve sewing thread.
- As a component of sealing wax
- Beeswax is the traditional material from which to make didgeridoo mouthpieces and the frets on the Philippine kutiyapi, a type of boat lute.
- Beeswax has been used for hundreds of years as a sealant or lubricant for bullets in cap and ball and firearms that use black powder. It is often mixed with other ingredients such as olive oil (sweet oil) and sometimes paraffin. Beeswax was used to stabilize the military explosive Torpex before being replaced by a petroleum-based product.
- Beeswax from Timor island in the south-east Asia archipelogo was used for Javanese batik in the early 1500s, with a significant trade continued by European companies into the late 1700s.

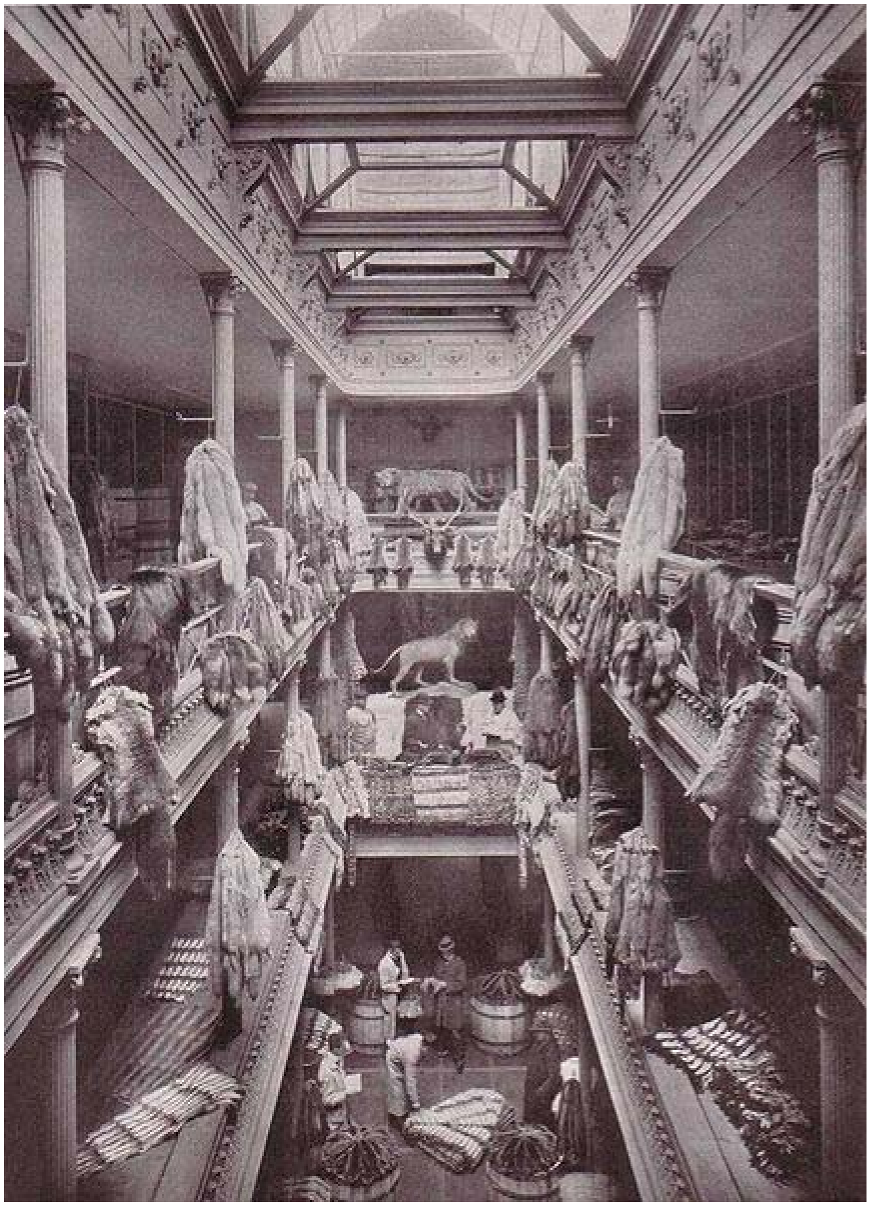
Chapter 3

Fur Clothing

Fur clothing is clothing made entirely of, or partially of, the fur of animals. Fur is one of the oldest forms of clothing, thought widely used as hominids first expanded outside of Africa. Some view fur as luxurious and warm; others reject it due to moral beliefs. The term 'a fur' is often used to refer to a coat, wrap, or shawl made from the fur of animals.

A fur mozetta, worn by a canon, Flanders

History and use



Wholesale dealer (Leipzig, 1862)

Fur is generally thought to have been among the first materials used for clothing and bodily decoration. The exact date when fur was first used in clothing is debated. It is known that several species of hominoids including *Homo sapiens* and *Homo neanderthalensis* used fur clothing.

Nutria jacket, reversible (2008)

Fur is still worn in most mild and cool climates around the world due to its superior warmth and durability. It is also sometimes associated with glamour and lavish spending, although a number of consumers and designers reject fur due to moral beliefs and perceived cruelty to animals. Fur is still used by indigenous people and underdeveloped societies, due to its availability and superior insulation properties. The Inuit peoples of the Arctic relied on fur for most of their clothing, and it also forms a part of traditional Russian, Scandinavian and Japanese clothing.

Animal furs used in garments and trim may be dyed bright colors or with patterns, often to mimic exotic animal pelts: alternatively they may be left their original pattern and color. Fur may be shorn down to imitate the feel of velvet, creating a fabric called shearling.

Sources

Common animal sources for fur clothing and fur trimmed accessories include fox, rabbit, mink, beaver, stoat (ermine), otter, sable, seals, cats, dogs, coyotes, chinchilla, and possum. Some of these are more highly prized than others, and there are many grades and colors.

Processing of fur

Traditional Sami fur footwear

The manufacturing of fur clothing involves obtaining animal pelts where the hair is left on. Depending on the type of fur and its purpose, some of the chemicals involved in fur processing are table salts, alum salts, acids, soda ash, sawdust, cornstarch, lanolin, degreasers and less commonly bleaches, dyes and toners (for dyed fur) Workers exposed to fur dust created during fur processing have been shown to have reduced pulmonary function in direct proportion to their length of exposure.

In contrast, leather made from any animal hide involves removing the fur from the skin and using only the tanned skin. The use of wool involves shearing the animal's hair from the living animal, so that the wool can be regrown. Fake fur or "faux fur" designates any synthetic material, produced from oil, that attempts to mimic the appearance and feel of real fur.

The chemical treatment of fur to increase its felting quality is known as carroting, as the process tends to turn the tips of the fur a yellowish-red "carrot like" color.

A **furrier** is a person who makes, repairs, alters, cleans, or otherwise deals in furs of animals.

Anti-fur campaigns

Anti-fur activists approach fur clothing wearers with a sign reading 'Attention! Skin of tortured animals'

Anti-fur campaigns reached a peak in the 1980s and 1990s, with the participation of numerous celebrities. Fur clothing has become the focus of boycotts on the opinion that it is cruel and unnecessary. PETA and other animal rights organizations, celebrities, and animal rights ethicists, have called attention to fur farming. Whilst other organizations and celebrities have promoted the use of fur.

Animal rights advocates object to the trapping and killing of wildlife, and to the confinement and killing of animals on fur farms due to concerns about the animals suffering and death. They promote "alternatives" made from synthetics (oil-based) clothing.

Some animal rights groups have disrupted fur fashion shows with protests while others sponsor anti-fur poster contests and fashion shows featuring faux furs or other alternatives to fur clothing. These groups sponsor "Compassionate Fashion Day" on the third Saturday of August to promote their anti-fur message. Other groups participate in "Fur Free Friday", an event held annually on the Friday after Thanksgiving (Black Friday) that occurs globally with the intent to bring the issue of fur to light through educational displays, protests and other methods of campaigning.

In Canada, opposition to the annual seal hunt is viewed as an anti-fur issue, although the Humane Society of the United States claims that its opposition is to "the largest slaughter of marine mammals on Earth." IFAW, an anti-sealing group, claims that Canada has an "abysmal record of enforcement" of anti-cruelty laws surrounding the hunt although a Canadian government survey indicated that two-thirds of Canadians supported the hunting of seals if the regulations under Canadian law are enforced.

Products from all marine mammals, even from non-threatened populations and regulated hunts, such as the Canadian seal hunt, are banned in the United States.

Fur trade

The fur trade is the worldwide buying and selling of fur for clothing and other purposes. The fur trade was one of the driving forces of exploration of North America and the Russian Far East.

Chapter 4

Lanolin

Lanolin also called **Adeps Lanae**, **wool wax** or **wool grease**, is a yellow waxy substance secreted by the sebaceous glands of wool-bearing animals. Most lanolin used by humans comes from domestic sheep. Lanolin is also frequently, but incorrectly, referred to as 'Wool Fat' by many of the world's pharmacopoeia even though it has been known for more than 150 years that lanolin is devoid of glycerides and is in fact a wax, not a fat. Lanolin's waterproofing property aids sheep in shedding water from their coats. Certain breeds of sheep produce large amounts of lanolin, and the extraction can be performed by squeezing the sheep's harvested wool between rollers. Most or all of the lanolin is removed from wool when it is processed into textiles, such as yarn or felt.

Lanolin's role in nature is to protect wool and skin against the ravages of climate and the environment – it also seems to play a role in integumental hygiene. It is therefore not surprising that lanolin and its many derivatives are used extensively in products designed for the protection, treatment and beautification of human skin.

Composition

Like many natural products, lanolin has a complex and variable composition. For example, a typical high purity grade of lanolin is composed predominantly of long chain waxy esters (ca. 97% by weight) the remainder being lanolin alcohols, lanolin acids and lanolin hydrocarbons.

It has been estimated that there may be between 8,000 and 20,000 different types of lanolin ester present in lanolin resulting from combinations between the ca. 200 different lanolin acids and the ca. 100 different lanolin alcohols that have so far been identified.

Lanolin's complex composition of long chain esters, hydroxy esters, diesters, lanolin alcohols, lanolin acids means that in addition to it being a valuable product in its own right, it is also the starting point for the production of a whole spectrum of lanolin derivatives which possess wide-ranging chemical and physical properties. The main derivatisation routes include hydrolysis, fractional solvent crystallisation, esterification, hydrogenation, alkoxylation and quaternisation. Lanolin derivatives obtained from these processes are used widely in both high-value cosmetic and skin treatment products.

Hydrolysis of lanolin yields lanolin alcohols and lanolin acids. Lanolin alcohols are a rich source of cholesterol (an important skin lipid) and are powerful water-in-oil emulsifiers; they have been used extensively in skin care products for over 100 years. Interestingly, approximately 40% of the acids derived from lanolin are alpha hydroxy acids. The use of alpha hydroxy acids (AHA's) in skin care products has attracted a great deal of attention in recent years. Details of the AHA's isolated from lanolin can be seen in the table below.

Type of lanolic acid	Carbon chain length	Number identified
Alpha hydroxy normal	$C_{13} – C_{24}$	12
Alpha hydroxy iso	$C_{13} – C_{23}$	6
Alpha hydroxy anteiso	$C_{12} – C_{24}$	7

Modern developments

In addition to general purity requirements, there are now official requirements for the level of pesticide residues permissible in lanolin. The 5th Supplement of the United States Pharmacopoeia XXII published in 1992 was the first to specify limits for 34 named pesticides. A total limit of 40 p.p.m. (40 mg kg^{-1}) total pesticides was stipulated for lanolin of general use, with no individual limit greater than 10 p.p.m. (10 mg kg^{-1}).

A second monograph also introduced into the United States Pharmacopoeia XXII in 1992 was entitled 'Modified Lanolin.' Lanolin conforming to this monograph is intended for use in more exacting applications, for example on open wounds. In the Modified Lanolin monograph, the limit of total pesticides is reduced to 3 p.p.m. (3 mg kg^{-1}) total pesticides with no individual limit greater than 1 p.p.m. (1 mg kg^{-1}).

In 2000, the European Pharmacopoeia introduced pesticide residue limits into its lanolin monograph. This requirement, which is generally regarded as the new quality standard, extends the list of pesticides to 40 and imposes even lower concentration limits.

However, some very high purity grades of lanolin surpass monograph requirements. New products obtained using complex purification techniques produce lanolin esters in their natural state removing oxidative and environmental impurities resulting in white, odourless, hypoallergenic lanolin. These ultra-high purity grades of lanolin are ideally suited to the treatment of dermatological disorders such as eczema and on open wounds.

Some years ago, lanolin attracted a great deal of attention owing to a misunderstanding concerning its sensitising potential. A study carried out at New York University Hospital in the early 1950s had shown that approximately 1% of patients with dermatological disorders were allergic to the lanolin being used at that time. However, this figure was misinterpreted and taken out of context and became quoted as 1% of the general healthy (American) population. It has been estimated that this simple misunderstanding by failing to differentiate between the general healthy population and patients with dermatological disorders exaggerates the sensitising potential of lanolin by approximately 5,000 - 6,000 times.

By the time the European Cosmetics Directive was introduced in July 1976, there had been so much adverse (but completely unfounded) publicity concerning lanolin that it contained a stipulation that cosmetics which contained lanolin should be labelled to that effect. This ruling was challenged immediately and in the early 1980s it was overturned and removed from the Directive. Despite only being in force for a very short period of time this ruling did a great deal of harm both to the lanolin industry and to the reputation of lanolin in general. The irony is that the Cosmetics Directive ruling only applied to the presence of lanolin in cosmetic products – it did not apply to the many hundreds of different lanolin derivatives used in cosmetic products or to the use lanolin in dermatological products designed for the treatment of compromised skin conditions.

However, lanolin's safety and efficacy is probably best illustrated taking a look at the market. High lanolin content baby care products (some as high as 100%) and treatment products for nursing mothers are commonplace.

More recently, using modern scientific methods, attention has focused on the positive aspects of lanolin and on increasing our understanding about how lanolin achieves its beneficial skin effects.

Modern analytical methods have revealed that lanolin possesses a number of important chemical and physical similarities to human stratum corneum lipids; the lipids which help regulate the rate of trans-epidermal water loss and govern the hydration state of the skin.

Cryo-scanning electron microscopy has shown that lanolin, like human stratum corneum lipids, consists of a mass of liquid crystalline material. Cross-polarised light microscopy has shown the multi-lamellar vesicles formed by lanolin are identical to those formed by human stratum corneum lipids. It is well known that the incorporation of bound water into the stratum corneum involves the formation of multi-lamellar vesicles.

Skin bio-engineering studies have shown that the durational effect of the emollient (skin smoothing) action produced by lanolin is very significant and lasts for many hours. Lanolin applied to the skin at 2mg cm^{-2} has been shown to reduce roughness by ca. 35% after 1 hour and ca. 50% after 2 hours with the overall lasting for considerably more than 8 hours. Lanolin is also known to form semi-occlusive (i.e. breathable) films on the skin. When applied daily at ca. 4 mg cm^{-2} for five consecutive days, the positive moisturising effects of lanolin were detectable until ca. 72 hours after final application. It has been postulated that lanolin may achieve some of its moisturising effects forming a secondary moisture reservoir within the skin.

In other studies, the barrier repair properties of lanolin have been reported to be superior to those produced by both petrolatum and glycerin. In a small clinical study conducted on volunteer subjects with terribly dry (xerotic) hands, lanolin was shown to be superior to

Petrolatum in reducing the signs and symptoms of dryness and scaling, cracks and abrasions, and pain and itch.8 In another study, a high purity grade of lanolin was found to be significantly superior to Petrolatum in assisting the healing of superficial wounds. Lanolin could thus be described as the definitive, natural skin barrier repair agent.

Applications

Lanolin ointment

Lanolin and its many derivatives are used extensively in both the personal care (e.g. in high value cosmetics, facial cosmetics, lip products etc) and health care sectors. Lanolin is frequently used in protective baby skin treatment (and nursing mother) markets.

Lanolin is used commercially in many industrial products ranging from rust-proof coatings to lubricants. Some sailors use lanolin to create a slippery surface on their propellers and stern gear to which barnacles cannot adhere. The water-repellent properties make it valuable as a lubricant grease where corrosion would otherwise be a problem.

Lanolin is often used as a raw material for producing cholecalciferol (vitamin D_3).

Lanolin is often used by baseball players to soften and break in their baseball gloves (shaving cream that contains lanolin is popularly used for this).

Anhydrous lanolin is also used as a lubricant for brass instrument tuning slides.

Lanolin can also be restored to woolen garments to make them waterproof, such as for cloth diaper covers.

A flaxseed oil-based lubricant commonly known as "wool wax" is used to polish wood furniture; however, it is unrelated to lanolin. Its name is derived from the fact that it is a paste wax that is applied using steel wool.

Production

Crude lanolin constitutes approximately 5-25% of the weight of freshly shorn wool. The wool from one Merino sheep will produce about 250-300 ml of recoverable wool grease. Lanolin is extracted by washing the wool in hot water with a special wool scouring detergent to remove dirt, wool grease (crude lanolin), suint (sweat salts), and anything else stuck to the wool. The wool grease is continuously removed during this washing process by centrifugal separators, which concentrate the wool grease into a wax-like substance melting at approximately 38 °C (100 °F).

Chapter 5

Leather

Modern leather-working tools

Leather is a durable and flexible material created via the tanning of putrescible animal rawhide and skin, primarily cattlehide. It can be produced through different manufacturing processes, ranging from cottage industry to heavy industry.

Forms of leather

Several tanning processes transform hides and skins into leather:

- **Vegetable-tanned leather** is tanned using tannin and other ingredients found in vegetable matter, such as tree bark prepared in bark mills, and other such sources. It is supple and brown in color, with the exact shade depending on the mix of chemicals and the color of the skin. It is the only form of leather suitable for use in leather carving or stamping. Vegetable-tanned leather is not stable in water; it tends to discolor, and if left to soak and then dry it will shrink and become less supple and harder. In hot water, it will shrink drastically and partly gelatinize, becoming rigid and eventually brittle. Boiled leather is an example of this, where the leather has been hardened by being immersed in hot water, or in boiled wax or similar substances. Historically, it was occasionally used as armor after hardening, and it has also been used for book binding.
- **Chrome-tanned leather**, invented in 1858, is tanned using chromium sulfate and other salts of chromium. It is more supple and pliable than vegetable-tanned leather, and does not discolor or lose shape as drastically in water as vegetable-tanned. It is also known as wet-blue for its color derived from the chromium. More esoteric colors are possible using chrome tanning.
- **Aldehyde-tanned leather** is tanned using glutaraldehyde or oxazolidine compounds. This is the leather that most tanners refer to as wet-white leather due to its pale cream or white color. It is the main type of "chrome-free" leather, often seen in automobiles and shoes for infants.
    - **Formaldehyde** tanning (being phased out due to its danger to workers and the sensitivity of many people to formaldehyde) is another method of aldehyde tanning. Brain-tanned leathers fall into this category and are exceptionally water absorbent.
        - **Brain tanned** leathers are made by a labor-intensive process which uses emulsified oils, often those of animal brains. They are known for their exceptional softness and their ability to be washed.
    - **Chamois leather** also falls into the category of aldehyde tanning and like brain tanning produces a highly water absorbent leather. Chamois leather is made by using oils (traditionally cod oil) that oxidize easily to produce the aldehydes that tan the leather to make the fabric the color it is.
- **Synthetic-tanned leather** is tanned using aromatic polymers such as the Novolac or Neradol types (syntans, contraction for *synthetic tannins*). This leather is white in color and was invented when vegetable tannins were in short supply during the Second World War. Melamine and other amino-functional resins fall into this category as well and they provide the filling that modern leathers often require. Urea-formaldehyde resins were also used in this tanning method until dissatisfaction about the formation of free formaldehyde was realized.

- **Alum-tawed leather** is transformed using aluminium salts mixed with a variety of binders and protein sources, such as flour and egg yolk. Purists argue that alum-tawed leather is technically not tanned, as the resulting material will rot in water. Very light shades of leather are possible using this process, but the resulting material is not as supple as vegetable-tanned leather.
- **Rawhide** is made by scraping the skin thin, soaking it in lime, and then stretching it while it dries. Like alum-tawing, rawhide is not technically "leather", but is usually lumped in with the other forms. Rawhide is stiffer and more brittle than other forms of leather, and is primarily found in uses such as drum heads where it does not need to flex significantly; it is also cut up into cords for use in lacing or stitching, or for making many varieties of dog chews.

Leather—usually vegetable-tanned—can be oiled to improve its water resistance. This supplements the natural oils remaining in the leather itself, which can be washed out through repeated exposure to water. Frequent oiling of leather, with mink oil, neatsfoot oil or a similar material, keeps it supple and improves its lifespan dramatically.

Leather with the hair still attached is called *hair-on*.

Leather types

In general, leather is sold in four forms:

- **Full-grain** leather refers to the leather which has not had the upper "top grain" and "split" layers separated. The upper section of a hide that previously contained the epidermis and hair, but were removed from the hide/skin. Full-grain refers to hides that have not been sanded, buffed, or snuffed (as opposed to top-grain or corrected leather) to remove imperfections (or natural marks) on the surface of the hide. The grain remains allowing the fiber strength and durability. The grain also has breathability, resulting in less moisture from prolonged contact. Rather than wearing out, it will develop a patina over time. Leather furniture and footwear are made from full-grain leather. Full-grain leathers are typically available in two finish types: aniline and semi-aniline.

- **Top-grain** leather is the second-highest quality and has had the "split" layer separated away, making it thinner and more pliable than full grain. Its surface has been sanded and a finish coat added to the surface which results in a colder, plastic feel with less breathability, and will not develop a natural patina. It is typically less expensive, and has greater resistance to stains than full-grain leather, so long as the finish remains unbroken.

- **Corrected-grain** leather is any leather that has had an artificial grain applied to its surface. The hides used to create corrected leather do not meet the standards for use in creating vegetable-tanned or aniline leather. The imperfections are corrected or sanded off and an artificial grain impressed into the surface and dressed with stain or dyes. Most corrected-grain leather is used to make pigmented leather as the solid pigment helps hide the corrections or imperfections. Corrected grain leathers can mainly be bought as two finish types: semi-aniline and pigmented.

- **Split** leather is leather created from the fibrous part of the hide left once the top-grain of the rawhide has been separated from the hide. During the splitting operation, the top grain and drop split are separated. The drop split can be further split (thickness allowing) into a middle split and a flesh split. In very thick hides, the middle split can be separated into multiple layers until the thickness prevents further splitting. Split leather then has an artificial layer applied to the surface of the split and is embossed with a leather grain (bycast leather). Splits are also used to create suede. The strongest suedes are usually made from grain splits (that have the grain completely removed) or from the flesh split that has been shaved to the correct thickness. Suede is "fuzzy" on both sides. Manufacturers use a variety of techniques to make suede from full-grain. A reversed suede is a grained leather that has been designed into the leather article with the grain facing away from the visible surface. It is not considered to be a true form of suede.

Less-common leathers include:

- **Buckskin** or **brained leather** is a tanning process that uses animal brains or other fatty materials to alter the leather. The resulting supple, suede-like hide is usually smoked heavily to prevent it from rotting.

- **Patent leather** is leather that has been given a high-gloss finish. The original process was developed in Newark, New Jersey, by inventor Seth Boyden in 1818. Patent leather usually has a plastic coating.

- **Shagreen** is also known as **stingray skin/leather**. Applications used in furniture production date as far back as the art deco period. The word "shagreen" originates from France.

- **Vachetta leather** is used in the trimmings of luggage and handbags. The leather is left untreated and is therefore susceptible to water and stains. Sunlight will cause the natural leather to darken in shade, called a patina.

- **Slink** is leather made from the skin of unborn calves. It is particularly soft, and is valued for use in making gloves.

- **Deerskin** is a tough leather, possibly due to the animal's adaptations to the its thorny and thicket-filled habitats. Deerskin has been used by many societies including indigenous Americans. Most modern deer skin is no longer procured from the wild, with deer farms breeding the animals specifically for the purpose of their skins. Large quantities are still tanned from wild deer hides in historic tanning towns such as Gloversville and Johnstown in upstate New York. Deerskin is used in jackets and overcoats, martial arts equipment such as kendo and bogu, as well as personal accessories like handbags and wallets.

- **Nubuck** is top-grain cattle hide leather that has been sanded or buffed on the grain side, or outside, to give a slight nap of short protein fibers, producing a velvet-like surface.

There are two other types of leather commonly used in specialty products, such as briefcases, wallets, and luggage:

- **Belting leather** is a full-grain leather that was originally used in driving pulley belts and other machinery. It is found on the surface of briefcases, portfolios, and wallets, and can be identified by its thick, firm feel and smooth finish. Belting leather is generally a heavy-weight of full-grain, vegetable-tanned leather.

- **Nappa leather**, or Napa leather, is chrome-tanned and is soft and supple. It is commonly found in wallets, toiletry kits, and other personal leather goods.

The following are not "true" leathers, but contain leather material. Depending on jurisdiction, they may still be labeled as "Genuine Leather":

- **Bonded leather** , or "reconstituted Leather", is composed of 90% to 100% leather fibers (often scrap from leather tanneries or leather workshops) bonded together with latex binders to create a look and feel similar to that of leather at a fraction of the cost. This bonded leather is not as durable as other leathers, and is recommended for use only if the product will be used infrequently. Bonded leather upholstery is a vinyl upholstery that contains about 17% leather fiber in its backing material. The vinyl is stamped to give it a leather-like texture. Bonded leather upholstery is durable and its manufacturing process is more environmentally-friendly than leather production.

- **Bycast leather** is a split leather with a layer of polyurethane applied to the surface and then embossed. Bycast was originally made for the shoe industry and recently was adopted by the furniture industry. The original formula created by Bayer was strong but expensive. Most of the bycast used today is very strong and durable product. The result is a slightly stiffer product that is cheaper than top grain leather but has a much more consistent texture and is easier to clean and maintain.

Leather from other animals

Tanned leather in Marrakech

Today, most leather is made of cattle skin, but many exceptions exist. Lamb and deer skin are used for soft leather in more expensive apparels. Deer and elk skin are widely used in work gloves and indoor shoes. Pigskin is used in apparel and on seats of saddles. Buffalo, goats, alligators, dogs, snakes, ostriches, kangaroos, oxen, and yaks may also be used for leather.

Kangaroo skin is used to make items which need to be strong but flexible—it is the material most commonly used in bullwhips. Kangaroo leather is favored by some motorcyclists for use in motorcycle leathers specifically because of its light weight and abrasion resistance. Kangaroo leather is also used for falconry jesses and soccer footwear.

At different times in history, leather made from more exotic skins has been considered desirable. For this reason certain species of snakes and crocodiles have been hunted to near extinction.

Although originally raised for their feathers in the 19th century, ostriches are now more popular for both meat and leather. There are different processes to produce different finishes for many applications, i.e., upholstery, footwear, automotive products, accessories and clothing. Ostrich leather is currently used by many major fashion houses such as Hermès, Prada, Gucci, and Louis Vuitton. Ostrich leather has a characteristic "goose bump" look because of the large follicles from which the feathers grew.

In Thailand, sting ray leather is used in wallets and belts. Sting ray leather is tough and durable. The leather is often dyed black and covered with tiny round bumps in the natural pattern of the back ridge of an animal. These bumps are then usually dyed white to highlight the decoration. Sting ray leather is also used as grips on Japanese katana.

Leather production processes

Barrel for leather tanning, Igualada Leather Museum, Spain

Leather tanning in Fes, Morocco

The leather manufacturing process is divided into three fundamental sub-processes: **preparatory stages**, **tanning** and **crusting**. All true leathers will undergo these sub-processes. A further sub-process, surface coating, can be added into the leather process sequence but not all leathers receive surface treatment. Since many types of leather exist, it is difficult to create a list of operations that all leathers must undergo.

The **preparatory stages** are when the hide/skin is prepared for tanning. Preparatory stages may include: preservation, soaking, liming, unhairing, fleshing, splitting, reliming, deliming, bating, degreasing, frizing, bleaching, pickling and depickling.

Tanning is the process which converts the protein of the raw hide or skin into a stable material which will not putrefy and is suitable for a wide variety of end applications. The principal difference between raw hides and tanned hides is that raw hides dry out to form a hard inflexible material that when re-wetted (or wetted back) putrefy, while tanned material dries out to a flexible form that does not become putrid when wetted back. Many different tanning methods and materials can be used; the choice is ultimately dependent on the end application of the leather. The most commonly used tanning material is chromium, which leaves the leather, once tanned, a pale blue color (due to the chromium); this product is commonly called "wet blue". The hides once they have finished pickling will typically be between pH 2.8 and 3.2. At this point, the hides would be loaded in a drum and immersed in a float containing the tanning liquor. The hides are allowed to soak (while the drum slowly rotates about its axle) and the tanning liquor slowly penetrates through the full substance of the hide. Regular checks will be made to see the penetration by cutting the cross-section of a hide and observing the degree of penetration. Once a good, even degree of penetration exists, the pH of the float is slowly raised in a process called basification. This basification process fixes the tanning material to the leather and the more tanning material fixed, the higher the hydrothermal stability and increased shrinkage temperature resistance of the leather. The pH of the leather when chrome tanned would typically finish somewhere between 3.8 and 4.2.

Crusting is when the hide/skin is thinned, retanned and lubricated. Often, a coloring operation is included in the crusting subprocess. The chemicals added during crusting have to be fixed in place. The culmination of the crusting subprocess is the drying and softening operations. Crusting may include the following operations: wetting back, sammying, splitting, shaving, rechroming, neutralization, retanning, dyeing, fatliquoring, filling, stuffing, stripping, whitening, fixating, setting, drying, conditioning, milling, staking, and buffing.

For some leathers, a surface coating is applied. Tanners refer to this as finishing. Finishing operations may include: oiling, brushing, padding, impregnation, buffing, spraying, roller coating, curtain coating, polishing, plating, embossing, ironing, ironing/combing (for hair-on), glazing and tumbling.

Environmental impact

Leather is a product with high environmental impact, most notably due to:

- the impact of livestock
- the heavy use of polluting chemicals in the tanning process
- air pollution due to the transformation process (hydrogen sulfide during dehairing and ammonia during deliming, solvent vapors).
- Leather biodegrades slowly, and takes 25–40 years to decompose.

One tonne of hide or skin generally leads to the production of 20 to 80 m^3 of wastewater including chromium levels of 100–400 mg/L, sulfide levels of 200–800 mg/L and high levels of fat and other solid wastes, as well as notable pathogen contamination. Pesticides are also often added for hide conservation during transport. With solid wastes representing up to 70% of the wet weight of the original hides, the tanning process comes at a considerable strain on water treatment installations.

Tanning is especially polluting in countries where environmental regulations are lax, such as in India, the world's third-largest producer and exporter of leather. To give an example of an efficient pollution prevention system, chromium loads per produced tonne are generally abated from 8 kg to 1.5 kg. VOC emissions are typically reduced from 30 kg/t to 2 kg/t in a properly managed facility. A review of the total pollution load decrease achievable according to the United Nations Industrial Development Organization posts precise data on the abatement achievable through industrially proven low-waste advanced methods, while noting that "even though the chrome pollution load can be decreased by 94% on introducing advanced technologies, the minimum residual load 0.15 kg/t raw hide can still cause difficulties when using landfills and composting sludge from wastewater treatment on account of the regulations currently in force in some countries."

In Kanpur, the self-proclaimed "Leather City of World" and a city of 3 million people on the banks of the river Ganges, pollution levels were so high that despite an industry crisis, the pollution control board has decided to seal 49 high-polluting tanneries out of 404 in July 2009. In 2003 for instance, the main tanneries effluent disposal unit was dumping 22 tonnes of chromium-laden solid waste per day in the open. Scientists at the Central Leather Research Institute in India have developed biological methods for pretanning as well as better chromium management.

The higher cost associated to the treatment of effluents that to untreated effluent discharging leads to illegal dumping to save on costs. For instance, in Croatia in 2001, proper pollution abatement cost 70-100 USD/t of raw hides processed against 43 USD/t for irresponsible behaviour.

No general study seems to exist but the current news is rife with documented examples. In November 2009 for instance, it was discovered that one of Uganda's main leather producing companies directly dumped its waste water in a wetland adjacent to Lake Victoria.

Role of enzymes in leather production

Enzymes like proteases, lipases and amylases have an important role in the soaking, dehairing, degreasing, and bating operations of leather manufacturing.

Proteases are the most commonly used enzymes in leather production. The enzyme used should not damage or dissolve collagen or keratin, but should be able to hydrolyze casein, elastin, albumin and globulin-like proteins, as well as non-structured proteins which are not essential for leather making. This process is called bating.

Lipases are used in the degreasing operation to hydrolyze fat particles embedded in the skin.

Amylases are used to soften skin, to bring out the grain, and to impart strength and flexibility to the skin. These enzymes are rarely used.

Preservation and conditioning of leather

The natural fibers of leather will break down with the passage of time. Acidic leathers are particularly vulnerable to red rot, which causes powdering of the surface and a change in consistency. Damage from red rot is aggravated by high temperatures and relative humidities, and is irreversible.

Exposure to long periods of low relative humidities (below 40%) can cause leather to become desiccated, irreversibly changing the fibrous structure of the leather.

Various treatments are available such as conditioners, but these are not recommended by conservators since they impregnate the structure of the leather artifact with active chemicals, are sticky, and attract stains.

Leather in book binding

Leather used in book binding has many of the same preservation needs: protection from high temperatures, high relative humidity, low relative humidity, fluctuations in relative humidity, light exposure, dust buildup, pollution, mold, and bug infestation.

For books with red rot, acid-free phase boxes and/or polyester dust jackets (Dupont Mylar Type D or ICI Mellinex 516) are recommended to protect the leather from further handling damage and as well as to prevent the residues from getting on hands, clothes, the text block, and nearby books.

The debate on the use of dressings for preservation of book bindings has spanned several decades as research and experimental evidence have slowly accumulated. The main argument is that, done incorrectly, there are multiple disadvantages and that, done correctly, there is little to no preservation advantage. Pamphlets and guidelines give numerous downsides to dressings use, including: the dressing becoming increasingly acidic, discolor and stain the leather, oxidize (penetration and expansion of oils including displacement and weakening of fibers) and stiffen, leave a sticky surface, collect dust, wick into adjacent materials, form unstable surface spews, encourage biological deterioration and mold growth, block surface porosity, impede further treatment, wet and swell the leather, affect surface finishes, and desiccate or dry out the leather. Meanwhile, scientific experiments have shown no substantial benefits. The main authorities on the subject therefore discourage it, with a caveat for special cases done under the direction of a conservator.

Working with leather

Leather can be decorated by a variety of methods, including pyrography and beading.

Cordwain, "Cordovan" or "Spanish leather"

Fragment of Cordwain

Cordwain, once a synonym of cordovan (through Old French *cordewan*) meaning "from Córdoba" describes painted or gilded embossed leather hangings manufactured in panels and assembled for covering walls as an alternative to tapestry. Such "Cordovan leathers" were a north African style that was introduced to Spain in the ninth century (hence it is sometimes referred to as 'Spanish leather'); in Spain such embossed leather hangings were known as *guadamecí* or guadamecil, from the Libyan town of Ghadames, while *cordobanes* signified soft goat leather. Leather was even more proof against draughts and dampness than tapestry, and it was unaffected by insects. From the fourteenth century, the technique in which panels of wet leather were shaped over wooden moulds, painted, then oil-gilded and lacquered, reached Flanders and Brabant in the Low Countries. Though there were craftsmen in several cities (such as Antwerp, Brussels, Ghent), the major handicraft center for this *cordwain* was Mechelen, where it was mentioned as early as 1504.

Embossed gilded leather hangings in a Dutch interior, ca 1730, painted by Philip van Dijk (Mauritshuis)

Patterns for these panels followed fashions in silk damask, at some lag in time, since the high-relief wooden moulds were laborious to make. After the second half of the 18th century, this luxurious artisan product was no longer made, its place taken in part by chintz hangings and printed wallpapers. *Cordwainer* is still used to describe someone in the profession of shoemaking.

Leather in modern culture

Due to its excellent resistance to abrasion and wind, leather found a use in rugged occupations. The enduring image of a cowboy in leather chaps gave way to the leatherjacketed and leather-helmeted aviator. When motorcycles were invented, some riders took to wearing heavy leather jackets to protect from road rash and wind blast; some also wear chaps or full leather pants to protect the lower body. In fact, top-quality motorcycle leather is superior for abrasion protection to any practical man-made fabric, and is still used in racing. Many sports still use leather to help in playing the game or protecting players; its flexibility allows it to be formed and flexed.

The term **leathering** is sometimes used in the sense of a physical punishment (such as a severe spanking) applied with a leather whip, martinet, etc.

Leather fetishism is the name popularly used to describe a fetishistic attraction to people wearing leather, or in certain cases, to the garments themselves.

Many rock groups (particularly heavy metal and punk groups in the 1980s) are well-known for wearing leather clothing. Leather clothing, particularly jackets, are common in the heavy metal and Punk subculture. Extreme metal bands (especially black metal bands) and Goth rock groups have extensive leather clothing, i.e. leather pants, accessories, etc.

Many cars and trucks come with optional or standard "leather" seating. This can range from cheap vinyl imitation leather, found on some low cost vehicles, to real Nappa leather, found on luxury car brands like Mercedes-Benz, BMW, and Audi.

Leather is used exclusively by publishers like The Easton Press to bind books, for both practical and aesthetic purposes.

Religious sensitivities to leather

In religiously diverse countries, leather vendors are typically careful to clarify the kinds of leather used in their products. For example, leather shoes will bear a label identifying the animal from which the leather was taken. In this way, a Muslim would not accidentally purchase pigskin leather, and a Hindu could avoid cow leather. Many Hindus who are vegetarians will not use any kind of leather.

Such taboos increase the demand for religiously neutral leathers like ostrich and deer.

Judaism forbids the comfort of wearing shoes made with leather on Yom Kippur, Tisha B'Av, and during mourning.

Jainism prohibits the use of leather since it is obtained by killing animals.

Concern for animals and the environment and alternatives

Vegans and animal rights activists boycott the use of all items made from leather, believing the practice of wearing animal hides is unnecessary and cruel in today's society.

Animal rights groups such as PETA have called for boycotts and encourage the use of alternative materials such as synthetic leathers.

Many pseudo-leather materials have been developed, allowing those who wish to wear leather-like garments to do so without actually wearing leather. One example of this is vegan microfiber, which claims to be stronger than leather when manufactured with strength in mind. Vinyl materials, pleather, Naugahyde, Durabuck, NuSuede, Hydrolite, and other alternatives exist, providing some features similar to leather.

Chapter 6

Shellac

Some of the many different colors of shellac

Shellac is a resin secreted by the female lac bug, on trees in the forests of India and Thailand. It is processed and sold as dry flakes (pictured at right), which are dissolved in denatured alcohol to make liquid shellac, which is used as a brush-on colorant, food glaze and wood finish. Shellac functions as a tough all-natural primer, sanding sealant, tannin-blocker, odour-blocker, stain, and high-gloss varnish. Shellac was once used in electrical applications as it possesses good insulation qualities and it seals out moisture. Phonograph (gramophone) records were also made of it during the pre-1950s, 78-rpm recording era.

Shellac is often the only historically appropriate finish for early 20th-century hardwood floors, and wooden wall and ceiling paneling.

From the time it replaced oil and wax finishes in the 19th century, shellac was the dominant wood finish in the western world until it was replaced by nitrocellulose lacquer in the 1920s and 1930s.

Production

Shellac is scraped from the bark of the trees where the female lac bug, *Kerria lacca*, Order *Hemiptera*, Family *Coccidae* secretes it to form a tunnel-like tube as it traverses the branches of tree. Though these tunnels are sometimes referred to as "cocoons", they are not literally cocoons in the entomological sense. This insect is in the same family as the insect from which cochineal is obtained. The insects suck the sap of the tree and excrete "stick-lac" almost constantly. The least coloured shellac is produced when the insects are parasitic upon the kursum tree, (*Schleichera trijuga*). The raw shellac, which contains bark shavings and lac bug parts, is placed in canvas tubes (much like long socks) and heated over a fire. This causes the shellac to liquefy, and it seeps out of the canvas leaving the bark and bug parts behind. The thick sticky shellac is then dried into a flat sheet and broken up into flakes when dried, or dried into "buttons" (pucks/cakes), and then bagged and sold. The end-user then mixes it with denatured alcohol on-site a few days prior to use in order to dissolve the flakes and make liquid shellac.

Liquid shellac has a limited shelf life (about 1 year), hence it is also sold in dry form for dissolution prior to use. Liquid shellac sold in hardware stores is clearly marked with the production (mixing) date, so that the consumer can know whether the shellac inside is still good. Alternatively, old shellac may be tested to see if it is still usable: a few drops on glass should quickly dry to a hard surface. Shellac that remains tacky for a long time is no longer usable. Storage life depends on peak temperature.

The thickness (strength) of shellac is measured by the unit "pound cut", referring to the amount (in pounds) of shellac flakes dissolved in a gallon of denatured alcohol. For example: a 1-lb. cut (said as "one pound cut") of shellac is the strength obtained by dissolving one pound of shellac flakes in a gallon of alcohol. A 5-lb. cut is the strength of five pounds of shellac flakes dissolved in a gallon of alcohol. Most pre-mixed commercial preparations come at a 3-lb. cut. Multiple thin layers of shellac produce a significantly better end result than a few thick layers—thick layers of shellac do not adhere to the substrate or to each other well, and thus can be peeled off with relative ease; in addition, thick shellac will fill in (and thus ruin) carved designs in wood and other substrates.

Shellac naturally dries to a high-gloss sheen. For applications where a flatter (less shiny) sheen is desired, products containing amorphous silica, such as "Shellac Flat," may be added to the dissolved shellac.

Shellac naturally contains a small amount of wax (3%-5% by volume), which comes from the lac bug. In some preparations, this wax is removed (the resulting product being called "dewaxed shellac"). This is done for applications where the shellac will be coated with something else (such as paint or varnish), so that the topcoat will be able to stick. Waxy (non-dewaxed) shellac appears milky in liquid form, but dries clear.

Colours and availability

Shellac comes in many warm colours, ranging from a very light blond ("platina") to a very dark brown ("garnet"), with all shades of brown, yellow, orange and red in between. The colour is influenced by the sap of the tree the lac bug is living on, as well as the time of harvest. Historically, the most commonly-sold shellac is called "orange shellac", and was used extensively as a combination stain and protectant on wood paneling and cabinetry in the 20th century.

Shellac was once very common, being available any place paints or varnishes were sold (such as hardware stores). However, less expensive, more transparent, and more abrasion- and chemical-resistant finishes, such as polyurethane, have almost completely replaced it in the world of decorative residential wood finishing such as for hardwood floors, wooden wainscoting and plank paneling, and kitchen cabinets. These alternative products, however, must be applied over a stain if the user wants the wood coloured; shellac wasn't applied over a stain, as it was orange/amber in colour by itself, and so functioned as a combination stain and protective topcoat. "Wax over shellac" (an application of buffed-on paste wax over several coats of shellac) is often regarded as a beautiful finish for hardwood floors.

Properties

A decorative medal made in France in early 20th century moulded from shellac compound, the same used for phonograph records of the period.

Shellac is a natural polymer and is chemically similar to synthetic polymers, and thus can be considered a natural form of plastic. It can be turned into a moulding compound when mixed with wood flour and moulded under heat and pressure methods, so it can also be classified as thermoplastic.

Shellac is soluble in alkaline solutions such as ammonia, sodium borate, sodium carbonate, and sodium hydroxide, and also in various organic solvents. When dissolved in alcohol blends containing ethanol and methanol, shellac yields a coating of superior durability and hardness.

Upon mild hydrolysis shellac gives a complex mix of aliphatic and alicyclic hydroxy acids and their polymers that varies in exact composition depending upon the source of the shellac and the season of collection. The major component of the aliphatic component is aleuritic acid, whereas the main alicyclic component is shellolic acid.

History

The earliest record of shellac goes back 3000 years, but shellac is known to have been used earlier. According to the Mahabharata, an entire palace was built out of dried shellac.

Shellac was in rare use as a dyestuff for as long as there was a trade with the East Indies. Merrifield cites 1220 for the introduction of shellac as an artist's pigment in Spain. This isn't unreasonable, given that lapis lazuli as ultramarine pigment from Afghanistan was already being imported long before this.

The use of overall paint or varnish decoration on large pieces of furniture was first popularised in Venice (then later throughout Italy). There are a number of 13th century references to painted or varnished cassone, often dowry cassone that were made deliberately impressive as part of dynastic marriages. The definition of varnish is not always clear, but it seems to have been a spirit varnish based on gum benjamin or mastic, both traded around the Mediterranean. At some time, shellac began to be used as well. An article from the Journal of the American Institute of Conservation describes the use of infrared spectroscopy to identify a shellac coating on a 16th century cassone. This is also the period in history where "varnisher" was identified as a distinct trade, separate from both carpenter and artist.

Another consumer of shellac is sealing wax. Woods's *The Nature and Treatment of Wax and Shellac Seals* discusses the various formulations, and the period when shellac started to be added to the previous beeswax recipes.

The "period of widespread introduction" would seem to be around 1550 to 1650, when it moves from being a rarity on highly decorated pieces to being a substance described in the standard texts of the day.

Uses

In the early- and mid-20th century, orange shellac was used as a one-product finish (combination stain and varnish-like topcoat) on decorative wood paneling used on walls and ceilings in homes, particularly in America. In the American South, use of knotty pine plank paneling covered with orange shellac was once as common in new construction as drywall is today. It was also often used on kitchen cabinets and hardwood floors, prior to the advent of polyurethane.

It is the central element of the traditional "French polish" method of finishing furniture, and fine viols and guitars.

Shellac was used from mid-19th century to produce small moulded goods like picture frames, boxes, toilet articles, jewelry, inkwells and even dentures. Although advancement in plastics have rendered shellac obsolete as a moulding compound, it remains popular for a number of other uses. In dental technology, it is still occasionally used in the production of custom impression trays and (partial) denture production.

Shellac is used by many cyclists as a protective and decorative coating for their handlebar tape. Shellac is used as a hard-drying adhesive for tubular cycle tires, particularly for track racing.

Orange shellac is also the preferred adhesive for reattaching ink sacs when restoring vintage fountain pens. It has always been the preferred hot-melt adhesive for fixing leather saxophone pads into their metal key-cups.

Until the advent of vinyl around the 1940s, most gramophone records were pressed from shellac compounds. This use was common until the 1950s, and continued into the 1970s in some non-Western countries.

Sheets of Braille were coated with shellac to help protect them from wear due to being read by hand.

Shellac is used as a binder in India ink.

Shellac was historically used as a protective coating on paintings.

Shellac is edible and it is used as a glazing agent on pills and candies in the form of *pharmaceutical glaze* (alternatively, *confectioner's glaze*). Because of its alkaline properties, shellac-coated pills may be used for a timed enteric or colonic release. It is also used to replace the natural wax of the apple, which is removed during the cleaning process. When used for this purpose, it has the food additive E number E904. This coating is not vegan and most likely not vegetarian either as it may, and probably does, contain crushed insects.

Because it is compatible with most other finishes, shellac is also used as a barrier or primer coat on wood to prevent the bleeding of resin or pigments into the final finish, or to prevent wood stain from blotching.

Shellac is an odour and stain blocker and so is often used as the base of "solves all problems" primers. Although its durability against abrasives and many common solvents is not very good, shellac provides an excellent barrier against water vapour penetration. Shellac based primers are an effective sealant to control odours associated with fire damage.

Shellac was once used for fixing inductor, motor, generator and transformer windings, where it was applied directly to single layer windings as an alcoholic solution in much the same manner as it is applied to timber. For multilayer windings, the whole coil was submerged in the shellac solution and then removed, drained and placed in a warm place to allow the alcohol to evaporate. The shellac then holds the turns in place, provides extra insulation and prevents movement and vibration, reducing buzz and hum. In motors and generators it also provides a medium for transfer of forces generated by magnetic attraction and repulsion from the windings to the rotor or armature. In more recent times synthetic resins, such as Glyptol, (Glyptal), have been substituted for the shellac. Some applications use shellac mixed with other natural or synthetic resins, such as pine resin or Phenol-Formaldehyde Resin, of which Bakelite is the best known, for electrical use. Mixed with other resins, Barium sulfate, Calcium Carbonate, Zinc Sulfide, Aluminum Oxide and/or Cuprous Carbonate, (Malachite), shellac forms a component of *Heat Cured Capping Cement* used to fasten the caps or bases to the bulbs of electric lamps.

As a natural resin, shellac has similarities to other natural resins such as Myrrh and Frankincense.

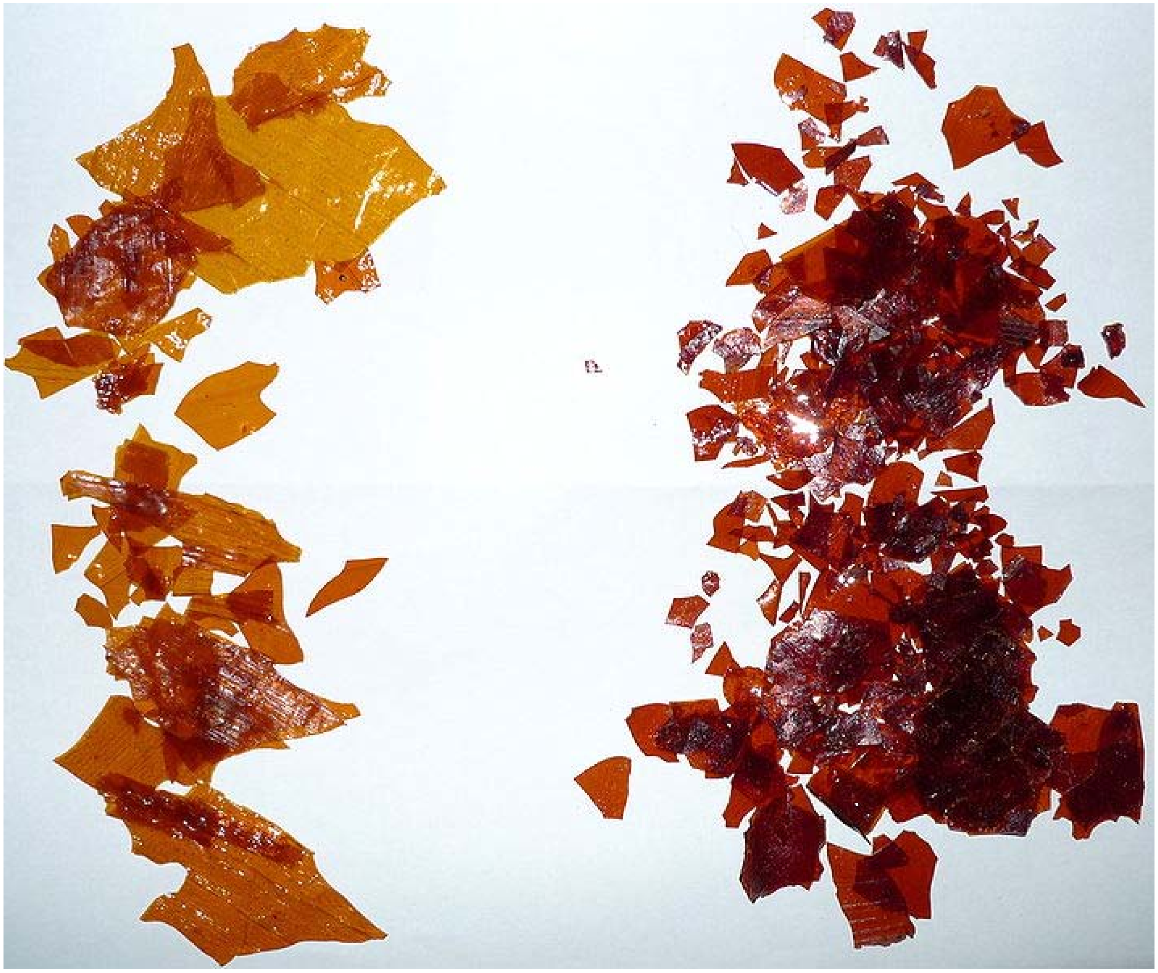
Shellac finds a use in pyrotechnic compositions as a low temperature fuel where it allows the creation of pure 'greens' and 'blues', colours difficult to achieve with other fuel systems in fireworks formulae.

Trivia

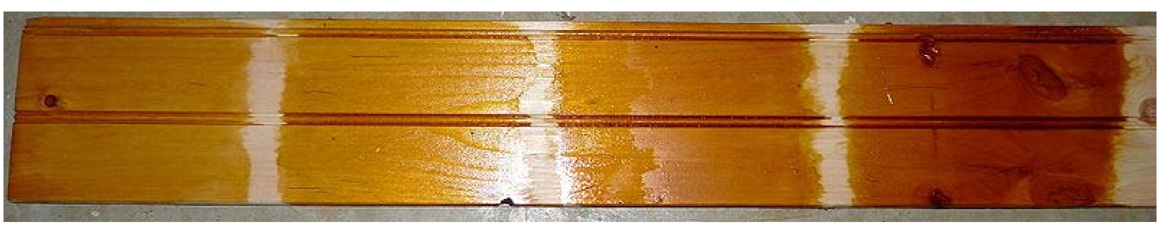
- It takes about 100,000 lac bugs to make 500 g of shellac flakes.
- Shellac is UV-resistant, and does not darken as it ages (though the wood under it may do so on its own, as in the case of pine).
- Shellac scratches less easily than most usual lacquers, and damaged areas can easily be touched-up with another coat of shellac (unlike with polyurethane) because the new coat merges with and bonds to the existing coat(s), but shellac is much softer than Urushi lacquer for instance, which is far superior in regards to both chemical and mechanical resistance.

Blonde shellac flakes

Dewaxed Bona (L) and Waxy #1 Orange (R) shellac flakes. The latter -- orange shellac -- is the traditional shellac used for decades to finish wooden wall paneling and kitchen cabinets.



Closeup of Waxy #1 Orange (L) and Dewaxed Bona (R) shellac flakes. The former -- orange shellac -- is the traditional shellac used for decades to finish wooden wall paneling and kitchen cabinets.



"Quick and dirty" example of a pine board coated with 1-5 coats of Dewaxed Dark shellac (a darker version of traditional orange shellac)

Chapter 7

Silk

Four of the most important domesticated silk worms, together with their adult moth forms, Meyers Konversations-Lexikon (1885-1892)

Silk is a natural protein fibre, some forms of which can be woven into textiles. The best-known type of silk is obtained from the cocoons of the larvae of the mulberry silkworm *Bombyx mori* reared in captivity (sericulture). The shimmering appearance of silk is due to the triangular prism-like structure of the silk fibre, which allows silk cloth to refract incoming light at different angles, thus producing different colors.

Silks are produced by several other insects, but only the silk of moth caterpillars has been used for textile manufacturing. There has been some research into other silks, which differ at the molecular level. Silks are mainly produced by the larvae of insects undergoing complete metamorphosis, but also by some adult insects such as webspinners. Silk production is especially common in the Hymenoptera (bees, wasps, and ants), and is sometimes used in nest construction. Other types of arthropod produce silk, most notably various arachnids such as spiders.

History

Woven silk textile from tomb no 1. at Mawangdui in Changsha, Hunan province, China, from the Western Han Dynasty, 2nd century BC

Landscape of quick water from high mountain by Zhao Zho, Ming Dynasty, 1611 AD. Hand scroll, ink and colour on silk.

Wild silk

A variety of wild silks, produced by caterpillars other than the mulberry silkworm have been known and used in China, South Asia, and Europe since ancient times. However, the scale of production was always far smaller than that of cultivated silks. They differ from the domesticated varieties in color and texture, and cocoons gathered in the wild usually have been damaged by the emerging moth before the cocoons are gathered, so the silk thread that makes up the cocoon has been torn into shorter lengths. Commercially reared silkworm pupae are killed by dipping them in boiling water before the adult moths emerge, or by piercing them with a needle, allowing the whole cocoon to be unraveled as one continuous thread. This permits a much stronger cloth to be woven from the silk. Wild silks also tend to be more difficult to dye than silk from the cultivated silkworm.

China

Silk fabric was first developed in ancient China, with some of the earliest examples found as early as 3500 BC. Legend gives credit for developing silk to a Chinese empress, Lei Zu (Hsi-Ling-Shih, Lei-Tzu). Silks were originally reserved for the Kings of China for their own use and gifts to others, but spread gradually through Chinese culture and trade both geographically and socially, and then to many regions of Asia. Silk rapidly became a popular luxury fabric in the many areas accessible to Chinese merchants because of its texture and luster. Silk was in great demand, and became a staple of pre-industrial international trade. In July 2007, archeologists discovered intricately woven and dyed silk textiles in a tomb in Jiangxi province, dated to the Eastern Zhou Dynasty roughly 2,500 years ago. Although historians have suspected a long history of a formative textile industry in ancient China, this find of silk textiles employing "complicated techniques" of weaving and dyeing provides direct and concrete evidence for silks dating before the Mawangdui-discovery and other silks dating to the Han Dynasty (202 BC-220 AD).

The first evidence of the silk trade is the finding of silk in the hair of an Egyptian mummy of the 21st dynasty, c.1070 BC. Ultimately the silk trade reached as far as the Indian subcontinent, the Middle East, Europe, and North Africa. This trade was so extensive that the major set of trade routes between Europe and Asia has become known as the Silk Road. The highest development was in China.

The Emperors of China strove to keep knowledge of sericulture secret to maintain the Chinese monopoly. Nonetheless sericulture reached Korea around 200 BC, about the first half of the 1st century AD had reached ancient Khotan, and by AD 300 the practice had been established in India.

Thailand

Silk is produced, year round, in Thailand by two types of silkworms, the cultured Bombycidae and wild Saturniidae. Most production is after the rice harvest in the southern and northeast parts of the country. Women traditionally weave silk on hand looms, and pass the skill on to their daughters as weaving is considered to be a sign of maturity and eligibility for marriage. Thai silk textiles often use complicated patterns in various colours and styles. Most regions of Thailand have their own typical silks. A single thread filament is too thin to use on its own so women combine many threads to produce a thicker, usable fibre. They do this by hand-reeling the threads onto a wooden spindle to produce a uniform strand of raw silk. The process takes around 40 hours to produce a half kilogram of Thai silk.

Many local operations use a reeling machine for this task, but some silk threads are still hand-reeled. The difference is that hand-reeled threads produce three grades of silk: two fine grades that are ideal for lightweight fabrics, and a thick grade for heavier material.

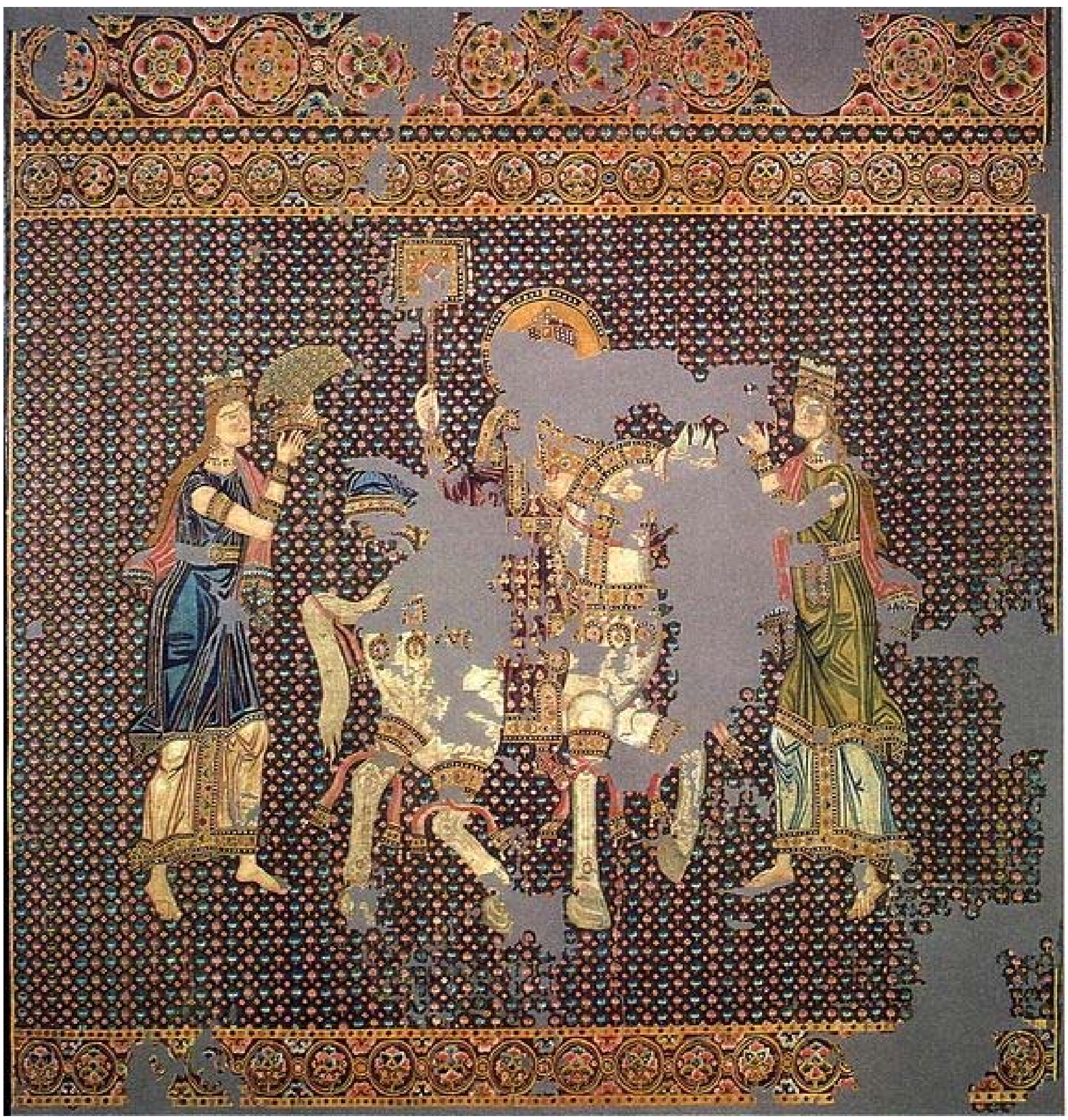
The silk fabric is soaked in extremely cold water and bleached before dyeing to remove the natural yellow coloring of Thai silk yarn. To do this, skeins of silk thread are immersed in large tubs of hydrogen peroxide. Once washed and dried, the silk is woven on a traditional hand operated loom.

Woven silk from Cambodia

India

Silk, known as "Paat" in Eastern India, *Pattu* in southern parts of India and *Resham* in Hindi/Urdu, has a long history in India. Recent archaeological discoveries in Harappa and Chanhu-daro suggest that sericulture, employing wild silk threads from native silkworm species, existed in South Asia during the time of the Indus Valley Civilization, roughly contemporaneous with the earliest known silk use in China. Silk is widely produced today. India is the second largest producer of silk after China. A majority of the silk in India is produced in Karnataka State, particularly in Mysore and the North Bangalore regions of Muddenahalli, Kanivenarayanapura, and Doddaballapur. India is also the largest consumer of silk in the world. The tradition of wearing silk sarees in marriages by the brides is followed in southern parts of India. Silk is worn by people as a symbol of royalty while attending functions and during festivals. Historically silk was used by the upper classes, while cotton was used by the poorer classes. Today silk is mainly produced in Bhoodhan Pochampally (also known as Silk City), Kanchipuram, Dharmavaram, Mysore, etc. in South India and Banaras in the North for manufacturing garments and sarees. "Murshidabad silk", famous from historical times, is mainly produced in Malda and Murshidabad district of West Bengal and woven with hand looms in Birbhum and Murshidabad district. Another place famous for production of silk is Bhagalpur. The silk from Pochampally is particularly well-known for its classic designs and enduring quality. The silk is traditionally hand-woven and hand-dyed and usually also has silver threads woven into the cloth. Most of this silk is used to make sarees. The sarees usually are very expensive and vibrant in color. Garments made from silk form an integral part of Indian weddings and other celebrations. In the northeastern state of Assam, three different types of silk are produced, collectively called Assam silk: Muga, Eri and Pat silk. Muga, the golden silk, and Eri are produced by silkworms that are native only to Assam. The heritage of silk rearing and weaving is very old and continues today especially with the production of Muga and Pat *riha* and *mekhela chador*, the three-piece silk sarees woven with traditional motifs. *Mysore Silk Sarees*, which are known for their soft texture, last many years if carefully maintained.

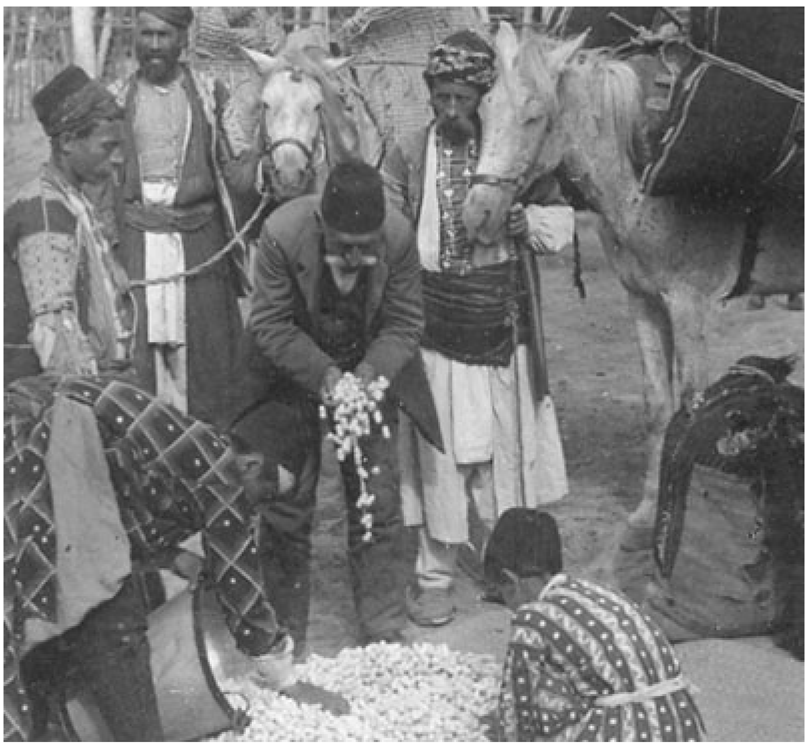
Ancient Mediterranean



The *Gunthertuch*, an 11th-century silk celebrating a Byzantine emperor's triumph

In the Odyssey, 19.233, when Odysseus, while pretending to be someone else, is questioned by Penelope about her husband's clothing, he says that he wore a shirt "gleaming like the skin of a dried onion" (varies with translations, literal translation here) which could refer to the lustrous quality of silk fabric. The Roman Empire knew of and traded in silk. During the reign of emperor Tiberius, sumptuary laws were passed that forbade men from wearing silk garments, but these proved ineffectual. Despite the popularity of silk, the secret of silk-making only reached Europe around AD 550, via the Byzantine Empire. Legend has it that monks working for the emperor Justinian I smuggled silkworm eggs to Constantinople in hollow canes from China. All top-quality looms and weavers were located inside the Palace complex in Constantinople and the cloth produced was used in imperial robes or in diplomacy, as gifts to foreign dignitaries. The remainder was sold at very high prices.

Middle East



Purchasing silkworm cocoons in Antioch, circa 1895.

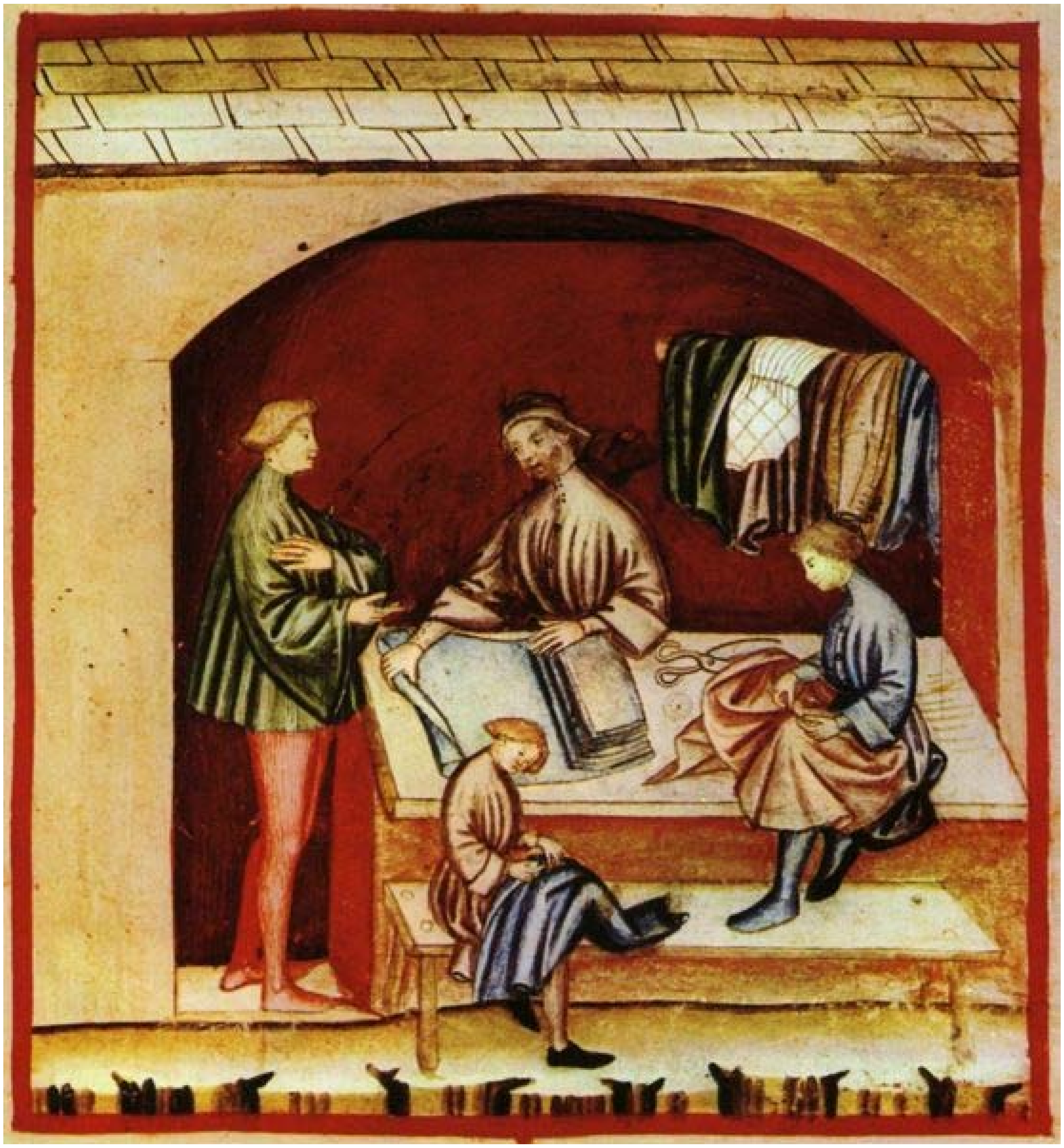
Dress made from silk

In Islamic teachings, Muslim men are forbidden to wear silk. Many religious jurists believe the reasoning behind the prohibition lies in avoiding clothing for men that can be considered feminine or extravagant. There are disputes regarding the amount of silk a fabric can consist of (i.e., whether a small decorative silk piece on a cotton caftan is permissible or not) for it to be lawful for men to wear but the dominant opinion of most Muslim scholars is that the wearing of silk for men is forbidden.

Despite injunctions against silk for men, silk has retained its popularity in the Islamic world because of its permissibility for women. The Muslim Moors brought silk with them to Spain during their conquest of the Iberian Peninsula.

Medieval and modern Europe

Venetian merchants traded extensively in silk and encouraged silk growers to settle in Italy. By the 13th century, Italian silk was a significant source of trade. Since that period, the silk worked in the province of Como has been the most valuable silk in the world. The wealth of Florence was largely built on textiles, both wool and silk, and other cities like Lucca also grew rich on the trade. Italian silk was so popular in Europe that Francis I of France invited Armenian silk makers to France to create a French silk industry, especially in Lyon. Mass emigration (especially of Huguenots) during periods of religious dispute had seriously damaged French industry and introduced these various textile industries, including silk, to other countries. Silk was expensive in Medieval Europe and used only by the rich. Italian merchants like Giovanni Arnolfini became hugely wealthy trading it to the Courts of Northern Europe.



Silk clothing in the Tacuinum Sanitatis (XIV century)

James I attempted to establish silk production in England, purchasing and planting 100,000 mulberry trees, some on land adjacent to Hampton Court Palace, but they were of a species unsuited to the silk worms, and the attempt failed. In 1717, John Lombe, visited Piedmont and returned to England with details of the Italian machines, and some Italian craftsmen. He was granted a fourteen year patent, and built Lombe's Mill in Derby. The King of Sardinia retaliated by prohibiting the export of raw silk. Nethertheless, in 1732 John Guardivaglio set up a silk throwing enterprise at Logwood mill in Stockport, and in 1744, Burton Mill was erected in Macclesfield and in 1753 Old Mill was built in Congleton.. These three towns remained the centre of the English silk throwing industry until silk throwing was replaced by silk waste spinning. British enterprise also established silk filature in Cyprus in 1928. In England in the mid 20th

Century, raw silk was produced at Lullingstone Castle in Kent. Silkworms were raised and reeled under the direction of Zoe Lady Hart Dyke. Production started elsewhere later.

In Italy, the Stazione Bacologica Sperimentale was founded in Padua in 1871 to research sericulture. In the late 19th century, China, Japan, and Italy were the major producers of silk. The most important cities for silk production in Italy were Como and Meldola (Forlì).

North America

James I of England introduced silk-growing to the American colonies around 1619, ostensibly to discourage tobacco planting. The Shakers in Kentucky adopted the practice as did a cottage industry in New England. In the 19th century a new attempt at a silk industry began with European-born workers in Paterson, New Jersey, and the city became a US silk center, although Japanese imports were still more important.

World War II interrupted the silk trade from Japan. Silk prices increased dramatically, and US industry began to look for substitutes, which led to the use of synthetics such as nylon. Synthetic silks have also been made from lyocell, a type of cellulose fiber, and are often difficult to distinguish from real silk.

Properties

Models in silk dresses at the MoMo Falana fashion show

Physical properties

Silk fibres from the *Bombyx mori* silkworm have a triangular cross section with rounded corners, 5-10 μm wide. The fibroin-heavy chain is composed mostly of beta-sheets, due to a 59-mer aminoacid repeat sequence with some variations. The flat surfaces of the fibrils reflect light at many angles, giving silk a natural shine. The cross-section from other silkworms can vary in shape and diameter: crescent-like for *Anaphe* and elongated wedge for *tussah*. Silkworm fibres are naturally extruded from two silkworm glands as a pair of primary filaments (brin), which are stuck together, with sericin proteins that act like glue, to form a bave. Bave diameters for tussah silk can reach 65 μm.

Silk has a smooth, soft texture that is not slippery, unlike many synthetic fibers.

Silk is one of the strongest natural fibres but loses up to 20% of its strength when wet. It has a good moisture regain of 11%. Its elasticity is moderate to poor: if elongated even a small amount, it remains stretched. It can be weakened if exposed to too much sunlight. It may also be attacked by insects, especially if left dirty.

Silk is a poor conductor of electricity and thus susceptible to static cling.

Unwashed silk chiffon may shrink up to 8% due to a relaxation of the fibre macrostructure. So silk should either be washed prior to garment construction, or dry cleaned. Dry cleaning may still shrink the chiffon up to 4%. Occasionally, this shrinkage can be reversed by a gentle steaming with a press cloth. There is almost no gradual shrinkage nor shrinkage due to molecular-level deformation.

Natural and synthetic silk is known to manifest piezoelectric properties in proteins, probably due to its molecular structure.

Silkworm silk was used as the standard for the denier, a measurement of linear density in fibers. Silkworm silk therefore has a linear density of approximately 1 den, or 1.1 dtex.

Comparison of silk fibers	**Linear Density(dtex)**	**Diameter (μm)**	**Coeff. Variation**
Moth: *Bombyx mori*	1.17	12.9	24.8%
Spider: *Argiope aurentia*	0.14	3.57	14.8%

Chemical properties

Silk emitted by the silkworm consists of two main proteins, sericin and fibroin, fibroin being the structural center of the silk, and serecin being the sticky material surrounding it. Fibroin is made up of the amino acids Gly-Ser-Gly-Ala-Gly-Ala and forms beta pleated sheets. Hydrogen bonds form between chains, and side chains form above and below the plane of the hydrogen bond network.

The high proportion (50%) of glycine, which is a small amino acid, allows tight packing and the fibers are strong and resistant to breaking. The tensile strength is due to the many interseeded hydrogen bonds, and when stretched the force is applied to these numerous bonds and they do not break.

Silk is resistant to most mineral acids, except for sulfuric acid, which dissolves it. It is yellowed by perspiration.

Uses

Silk filaments being unraveled from silk cocoons, Cappadocia, Turkey, 2007.

Silk's absorbency makes it comfortable to wear in warm weather and while active. Its low conductivity keeps warm air close to the skin during cold weather. It is often used for clothing such as shirts, ties, blouses, formal dresses, high fashion clothes, lingerie, pyjamas, robes, dress suits, sun dresses and kimonos.

Silk's attractive luster and drape makes it suitable for many furnishing applications. It is used for upholstery, wall coverings, window treatments (if blended with another fiber), rugs, bedding and wall hangings.

While on the decline now, due to artificial fibers, silk has had many industrial and commercial uses; parachutes, bicycle tires, comforter filling and artillery gunpowder bags.

A special manufacturing process removes the outer irritant sericin coating of the silk, which makes it suitable as non-absorbable surgical sutures. This process has also recently led to the introduction of specialist silk underclothing for children and adults with eczema where it can significantly reduce itch.

Production

The cultivation of silk is called sericulture. Over 30 countries produce silk, the major ones are China (54%) and India (14%).

To produce 1 kg of silk, 104 kg of mulberry leaves must be eaten by 3000 silkworms. It takes about 5000 silkworms to make a pure silk kimono.

Top Ten Cocoons (Reelable) Producers — 2005

Country	Production (Int $1000)	Footnote	Production (1000 kg)	Footnote
People's Republic of China	978,013	C	290,003	F
India	259,679	C	77,000	F
Uzbekistan	57,332	C	17,000	F
Brazil	37,097	C	11,000	F
Iran	20,235	C	6,000	F
Thailand	16,862	C	5,000	F
Vietnam	10,117	C	3,000	F
Democratic People's Republic of Korea	5,059	C	1,500	F
Romania	3,372	C	1,000	F
Japan	2,023	C	600	F

No symbol = official figure, F = FAO estimate, * = Unofficial figure, C = Calculated figure;

Production in Int $1000 have been calculated based on 1999-2001 international prices
Source: Food And Agricultural Organization of United Nations: Economic And Social Department: The Statistical Division

Cultivation

Cocoon

Silk moths lay eggs on specially prepared paper. The eggs hatch and the caterpillars (silkworms) are fed fresh mulberry leaves. After about 35 days and 4 moltings, the caterpillars are 10,000 times heavier than when hatched and are ready to begin spinning a cocoon. A straw frame is placed over the tray of caterpillars, and each caterpillar begins spinning a cocoon by moving its head in a "figure 8" pattern. Two glands produce liquid silk and force it through openings in the head called spinnerets. Liquid silk is coated in sericin, a water-soluble protective gum, and solidifies on contact with the air. Within 2–3 days, the caterpillar spins about 1 mile of filament and is completely encased in a cocoon. The silk farmers then kill most caterpillars by heat, leaving some to metamorphose into moths to breed the next generation of caterpillars.

Harvested cocoons are then soaked in boiling water to soften the sericin holding the silk fibers together in a cocoon shape. The fibers are then unwound to produce a continuous thread. Since a single thread is too fine and fragile for commercial use, anywhere from three to ten strands are spun together to form a single thread of silk.

Research

Dr Willy Tan, a Republic Polytechnic researcher, is "leading a project that coaxes silkworms to spin stronger silk by exposing them to an electric field before they spin." The collaborative work between Republic Polytechnic and National University of Singapore aims to produce "super" silk which has a number of advantages over carbon/glass fibres and Kevlar.

Dr Natalia Tansil has led a research program into a "new, more environmentally friendly method allows us to integrate colours into the very fabric of silk and does away with the need for manual dyeing." The study conducted at Singapore's Institute of Materials Research and Engineering (IMRE) involves introducing safe, luminescent dyes into the food of the silkworm in the last four days of its larval stage, which has enabled the researchers to produce brightly coloured silk that isn't as nearly as wasteful as conventional dyeing methods.

Animal rights

As the process of harvesting the silk from the cocoon kills the larvae, sericulture has been criticized in the early 21st century by animal rights activists, especially since artificial silks are available. Mohandas Gandhi was also critical of silk production based on the Ahimsa philosophy "not to hurt any living thing." This led to Gandhi's promotion of cotton spinning machines, an example of which can be seen at the Gandhi Institute. He also promoted *Ahimsa silk*, wild silk made from the cocoons of wild and semi-wild silk moths. Ahimsa silk is promoted in parts of Southern India for those who prefer not to wear silk produced by killing silkworms.

Chapter 8

Wool

Long and short hair wool at the South Central Family Farm Research Center in Booneville, Arkansas

Wool section, Walcha show. The creamy fleeces on the left are crossbred wool.

Wool is the textile fiber obtained from sheep and certain other animals, including cashmere from goats, mohair from goats, qiviut from muskoxen, vicuña, alpaca, and camel from animals in the camel family, and angora from rabbits.

Wool has several qualities that distinguish it from hair or fur: it is crimped, it is elastic, and it grows in staples (clusters).

Characteristics

Champion hogget fleece, Walcha Show

Fleece of fine New Zealand Merino wool & combed wool top on a wool table.

Wool's scaling and crimp make it easier to spin the fleece by helping the individual fibers attach to each other, so that they stay together. Because of the crimp, wool fabrics have a greater bulk than other textiles, and retain air, which causes the product to retain heat. Insulation also works both ways; Bedouins and Tuaregs use wool clothes to keep the heat out.

The amount of crimp corresponds to the fineness of the wool fibers. A fine wool like Merino may have up to 100 crimps per inch, while the coarser wools like karakul may have as few as 1 to 2. Hair, by contrast, has little if any scale and no crimp, and little ability to bind into yarn. On sheep, the hair part of the fleece is called kemp. The relative amounts of kemp to wool vary from breed to breed, and make some fleeces more desirable for spinning, felting, or carding into batts for quilts or other insulating products.

Wool fibers are hygroscopic, meaning they readily absorb moisture. Wool fibers are hollow. Wool can absorb moisture almost one-third of its own weight. Wool absorbs sound like many other fabrics. Wool is generally a creamy white color, although some breeds of sheep produce natural colors such as black, brown, silver, and random mixes.

Wool ignites at a higher temperature than cotton and some synthetic fibers. It has lower rate of flame spread, low heat release, low heat of combustion, and does not melt or drip; it forms a char which is insulating and self-extinguishing, and contributes less to toxic gases and smoke than other flooring products, when used in carpets. Wool carpets are specified for high safety environments, such as trains and aircraft. Wool is usually specified for garments for fire-fighters, soldiers, and others in occupations where they are exposed to the likelihood of fire.

Wool is resistant to static electricity, as the moisture retained within the fabric conducts electricity. This is why wool garments are much less likely to spark or cling to the body. The use of wool car seat covers or carpets reduces the risk of a shock when a person touches a grounded object. Wool is considered by the medical profession to be hypoallergenic.

Processing

Shearing

Fine Merino shearing Lismore, Victoria

Sheep shearing is the process by which the woollen fleece of a sheep is cut off.

After shearing, the wool is separated into four main categories: fleece (which makes up the vast bulk), broken, bellies, and locks. The quality of fleeces is determined by a technique known as wool classing, whereby a qualified person called a wool classer groups wools of similar gradings together to maximize the return for the farmer or sheep owner. In Australia, before being auctioned all Merino fleece wool is objectively measured for micron, yield (including the amount of vegetable matter), staple length, staple strength, and sometimes color and comfort factor.

Scouring

Wool straight off a sheep, known as "greasy wool" or "wool in the grease", contains a high level of valuable lanolin, as well as dirt, dead skin, sweat residue, pesticide, and vegetable matter. Before the wool can be used for commercial purposes, it must be scoured, a process of cleaning the greasy wool. **Scouring** may be as simple as a bath in warm water, or as complicated as an industrial process using detergent and alkali, and specialized equipment. In commercial wool, vegetable matter is often removed by chemical carbonization. In less processed wools, vegetable matter may be removed by hand, and some of the lanolin left intact through use of gentler detergents. This semi-grease wool can be worked into yarn and knitted into particularly water-resistant mittens or sweaters, such as those of the Aran Island fishermen. Lanolin removed from wool is widely used in cosmetic products such as hand creams.

Quality

Various types and natural colours of wool, and a picture made from wool

The quality of wool is determined by the following factors, fiber diameter, crimp, yield, colour, and staple strength. Fiber diameter is the single most important wool characteristic determining quality and price.

Merino wool is typically 3-5 inches in length and is very fine (between 12-24 microns). The finest and most valuable wool comes from Merino hoggets. Wool taken from sheep produced for meat is typically more coarse, and has fibers that are 1.5 to 6 inches in length. Damage or breaks in the wool can occur if the sheep is stressed while it is growing its fleece, resulting in a thin spot where the fleece is likely to break.

Wool is also separated into grades based on the measurement of the wool's diameter in microns and also its style. These grades may vary depending on the breed or purpose of the wool. For example:

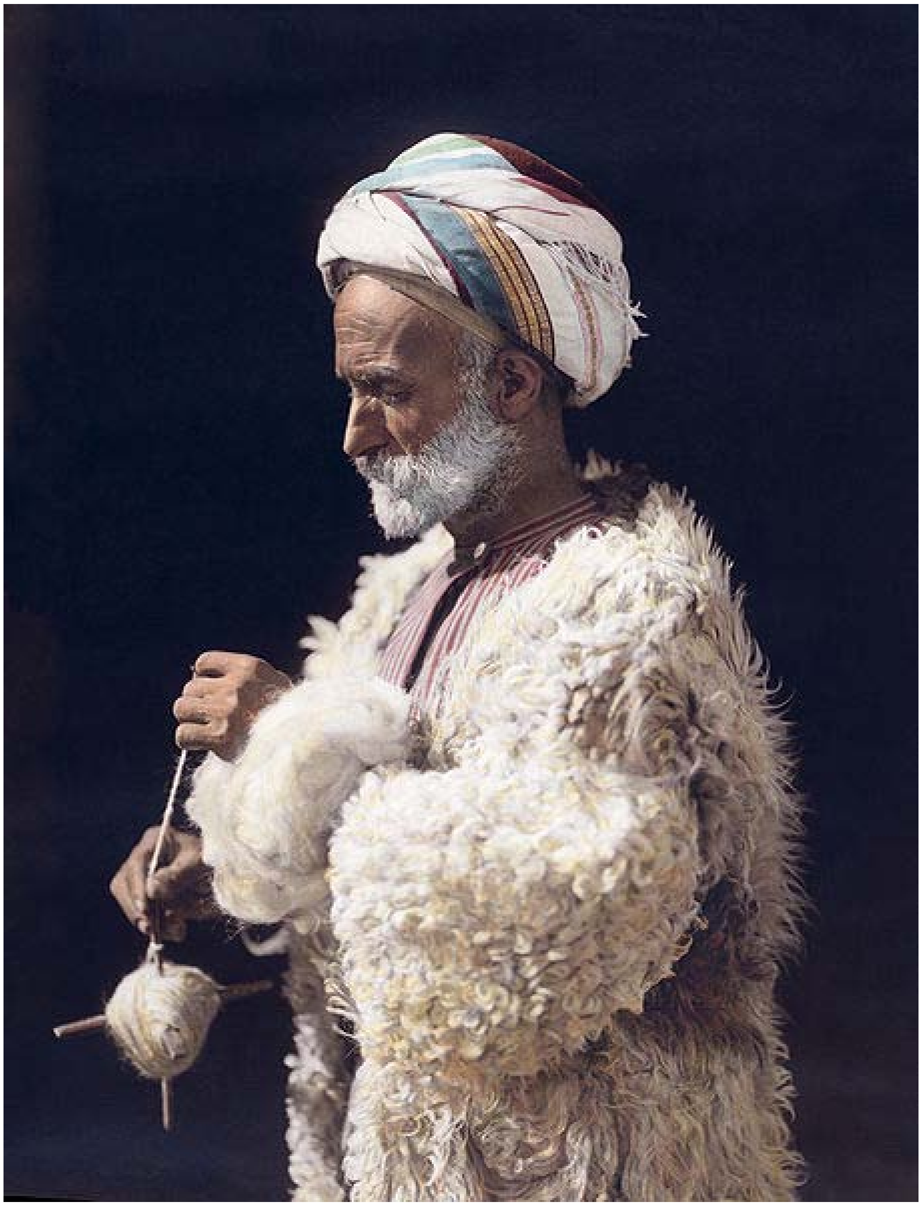
- <15.5 - Ultrafine Merino
- 15.6-18.5 - Superfine Merino
- 18.6-20 - Fine Merino
- 20.1-23 - Medium Merino
- 23< - Strong Merino

- Comeback: 21-26 microns, white, 90–180 mm long
- Fine crossbred: 27-31 microns, Corriedales etc.
- Medium crossbred: 32–35 microns
- Downs: 23-34 microns, typically lacks luster and brightness. Examples, Aussiedown, Dorset Horn, Suffolk etc.
- Coarse crossbred: 36> microns
- Carpet wools: 35-45 microns

Any wool finer than 25 microns can be used for garments, while coarser grades are used for outerwear or rugs. The finer the wool, the softer it is, while coarser grades are more durable and less prone to pilling.

The finest Australian and New Zealand Merino wools are known as 1PP which is the industry benchmark of excellence for Merino wool that is 16.9 micron and finer. This style represents the top level of fineness, character, color, and style as determined on the basis of a series of parameters in accordance with the original dictates of British Wool as applied today by the Australian Wool Exchange (AWEX) Council. Only a few dozen of the millions of bales auctioned every year can be classified and marked 1PP.

History



A man from Ramallah spinning wool. Hand tinted photograph from 1919, restored.

Wool skirting and rolling in Australia, circa 1900

As the raw material has been readily available since the widespread domestication of sheep - and of goats, another major provider of wool - the use of felted or woven wool for clothing and other fabrics characterizes some of the earliest civilizations. Prior to invention of shears - probably in the Iron Age - the wool was plucked out by hand or by bronze combs. The oldest known European wool textile, ca. 1500 BCE, was preserved in a Danish bog. Wool fibers from wild goats found in a prehistoric cave in the Republic of Georgia as far back 34,000 BCE suggest that wool fabrics were made even earlier than this.

In Roman times, wool, linen, and leather clothed the European population; the cotton of India was a curiosity that only naturalists had heard of; and silk, imported along the Silk Road from China, was an extravagant luxury. Pliny the Elder records in his Natural History that the reputation for producing the finest wool was enjoyed by Tarentum, where selective breeding had produced sheep with a superior fleece, but which required special care.

In medieval times, as trade connections expanded, the Champagne fairs revolved around the production of wool cloth in small centers such as Provins; the network that the sequence of annual fairs developed meant that the woollens of Provins might find their way to Naples, Sicily, Cyprus, Majorca, Spain, and even Constantinople. The wool trade developed into serious business, the generator of capital. In the thirteenth century, the wool trade was the economic engine of the Low Countries and of Central Italy; by the end of the following century Italy predominated, though in the 16th century Italian production turned to silk. Both pre-industries were based on English raw wool exports - rivaled only by the sheepwalks of Castile, developed from the fifteenth century - which were a significant source of income to the English crown, which from 1275 imposed an export tax on wool called the "Great Custom". The importance of wool to the English economy can be shown by the fact that since the 14th Century, the presiding officer of the House of Lords has sat on the "Woolsack", a chair stuffed with wool.

Economies of scale were instituted in the Cistercian houses, which had accumulated great tracts of land during the twelfth and early thirteenth centuries, when land prices were low and labor still scarce. Raw wool was baled and shipped from North Sea ports to the textile cities of Flanders, notably Ypres and Ghent, where it was dyed and worked up as cloth. At the time of the Black Death, English textile industries accounted for about 10% of English wool production; the English textile trade grew during the fifteenth century, to the point where export of wool was discouraged. Over the centuries, various British laws controlled the wool trade or required the use of wool even in burials. The smuggling of wool out of the country, known as owling, was at one time punishable by the cutting off of a hand. After the Restoration, fine English woollens began to compete with silks in the international market, partly aided by the Navigation Acts; in 1699 English crown forbade its American colonies to trade wool with anyone but England herself.

A great deal of the value of woollen textiles was in the dyeing and finishing of the woven product. In each of the centers of the textile trade, the manufacturing process came to be subdivided into a collection of trades, overseen by an entrepreneur in a system called by the English the "putting-out" system, or "cottage industry", and the *Verlagssystem* by the Germans. In this system of producing wool cloth, until recently perpetuated in the production of Harris tweeds, the entrepreneur provides the raw materials and an advance, the remainder being paid upon delivery of the product. Written contracts bound the artisans to specified terms. Fernand Braudel traces the appearance of the system in the thirteenth-century economic boom, quoting a document of 1275 The system effectively by-passed the guilds' restrictions.

Before the flowering of the Renaissance, the Medici and other great banking houses of Florence had built their wealth and banking system on their textile industry based on wool, overseen by the Arte della Lana, the wool guild: wool textile interests guided Florentine policies. Francesco Datini, the "merchant of Prato", established in 1383 an *Arte della Lana* for that small Tuscan city. The sheepwalks of Castile shaped the landscape and the fortunes of the *meseta* that lies in the heart of the Iberian peninsula; in the sixteenth century, a unified Spain allowed export of Merino lambs only with royal permission. The German wool market - based on sheep of Spanish origin - did not overtake British wool until comparatively late. Australia's colonial economy was based on sheep raising, and the Australian wool trade eventually overtook that of the Germans by 1845, furnishing wool for Bradford, which developed as the heart of industrialized woollens production.

Due to decreasing demand with increased use of synthetic fibers, wool production is much less than what it was in the past. The collapse in the price of wool began in late 1966 with a 40% drop; with occasional interruptions, the price has tended down. The result has been sharply reduced production and movement of resources into production of other commodities, in the case of sheep growers, to production of meat.

Superwash wool (or washable wool) technology first appeared in the early 1970s to produce wool that has been specially treated so that it is machine washable and may be tumble-dried. This wool is produced using an acid bath that removes the "scales" from the fiber, or by coating the fiber with a polymer that prevents the scales from attaching to each other and causing shrinkage. This process results in a fiber that holds longevity and durability over synthetic materials, while retaining its shape.

In December 2004, a bale of the world's finest wool, averaging 11.8 micron, sold for $3,000 per kilogram at auction in Melbourne, Victoria. This fleece wool tested with an average yield of 74.5%, 68 mm long, and had 40 newtons per kilotex strength. The result was $AUD279,000 for the bale. The finest bale of wool ever auctioned sold for a seasonal record of 269,000 cents per kilo during June 2008. This bale was produced by the Hillcreston Pinehill Partnership and measured 11.6 microns, 72.1% yield and had a 43 Newtons per kilotex strength measurement. The bale realized $247,480 and was exported to India.

During 2007 a new wool suit was developed and sold in Japan that can be washed in the shower, and dries off ready to wear within hours with no ironing required. The suit was developed using Australian Merino wool and it enables woven products made from wool, such as suits, trousers and skirts, to be cleaned using a domestic shower at home.

In December 2006 the General Assembly of the United Nations proclaimed 2009 to be the International Year of Natural Fibres, so to raise the profile of wool and other natural fibers.

Production

Global wool production is approximately 1.3 million tonnes per year, of which 60% goes into apparel. Australia is the leading producer of wool which is mostly from Merino sheep. New Zealand is the second-largest producer of wool, and the largest producer of crossbred wool. China is the third-largest producer of wool. Breeds such as Lincoln, Romney, Tukidale, Drysdale and Elliotdale produce coarser fibers, and wool from these sheep is usually used for making carpets.

In the United States, Texas, New Mexico and Colorado have large commercial sheep flocks and their mainstay is the Rambouillet (or French Merino). There is also a thriving home-flock contingent of small-scale farmers who raise small hobby flocks of specialty sheep for the hand spinning market. These small-scale farmers offer a wide selection of fleece.

1905 illustration of a Tibetan spinning wool.

Global woolclip (total amount of wool shorn) 2004/2005

1. Australia: 25% of global woolclip (475 million kg greasy, 2004/2005)
2. China: 18%
3. New Zealand: 11%
4. Argentina: 3%
5. Turkey: 2%
6. Iran: 2%
7. United Kingdom: 2%
8. India: 2%
9. Sudan: 2%

10. South Africa: 1%
11. United States: 0.77%

Organic wool is becoming more and more popular. This wool is very limited in supply and much of it comes from New Zealand and Australia. It is becoming easier to find in clothing and other products, but these products often carry a higher price. Wool is environmentally preferable (as compared to petroleum-based Nylon or Polypropylene) as a material for carpets as well, in particular when combined with a natural binding and the use of formaldehyde-free glues.

Animal rights groups have noted issues with the production of wool, such as Mulesing.

Marketing

Australia

Merino wool samples for sale by auction, Newcastle, New South Wales.

Wool buyers' room at a wool auction, Newcastle, New South Wales.

About 85% of wool sold in Australia is sold by open cry auction. Sale by Sample is a method in which a mechanical claw takes a sample from each bale in a line or lot of wool. These grab samples are bulked, objectively measured, and a sample of not less than 4 kg is displayed in a box for the buyer to examine. The Australian Wool Exchange (AWEX) conducts sales primarily in Sydney, Melbourne, Newcastle, and Fremantle. There are about 80 brokers and agents throughout Australia.

About 7% of Australian wool is sold by private treaty on farms or to local wool-handling facilities. This option gives wool growers benefit from reduced transport, warehousing, and selling costs. This method is preferred for small lots or mixed butts in order to make savings on reclassing and testing.

About 5% of Australian wool is sold over the internet on an electronic offer board. This option gives wool growers the ability to set firm price targets, reoffer passed in wool and offer lots to the market quickly and efficiently. This method works well for tested lots as buyers use these results to make a purchase. 97% of wool is sold without sample inspection however as of dec 2009, 59% of wool listed had been passed in from auction. Growers through certain brokers can allocate their wool to a sale and what price their wool will be reserved at.

Sale by tender can achieve considerable cost savings on wool clips large enough to make it worthwhile for potential buyers to submit tenders. Some marketing firms sell wool on a consignment basis, obtaining a fixed percentage as commission.

Forward selling: Some buyers offer a secure price for forward delivery of wool based on estimated measurements or the results of previous clips. Prices are quoted at current market rates and are locked in for the season. Premiums and discounts are added to cover variations in micron, yield, tensile strength, etc., which are confirmed by actual test results when available.

Another method of selling wool includes sales direct to wool mills.

Other countries

The British Wool Marketing Board operates a central marketing system for UK fleece wool with the aim of achieving the best possible net returns for farmers.

Less than half of New Zealand's wool is sold at auction, while around 45% for farmers sell wool directly to private buyers and end-users. Some businesses in New Zealand like Blue House Yarns have turned to selling organic wool, a new trend on wool production.

United States sheep producers market wool with private or cooperative wool warehouses, but wool pools are common in many states. In some cases, wool is pooled in a local market area but sold through a wool warehouse. Wool offered with objective measurement test results is preferred. Imported apparel wool and carpet wool goes directly to central markets, where it is handled by the large merchants and manufacturers.

Uses

Woollen garments in the wool samples area of a wool store, Newcastle, New South Wales.

In addition to clothing, wool has been used for blankets, horse rugs, saddle cloths, carpeting, felt, wool insulation and upholstery. Wool felt covers piano hammers, and it is used to absorb odors and noise in heavy machinery and stereo speakers. Ancient Greeks lined their helmets with felt, and Roman legionnaires used breastplates made of wool felt.

Wool has also been traditionally used to cover cloth diapers. Wool fiber exteriors are hydrophobic (repel water) and the interior of the wool fiber is hygroscopic (attracts water); this makes a wool garment able to cover a wet diaper while inhibiting wicking, so outer garments remain dry. Wool felted and treated with lanolin is water resistant, air permeable, and slightly antibacterial, so it resists the buildup of odor. Some modern cloth diapers use felted wool fabric for covers, and there are several modern commercial knitting patterns for wool diaper covers.

Initial studies of woollen underwear have found it prevented heat and sweat rashes because it more readily absorbs the moisture than other fibers.

Merino wool has been used in baby sleep products such as swaddle baby wrap blankets and infant sleeping bags.

Wool is an animal protein, and as such it can be used as a soil fertiliser, being a slow release source of nitrogen and ready made amino acids.

Yarns

Virgin wool is wool spun for the first time.

Shoddy or **recycled wool** is made by cutting or tearing apart existing wool fabric and respinning the resulting fibers. As this process makes the wool fibers shorter, the remanufactured fabric is inferior to the original. The recycled wool may be mixed with raw wool, wool noil, or another fiber such as cotton to increase the average fiber length. Such yarns are typically used as weft yarns with a cotton warp. This process was invented in the Heavy Woollen District of West Yorkshire and created a micro-economy in this area for many years.

Ragg is a sturdy wool fiber made into yarn and used in many rugged applications like gloves.

Worsted is a strong, long-staple, combed wool yarn with a hard surface.

Woollen is a soft, short-staple, carded wool yarn typically used for knitting. In traditional weaving, woollen weft yarn (for softness and warmth) is frequently combined with a worsted warp yarn for strength on the loom.

Events

Andean lady sorting wool as part of the theme park Los Aleros in Mérida, Venezuela.

A buyer of Merino wool, Ermenegildo Zegna, has offered awards for Australian wool producers. In 1963, the first Ermenegildo Zegna Perpetual Trophy was presented in Tasmania for growers of "Superfine skirted Merino fleece". In 1980, a national award, the Ermenegildo Zegna Trophy for Extrafine Wool Production, was launched. In 2004, this award became known as the Ermenegildo Zegna Unprotected Wool Trophy. In 1998, an Ermenegildo Zegna Protected Wool Trophy was launched for fleece from sheep coated for around nine months of the year.

In 2002, the Ermenegildo Zegna Vellus Aureum Trophy was launched for wool that is 13.9 micron and finer. Wool from Australia, New Zealand, Argentina, and South Africa may enter, and a winner is named from each country. In April 2008, New Zealand won the Ermenegildo Zegna Vellus Aureum Trophy for the first time with a fleece that measured 10.8 microns. This contest awards the winning fleece weight with the same weight in gold as a prize, hence the name.

In 2010 an ultra-fine, 10 micron fleece, from Windradeen, near Pyramul, New South Wales set a new world record in the fineness of wool fleeces when it won the Ermenegildo Zegna Vellus Aureum International Trophy.

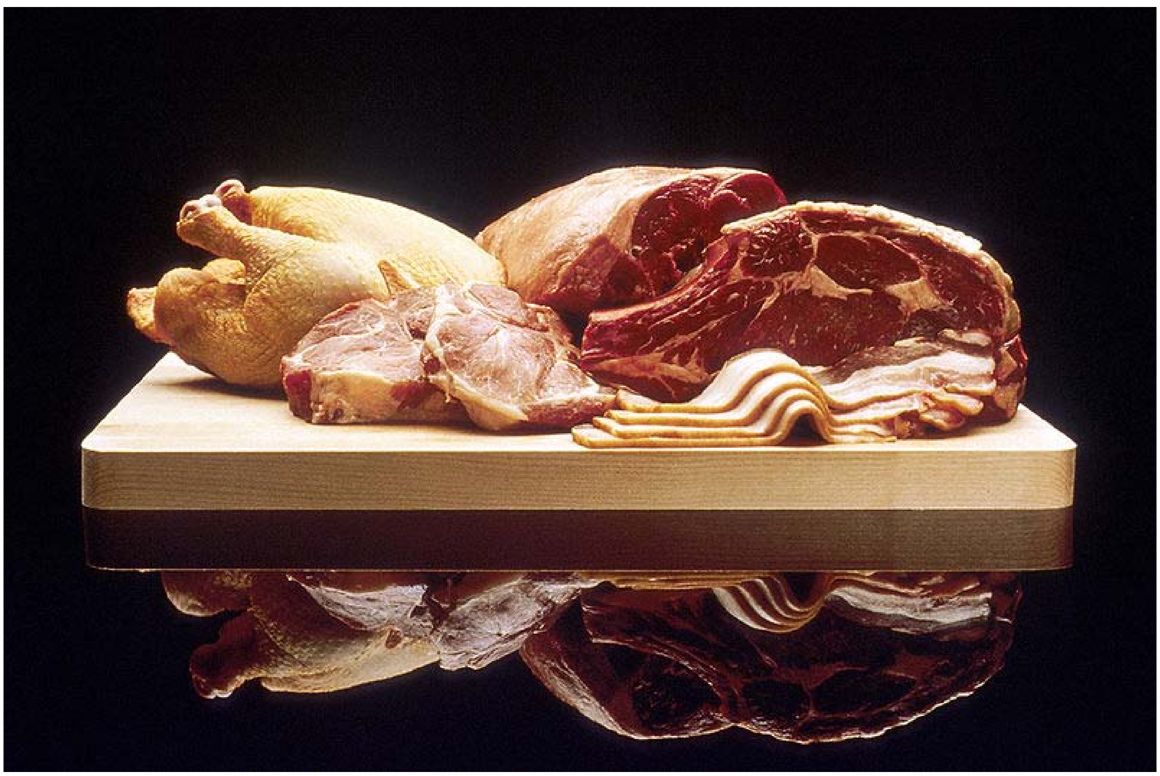
Since 2000, Loro Piana has awarded a cup for the world's finest bale of wool that produces just enough fabric for 50 tailor-made suits. The prize is awarded to an Australian or New Zealand wool grower who produces the year's finest bale.

The New England Merino Field days which display local studs, wool, and sheep are held during January, every two years (in even numbered years) around the Walcha, New South Wales district. The Annual Wool Fashion Awards, which showcase the use of Merino wool by fashion designers, are hosted by the city of Armidale, New South Wales in March each year. This event encourages young and established fashion designers to display their talents. During each May, Armidale hosts the annual New England Wool Expo to display wool fashions, handicrafts, demonstrations, shearing competitions, yard dog trials, and more.

In July, the annual Australian Sheep and Wool Show is held in Bendigo, Victoria. This is the largest sheep and wool show in the world, with goats and alpacas as well as woolcraft competitions and displays, fleece competitions, sheepdog trials, shearing, and wool handling. The largest competition in the world for objectively-measured fleeces is the Australian Fleece Competition, which is held annually at Bendigo. In 2008, there were 475 entries from all states of Australia with first and second prizes going to the Northern Tablelands, New South Wales fleeces.

Chapter 9

Meat



Varieties of meat

Meat is animal flesh that is used as food. Most often, this means the skeletal muscle and associated fat, but it may also describe other edible tissues such as organs, livers, skin, brains, bone marrow, kidneys, or lungs. The word *meat* is also used by the meat packing industry in a more restrictive sense—the flesh of mammalian species (pigs, cattle, lambs, etc.) raised and prepared for human consumption, to the exclusion of fish, poultry, and game.

Etymology

The word *meat* comes from the Old English word *mete*, which referred to food in general. The term is related to *mad* in Danish, *mat* in Swedish and Norwegian, and *matur* in Icelandic, which also mean 'food'. The word "mete" also exists in Old Frisian (and to a lesser extent, modern West Frisian) to denote important food, differentiating it from "swiets" (sweets) and "dierfied" (animal feed).

One definition that refers to meat as not including fish developed over the past few hundred years and has religious influences. The distinction between fish and "meat" is codified by the Jewish dietary law of *kashrut*, regarding the mixing of milk and meat, which does not forbid the mixing of milk and fish. Modern Jewish legal practice (*halakha*) on *kashrut* classifies the flesh of both mammals and birds as "meat"; fish are considered to be *parve*, neither meat nor a dairy food. The Catholic dietary restriction on "meat" on Fridays also does not apply to the cooking and eating of fish.

The Latin word *carō* "meat" (also the root of 'carnal', referring to the 'pleasures of the flesh') is often a euphemism for sexual pleasure, effected from the function performed by fleshy organs. Thus 'meat' may refer to the human body in a sensual, or sexual, connotation. A *meat market*, in addition to simply denoting a market where meat is sold, also refers to a place or situation where humans are treated or viewed as commodities, especially a place known as one where a sexual partner may be found.

"Meat" may also be used to refer to humans humorously or indifferently. In military slang, "meat shield" refers to soldiers sent towards an enemy to draw fire away from another unit.

History

Paleontological evidence suggests that meat constituted a substantial proportion of the diet of even the earliest humans. Early hunter-gatherers depended on the organized hunting of large animals such as bison and deer.

The domestication of animals, of which we have evidence dating back to the end of the last glacial period (c. 10,000 years BP), allowed the systematic production of meat and the breeding of animals with a view to improving meat production. The animals which are now the principal sources of meat were domesticated in conjunction with the development of early civilizations:

- Sheep, originating from western Asia, were domesticated with the help of dogs prior to the establishment of settled agriculture, likely as early as the eighth millennium BC. Several breeds of sheep were established in ancient Mesopotamia and Egypt by 3500–3000 BC. Presently, more than 200 sheep breeds exist.

- Cattle were domesticated in Mesopotamia after settled agriculture was established about 5000 BC, and several breeds were established by 2500 BC. Modern domesticated cattle fall into the groups *Bos taurus* (European cattle) and *Bos indicus* (zebu), both descended from the now-extinct aurochs. The breeding of beef cattle, cattle optimized for meat production as opposed to animals best suited for draught or dairy purposes, began in the middle of the 18th century.

- Domestic pigs, which are descended from wild boars, are known to have existed about 2500 BC in modern-day Hungary and in Troy; earlier pottery from Jericho and Egypt depicts wild pigs. Pork sausages and hams were of great commercial importance in Greco-Roman times. Pigs continue to be bred intensively as they are being optimized to produce meat best suited for specific meat products.

Other animals are, or have been raised or hunted for their flesh. The type of meat consumed varies much in different cultures, changes over time, and depends on different factors such as the availability of the animals and traditions.

- Horses are still commonly eaten in countries such as France or Japan. Horses (and other large mammals as reindeers) were hunted during the Late Paleolithic in western Europe.
- Dogs are widely consumed in China, Vietnam, the Philippines and South Korea. Dogs are also occasionally eaten in the Arctic regions. Historically, dog meat has been consumed in various part of the world, such as Hawaii, Japan, Switzerland and Mexico.
- Cats are consumed in Southern China, Peru and certain rural parts of Switzerland.
- Guinea pigs are raised for their flesh in the Andes.
- Whales and dolphins are still being hunted, partly for their flesh, by aboriginal communities in Alaska, Siberia, Canada, by the Faroe Islands, Greenland, Iceland, Saint Vincent and the Grenadines and by two small communities in Indonesia.

Modern agriculture employs a number of techniques, such as progeny testing, to make animals evolve rapidly towards having the qualities desired by meat producers. For instance, in the wake of well-publicised health concerns associated with saturated fats in the 1980s, the fat content of UK beef, pork and lamb fell from 20–26 percent to 4–8 percent within a few decades, both due to selective breeding for leanness and changed methods of butchery. Methods of genetic engineering aimed at improving the meat production qualities of animals are now also becoming available.

Even though it is a very old industry, meat production continues to be shaped strongly by the rapidly evolving demands of customers. The trend towards selling meat in pre-packaged cuts has increased the demand for larger breeds of cattle, which are better suited to producing such cuts. Even more animals not previously exploited for their meat are now being farmed, especially the more agile and mobile species, whose muscles tend to be developed better than those of cattle, sheep or pigs. Examples include the various antelope species, the zebra, water buffalo and camel, as well as nonmammals, such as the crocodile, emu and ostrich. Another important trend in contemporary meat production is organic farming which, while providing no organoleptic benefit to meat so produced, meets an increasing demand for numerous reasons.

Growth and development of meat animals

Agricultural science has identified several factors bearing on the growth and development of meat in animals.

Genetics

Trait	Heritability
Reproductive efficiency	2–10%
Meat quality	15–30%
Growth	20–40%
Muscle/fat ratio	40–60%

Several economically important traits in meat animals are heritable to some degree and can thus be selected for by breeding. In cattle, certain growth features are controlled by recessive genes which have not so far been controlled, complicating breeding. One such trait is dwarfism; another is the doppelender or "double muscling" condition, which causes muscle hypertrophy and thereby increases the animal's commercial value. Genetic analysis continues to reveal the genetic mechanisms that control numerous aspects of the endocrine system and, through it, meat growth and quality.

Genetic engineering techniques can shorten breeding programmes significantly because they allow for the identification and isolation of genes coding for desired traits, and for the reincorporation of these genes into the animal genome. To enable such manipulation, research is ongoing (as of 2006) to map the entire genome of sheep, cattle and pigs. Some research has already seen commercial application. For instance, a recombinant bacterium has been developed which improves the digestion of grass in the rumen of cattle, and some specific features of muscle fibres have been genetically altered.

Experimental reproductive cloning of commercially important meat animals such as sheep, pig or cattle has been successful. The multiple asexual reproduction of animals bearing desirable traits can thus be anticipated, although this is not yet practical on a commercial scale.

Environment

Heat regulation in livestock is of great economic significance, because mammals attempt to maintain a constant optimal body temperature. Low temperatures tend to prolong animal development and high temperatures tend to retard it. Depending on their size, body shape and insulation through tissue and fur, some animals have a relatively narrow zone of temperature tolerance and others (e.g. cattle) a broad one. Static magnetic fields, for reasons still unknown, also retard animal development.

Nutrition

The quality and quantity of usable meat depends on the animal's *plane of nutrition*, i.e., whether it is over- or underfed. Scientists disagree, however, about how exactly the plane of nutrition influences carcase composition.

The composition of the diet, especially the amount of protein provided, is also an important factor regulating animal growth. Ruminants, which may digest cellulose, are better adapted to poor-quality diets, but their ruminal microorganisms degrade high-quality protein if supplied in excess. Because producing high-quality protein animal feed is expensive, several techniques are employed or experimented with to ensure maximum utilization of protein. These include the treatment of feed with formalin to protect amino acids during their passage through the rumen, the recycling of manure by feeding it back to cattle mixed with feed concentrates, or the partial conversion of petroleum hydrocarbons to protein through microbial action.

In plant feed, environmental factors influence the availability of crucial nutrients or micronutrients, a lack or excess of which can cause a great many ailments. In Australia, for instance, where the soil contains limited phosphate, cattle are being fed additional phosphate to increase the efficiency of beef production. Also in Australia, cattle and sheep in certain areas were often found losing their appetite and dying in the midst of rich pasture; this was at length found to be a result of cobalt deficiency in the soil. Plant toxins are also a risk to grazing animals; for instance, fluoracetate, found in some African and Australian plants, kills by disrupting the cellular metabolism. Certain man-made pollutants such as methylmercury and some pesticide residues present a particular hazard due to their tendency to bioaccumulate in meat, potentially poisoning consumers.

Human intervention

Meat producers may seek to improve the fertility of female animals through the administration of gonadotrophic or ovulation-inducing hormones. In pig production, sow infertility is a common problem, possibly due to excessive fatness. No methods currently exist to augment the fertility of male animals. Artificial insemination is now routinely used to produce animals of the best possible genetic quality, and the efficiency of this method is improved through the administration of hormones that synchronize the ovulation cycles within groups of females.

Growth hormones, particularly anabolic agents such as steroids, are used in some countries to accelerate muscle growth in animals. This practice has given rise to the beef hormone controversy, an international trade dispute. It may also decrease the tenderness of meat, although research on this is inconclusive, and have other effects on the composition of the muscle flesh. Where castration is used to improve control over male animals, its side effects are also counteracted by the administration of hormones.

Sedatives may be administered to animals to counteract stress factors and increase weight gain. The feeding of antibiotics to certain animals has been shown to improve growth rates also. This practice is particularly prevalent in the USA, but has been banned in the EU, partly because it causes antibiotic resistance in pathogenic microorganisms.

Biochemical composition

Numerous aspects of the biochemical composition of meat vary in complex ways depending on the species, breed, sex, age, plane of nutrition, training and exercise of the animal, as well as on the anatomical location of the musculature involved. Even between animals of the same litter and sex there are considerable differences in such parameters as the percentage of intramuscular fat.

Main constituents

Adult mammalian muscle flesh consists of roughly 75 percent water, 19 percent protein, 2.5 percent intramuscular fat, 1.2 percent carbohydrates and 2.3 percent other soluble non-protein substances. These include nitrogenous compounds, such as amino acids, and inorganic substances such as minerals.

Muscle proteins are either soluble in water (sarcoplasmic proteins, about 11.5 percent of total muscle mass) or in concentrated salt solutions (myofibrillar proteins, about 5.5 percent of mass). There are several hundred sarcoplasmic proteins. Most of them – the glycolytic enzymes – are involved in the glycolytic pathway, i.e., the conversion of stored energy into muscle power. The two most abundant myofibrillar proteins, myosin and actin, are responsible for the muscle's overall structure. The remaining protein mass consists of connective tissue (collagen and elastin) as well as organelle tissue.

Fat in meat can be either adipose tissue, used by the animal to store energy and consisting of "true fats" (esters of glycerol with fatty acids), or intramuscular fat, which contains considerable quantities of phospholipids and of unsaponifiable constituents such as cholesterol.

Red and white meat

Meat can be broadly classified as "red" or "white" depending on the concentration of myoglobin in muscle fibre. When myoglobin is exposed to oxygen, reddish oxymyoglobin develops, making myoglobin-rich meat appear red. The redness of meat depends on species, animal age, and fibre type: Red meat contains more narrow muscle fibres that tend to operate over long periods without rest, while white meat contains more broad fibres that tend to work in short fast bursts.

The meat of adult mammals such as cows, sheep, goats, and horses is generally considered red, while domestic chicken and turkey breast meat is generally considered white.

Meat nutritional information

Typical Meat Nutritional Content from 110 grams (4 oz or .25 lb)				
Source	**calories**	**protein**	**carbs**	**fat**
fish	110–140	20–25 g	0 g	1–5 g
chicken breast	160	28 g	0 g	7 g
lamb	250	30 g	0 g	14 g
steak (beef top round)	210	36 g	0 g	7 g
steak (beef T-bone)	450	25 g	0 g	35 g

All muscle tissue is very high in protein, containing all of the essential amino acids, and in most cases is a good source of zinc, vitamin B_{12}, selenium, phosphorus, niacin, vitamin B_6, choline, riboflavin and iron. Several forms of meat are high in vitamin K_2, which is only otherwise known to be found in fermented foods, with natto having the highest concentration. Muscle tissue is very low in carbohydrates and does not contain dietary fiber. The fat content of meat can vary widely depending on the species and breed of animal, the way in which the animal was raised, including what it was fed, the anatomical part of the body, and the methods of butchering and cooking. Wild animals such as deer are typically leaner than farm animals, leading those concerned about fat content to choose game such as venison. Decades of breeding meat animals for fatness is being reversed by consumer demand for meat with less fat.

Red meat, such as beef, pork, and lamb, contains many essential nutrients necessary for healthy growth and development in children. Nutrients in red meat include iron, zinc, vitamin B_{12}, and protein. Most meats contain a full complement of the amino acids required for the human diet. Fruits and vegetables, by contrast, are usually lacking several essential amino acids contained in meat. It is for this reason that people who abstain from eating all meat need to plan their diet carefully to include sources of all the necessary amino acids.

The table here compares the nutritional content of several types of meat. While each kind of meat has about the same content of protein and carbohydrates, there is a very wide range of fat content. It is the additional fat that contributes most to the calorie content of meat, and to concerns about dietary health.

Production

Meat is produced by killing the animal in question and cutting the desired flesh out of it. These procedures are called slaughter and butchery, respectively.

Attesting to the long history of meat consumption in human civilizations, ritual slaughter has become part of the practice of several religions. These rituals, as well as other pre-industrial meat production methods such as these used by indigenous peoples, are not detailed here.

Transport

Upon reaching a predetermined age or weight, livestock are usually transported *en masse* from the farm to the slaughterhouse, a process called "live export". Depending on its length and circumstances, this exerts stress and injuries on the animals, and some may die *en route*. Apart from being arguably inhumane, unnecessary stress in transport may adversely affect the quality of the meat. In particular, the muscles of stressed animals are low in water and glycogen, and their pH fails to attain acidic values, all of which results in poor meat quality. Consequently, and also due to campaigning by animal welfare groups, laws and industry practices in several countries tend to become more restrictive with respect to the duration and other circumstances of livestock transports.

Slaughter

Animals are usually slaughtered by being first stunned and then exsanguinated (bled out). Death results from the one or the other procedure, depending on the methods employed. Stunning can be effected through asphyxiating the animals with carbon dioxide, shooting them with a gun or a captive bolt pistol, or shocking them with electric current. In most forms of ritual slaughter, stunning is not allowed.

Draining as much blood as possible from the carcase is necessary because blood causes the meat to have an unappealing appearance and is a very good breeding ground for microorganisms. The exsanguination is accomplished by severing the carotid artery and the jugular vein in cattle and sheep, and the anterior vena cava in pigs.

Dressing and cutting

After exsanguination, the carcase is dressed; that is, the head, feet, hide (except hogs and some veal), excess fat, viscera and offal are removed, leaving only bones and edible muscle. Cattle and pig carcases, but not those of sheep, are then split in half along the mid ventral axis, and the carcase is cut into wholesale pieces. The dressing and cutting sequence, long a province of manual labor, is progressively being fully automated.

Conditioning

Under hygienic conditions and without other treatment, meat can be stored at above its freezing point (–1.5 °C) for about six weeks without spoilage, during which time it undergoes an aging process that increases its tenderness and flavor.

During the first day after death, glycolysis continues until the accumulation of lactic acid causes the pH to reach about 5.5. The remaining glycogen, about 18 g per kg, is believed to increase the water-holding capacity and tenderness of the flesh when cooked. *Rigor mortis* sets in a few hours after death as ATP is used up, causing actin and myosin to combine into rigid actomyosin and lowering the meat's water-holding capacity, causing it to lose water ("weep"). In muscles that enter *rigor* in a contracted position, actin and myosin filaments overlap and cross-bond, resulting in meat that is tough on cooking – hence again the need to prevent pre-slaughter stress in the animal.

Over time, the muscle proteins denature in varying degree, with the exception of the collagen and elastin of connective tissue, and *rigor mortis* resolves. Because of these changes, the meat is tender and pliable when cooked just after death or after the resolution of *rigor*, but tough when cooked during *rigor.* As the muscle pigment myoglobin denatures, its iron oxidates, which may cause a brown discoloration near the surface of the meat. Ongoing proteolysis also contributes to conditioning. Hypoxanthine, a breakdown product of ATP, contributes to the meat's flavor and odor, as do other products of the discomposition of muscle fat and protein.

Spoilage and preservation

The spoilage of meat occurs, if untreated, in a matter of hours or days and results in the meat becoming unappetizing, poisonous or infectious. Spoilage is caused by the practically unavoidable infection and subsequent decomposition of meat by bacteria and fungi, which are borne by the animal itself, by the people handling the meat, and by their implements. Meat can be kept edible for a much longer time – though not indefinitely – if proper hygiene is observed during production and processing, and if appropriate food safety, food preservation and food storage procedures are applied. Without the application of preservatives and stabilizers, the fats in meat may also begin to rapidly decompose after cooking or processing, leading to an objectionable taste known as warmed over flavor.

Methods of preparation

A spit barbecue at a street fair in New York City's East Village.

Meat is prepared in many ways, as steaks, in stews, fondue, or as dried meat like beef jerky. It may be ground then formed into patties (as hamburgers or croquettes), loaves, or sausages, or used in loose form (as in "sloppy joe" or Bolognese sauce). Some meat is cured, by smoking, pickling, preserving in salt or brine. Other kinds of meat are marinated and barbecued, or simply boiled, roasted, or fried. Meat is generally eaten cooked, but there are many traditional recipes that call for raw beef, veal or fish (tartare). Meat is often spiced or seasoned, as in most sausages. Meat dishes are usually described by their source (animal and part of body) and method of preparation.

Meat is a typical base for making sandwiches. Popular varieties of sandwich meat include ham, pork, salami and other sausages, and beef, such as steak, roast beef, corned beef, pepperoni, and pastrami. Meat can also be molded or pressed (common for products that include offal, such as haggis and scrapple) and canned.

Issues with meat consumption

Processed meat in an American supermarket

Fresh meat in a Mexican supermarket

Ethics

Ethical issues regarding the consumption of meat can include objections to the act of killing animals or the agricultural practices surrounding the production of meat. Reasons for objecting to the practice of killing animals for consumption may include animal rights, environmental ethics, religious doctrine, or an aversion to inflicting pain or harm on other sentient creatures. The religion of Jainism has always opposed eating meat, and there are also many schools of Buddhism, Hinduism and Sikhism that condemn the eating of meat. Some people, while not vegetarians, refuse to eat the flesh of certain animals, such as cats, dogs, horses, or rabbits, due to cultural or religious taboo. In some cases, specific meats (especially from pigs and cows) are forbidden within religious traditions. Some people eat only the flesh of animals which they believe have not been mistreated, and abstain from the meat of animals reared in factory farms or from particular products such as foie gras and veal.

Health

Consumption of large quantities of meat, like overconsumption of any caloric food, has certain adverse effects which can include: obesity, heart disease, and constipation. The common misconception of *"I can't eat unless there is meat"* is largely due to cultural attitudes and how one is raised to think about food. In recent years, health concerns have been raised about the consumption of meat increasing the risk of cancer. In particular, red meat and processed meat were found to be associated with higher risk of cancers of the lung, esophagus, liver, and colon, among others, although also a reduced risk for some minor type of cancers. Another study found an increase risk of pancreatic cancer for red meat and pork. That study also suggests that fat and saturated fat are not likely contributors to pancreatic cancer. Animal fat, particularly from ruminants, tends to have a higher percentage of saturated fat vs. monounsaturated and polyunsaturated fat when compared to vegetable fats, with the exception of some tropical plant fats; consumption of which has been correlated with various health problems. The saturated fat found in meat has been associated with significantly raised risks of colon cancer, although evidence suggests that risks of prostate cancer are unrelated to animal fat consumption. USDA claims that consumption of meat as a source of protein in the human diet is crucial, have been resoundingly contradicted by recent studies.

The correlation of meat consumption to increased risk of heart disease is controversial. Some studies fail to find a link between red meat consumption and heart disease (although the same study found statistically significant correlation between the consumption of processed meat and cancer), while another study, a survey ,conducted in 1960, of 25,153 California Seventh-Day Adventists, found that the risk of heart disease is three times greater for 45-64 year old men who eat meat daily, versus those who did not eat meat. In another study in 2010 involving over one million people who ate meat found that only processed meat had an adverse risk in relation to coronary heart disease. The study suggests that eating 50g (less than 2oz) of processed meat per day increases risk of coronary heart disease by 42%, and diabetes by 19%. Equivalent levels of fat, including saturated fats, in unprocessed meat (even when eating twice as much per day) did not show any deleterious effects, leading the researchers to suggest that "differences in salt and preservatives, rather than fats, might explain the higher risk of heart disease and diabetes seen with processed meats, but not with unprocessed red meats."

A 2009 study by the National Cancer Institute revealed a correlation between the consumption of red meat and increased mortality from cancer and cardiovascular diseases. This study has been criticized for using an improperly validated food frequency questionnaire, which has been shown to have low levels of accuracy.

In response to changing prices as well as health concerns about saturated fat and cholesterol, consumers have altered their consumption of various meats. A USDA report points out that consumption of beef in the United States between 1970–1974 and 1990–1994 dropped by 21%, while consumption of chicken increased by 90%. During the same period of time, the price of chicken dropped by 14% relative to the price of beef. In 1995 and 1996, beef consumption increased due to higher supplies and lower prices.

Cooking

Meat can transmit certain diseases, but complete cooking and avoiding recontamination reduces this possibility.

Several studies published since 1990 indicate that cooking muscle meat creates heterocyclic amines (HCAs), which are thought to increase cancer risk in humans. Researchers at the National Cancer Institute published results of a study which found that human subjects who ate beef rare or medium-rare had less than one third the risk of stomach cancer than those who ate beef medium-well or well-done. While eating muscle meat raw may be the only way to avoid HCAs fully, the National Cancer Institute states that cooking meat below 212 °F (100 °C) creates "negligible amounts" of HCAs. Also, microwaving meat before cooking may reduce HCAs by 90%.

Nitrosamines, present in processed and cooked foods, have been noted as being carcinogenic, being linked to colon cancer. Also, toxic compounds called PAHs, or Polycyclic aromatic hydrocarbons, present in processed, smoked and cooked foods, are known to be carcinogenic.

In vitro and imitation

Various forms of imitation meat have been created to satisfy people wishing to reduce or eliminate meat consumption for health, environmental, or ethical considerations, but who still wish to taste the flavor and texture of meat. They are typically some form of processed soybean, (tofu, tempeh), but they can also be based on wheat gluten or even fungus (quorn).

In vitro meat, also known as cultured meat, is animal flesh that has never been part of a complete, living animal. Several research projects are currently experimentally growing in vitro meat, but no meat has yet been produced for public consumption. The goal is to grow fully developed muscle organs, but the first generation will most likely be minced meat products.

Environmental impact

The UN Food and Agriculture Organization (FAO) has estimated that direct emissions from meat production account for about 18% of the world's total greenhouse gas emissions. The FAO figure accounts for the entire meat production cycle - clearing forested land, making and transporting fertiliser, burning fossil fuels in agricultural machinery, and the front and rear end emissions of cattle and sheep. In tracking food animal production from the feed through to the dinner table, the inefficiencies of grain fed meat, milk and egg production range from a 4:1 energy input to protein output ratio up to 54:1, in the opinion of Roger Segelken.

Chapter 10

Lard

Lard

Wet-rendered lard, from pork fatback.

Fat composition	
Saturated fats	**38–43%:** **Palmitic acid: 25–28%** **Stearic acid: 12–14%** **Myristic acid: 1%**
Unsaturated fats	**56–62%**
Monounsaturated fats	**47–50%:** **Oleic acid: 44–47%** **Palmitoleic acid: 3%**
Polyunsaturated fats	**Linoleic acid: 6–10%**

Properties	
Food energy per 100g	**3770 kJ (900 kcal)**
Melting point	**backfat: 30–40 °C (86–104 °F)** **leaf fat: 43–48 °C (109–118 °F)** **mixed fat: 36–45 °C (97–113 °F)**

Smoke point	**121–218 °C (250–424 °F)**
Specific gravity at 20 °C	**0.917–0.938**
Iodine value	**45–75**
Acid value	**3.4**
Saponification value	**190–205**
Unsaponifiable	**0.8%**

Lard is pig fat in both its rendered and unrendered forms. Lard was commonly used in many cuisines as a cooking fat or shortening, or as a spread similar to butter. Its use in contemporary cuisine has diminished because of health concerns posed by its saturated-fat content and its often negative image; however, many contemporary cooks and bakers favor it over other fats for select uses. The culinary qualities of lard vary somewhat depending on the part of the pig from which the fat was taken and how the lard was processed. Lard is still commonly used to manufacture soap.

Lard production

Lard can be obtained from any part of the pig as long as there is a high concentration of fatty tissue. The highest grade of lard, known as **leaf lard**, is obtained from the "flare" visceral fat deposit surrounding the kidneys and inside the loin. Leaf lard has little pork flavor, making it ideal for use in baked goods, where it is valued for its ability to produce flaky, moist pie crusts. The next highest grade of lard is obtained from fatback, the hard subcutaneous fat between the back skin and muscle of the pig. The lowest grade (for purposes of rendering into lard) is obtained from the soft caul fat surrounding digestive organs, such as small intestines, though caul fat is often used directly as a wrapping for roasting lean meats or in the manufacture of pâtés.

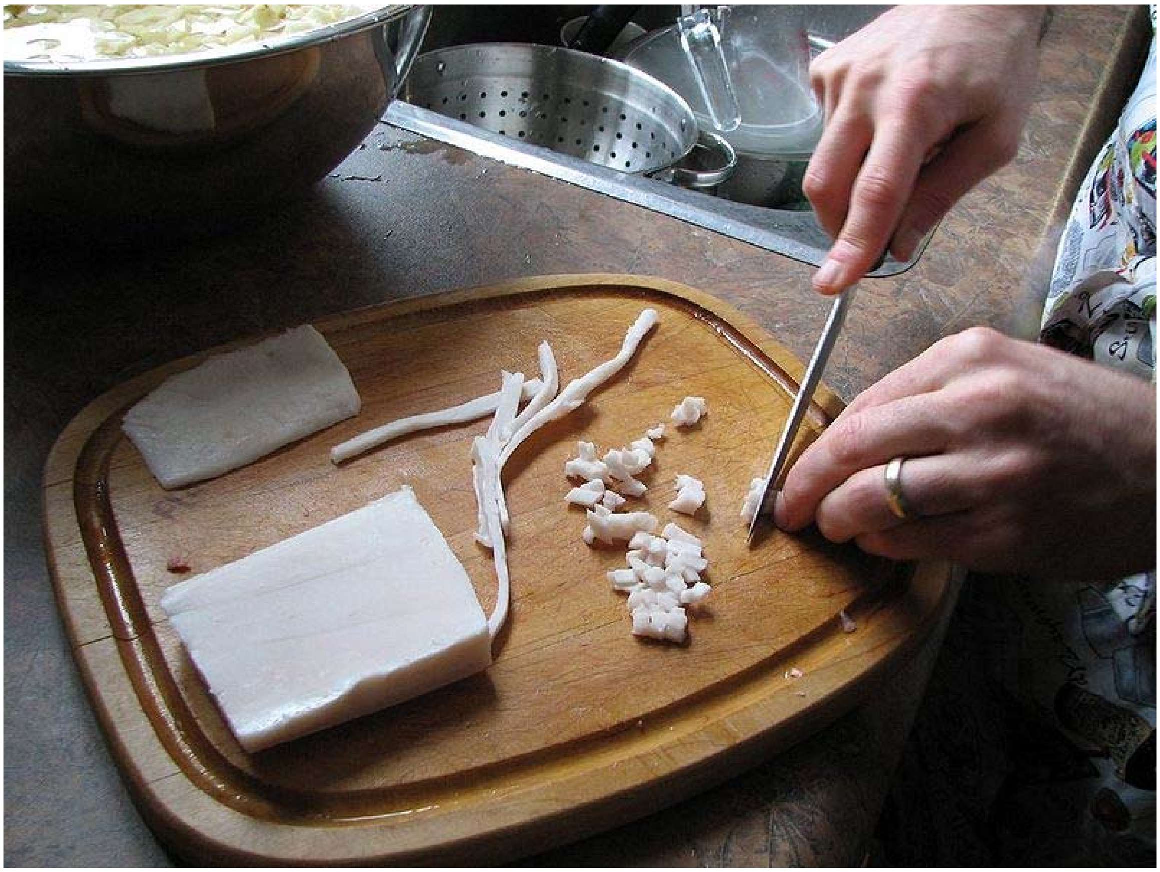
Lard may be rendered by either of two processes: wet or dry. In wet rendering, pig fat is boiled in water or steamed at a high temperature and the lard, which is insoluble in water, is skimmed off of the surface of the mixture, or it is separated in an industrial centrifuge. In dry rendering, the fat is exposed to high heat in a pan or oven without the presence of water (a process similar to frying bacon). The two processes yield somewhat differing products. Wet-rendered lard has a more neutral flavor, a lighter color, and a high smoke point. Dry-rendered lard is somewhat more browned in color and flavor and has relatively lower smoke point.

Industrially-produced lard, including much of the lard sold in supermarkets, is rendered from a mixture of high and low quality fat sources from throughout the pig. To improve stability at room temperature, lard is often "hydrogenated" a process that should not be confused with "partial hydrogenation" of vegetable oils which creates unhealthy trans-fats. Hydrogenated lard sold to consumers typically contains fewer than 0.5g of transfats per 13g serving. Lard is also often treated with bleaching and deodorizing agents, emulsifiers, and antioxidants, such as BHT. These treatments make lard more consistent and prevent spoilage. (Untreated lard must be refrigerated or frozen to prevent rancidity.)

Consumers seeking a higher-quality source of lard typically seek out artisanal producers of rendered lard, or render it themselves from leaf lard or fatback.

A by-product of dry-rendering lard is deep-fried meat, skin and membrane tissue known as cracklings.

History and cultural use



Raw fatback being diced to prepare tourtière.

Lard has always been an important cooking and baking staple in cultures where pork is an important dietary item, the fat of pigs often being as valuable a product as their meat. However, it is prohibited by dietary laws that forbid the consumption of pork, such as kashrut and halal.

During the 19th century, lard was used in a similar fashion as butter in North America and many European nations. Lard was also held at the same level of popularity as butter in the early 20th century and was widely used as a substitute for butter during World War II. As a readily available by-product of modern pork production, lard had been cheaper than most vegetable oils, and it was common in many people's diet until the industrial revolution made vegetable oils more common and more affordable. Vegetable shortenings were developed in the early 1900s, which made it possible to use vegetable-based fats in baking and in other uses where solid fats were called for.

By the late 20th century, lard had begun to be considered less healthy than vegetable oils (such as olive and sunflower oil) because of its high saturated fatty acid and cholesterol content. However, despite its reputation, lard has less saturated fat, more unsaturated fat, and less cholesterol than an equal amount of butter by weight. Unlike many margarines and vegetable shortenings, unhydrogenated lard contains no trans fat. It has also been regarded as a "poverty food".

Many restaurants in the western nations have eliminated the use of lard in their kitchens because of the religious and health-related dietary restrictions of many of their customers. Many industrial bakers substitute beef tallow for lard in order to compensate for the lack of mouthfeel in many baked goods and free their food products from pork-based dietary restrictions.

However, in the 1990s and early 2000s, the unique culinary properties of lard became widely recognized by chefs and bakers, leading to a partial rehabilitation of this fat among "foodies". This trend has been partially driven by negative publicity about the trans fat content of the partially hydrogenated vegetable oils in vegetable shortening. Chef and food writer Rick Bayless is a prominent proponent of the virtues of lard for certain types of cooking.

It is also again becoming popular in the United Kingdom among aficionados of traditional British cuisine. This led to a "lard crisis" in early 2006 in which British demand for lard was not met due to demand by Poland and Hungary (who had recently joined the European Union) for fatty cuts of pork that had served as an important source of lard.

Culinary use

Lard is one of the few edible oils with a relatively high smoke point, attributable to its high saturated fatty acids content. Pure lard is especially useful for cooking since it produces little smoke when heated and has a distinct taste when combined with other foods. Many chefs and bakers deem lard a superior cooking fat over shortening because of lard's range of applications and taste.

Lard

Nutritional value per 100 g (3.5 oz)

Energy	3,765.6 kJ (900.0 kcal)
Carbohydrates	0 g
Fat	100 g
saturated	39 g
monounsaturated	45 g
polyunsaturated	11 g

Protein	0 g
Cholesterol	95 mg
Zinc	0.1 mg
Selenium	0.2 mg

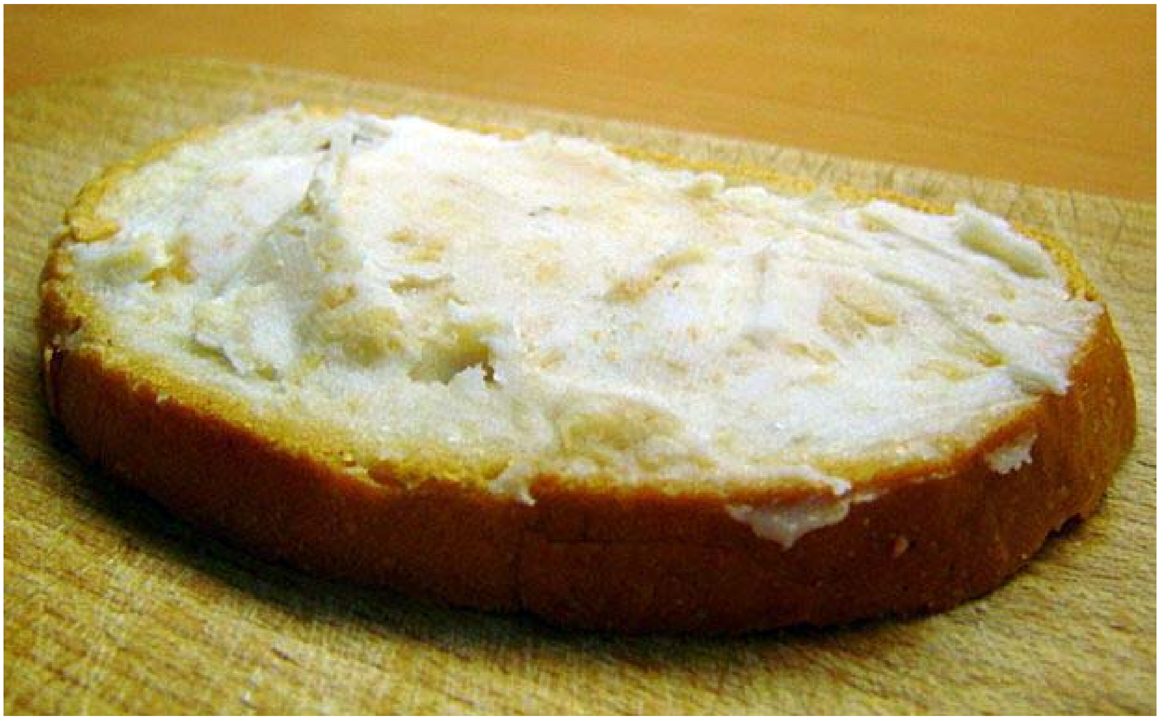
Comparative properties of common cooking fats (per 100g)					
	Total Fat	**Saturated Fat**	**Monounsaturated Fat**	**Polyunsaturated Fat**	**Smoke Point**
Vegetable Shortening (hydrogenated)	71g	23g	8g	37g	182°C (360°F)
Sunflower oil	100g	10g	20g	66g	232°C (450°F)
Soybean oil	100g	16g	23g	58g	232°C (450°F)
Peanut oil	100g	17g	46g	32g	232°C (450°F)
Olive oil	100g	14g	73g	11g	216°C (420°F)
Lard	100g	39g	45g	11g	188°C (370°F)
Suet	94g	52g	32g	3g	200°C (400°F)
Butter	81g	51g	21g	3g	177°C (350°F)

Because of the relatively large fat crystals found in lard, it is extremely effective as a shortening in baking. Pie crusts made with lard tend to be more flaky than those made with butter. Many cooks employ both types of fat in their pastries to combine the shortening properties of lard with the flavor of butter.

Lard was once widely used in the cuisines of Europe, China, and the New World and still plays a significant role in British, Central European, Mexican, and Chinese cuisines. In British cuisine, lard is used as a traditional ingredient in mince pies and Christmas puddings, lardy cake and for frying fish and chips, as well as many other uses.

Lard is traditionally one of the main ingredients in the Scandinavian pâté leverpostej.

In Catalan cuisine lard is used to make the dough for the pastry known as coca. In the Balearics particularly, ensaimades dough also contains lard.



A slice of bread spread with lard was a typical staple in traditional rural cuisine of many countries.

Lard consumed as a spread on bread was once very common in Europe and North America, especially those areas where dairy fats and vegetable oils were rare.

As the demand for lard grows in the high end restaurant industry, small farmers have begun to specialize in heritage hog breeds with higher body fat contents than the leaner, modern hog. Breeds such as the Mangalitsa hog of Hungary or Large Black of Great Britain are experiencing an enormous resurgence to the point that breeders are unable to keep up with demand.

Lard generally refers to wet-rendered lard in English, which has a very mild, neutral flavor, as opposed to the more noticeably pork flavored dry rendered lard, which is also referred to as dripping or schmalz. Dripping (or "schmalz") sandwiches are still popular in several European countries - in Hungary they're known as "Zsíroskenyér" or "Zsírosdeszka", and in Germany pork fat is seasoned to make "Fettbemme". Similar snacks are sometimes served with beer in Poland, Czech Republic and Slovakia. They are generally topped with onions, served with salt and paprika, and eaten as a side-dish with beer. All of these are commonly translated on menus as "lard" sandwiches, perhaps due to the lack of familiarity of most contemporary English native speakers with dripping. Attempts to use Hungarian "Zsir" or Polish "Smalec" in British recipes calling for lard will soon reveal the difference between the wet-rendered lard and dripping. In Taiwan, Hong Kong as well as many parts of mainland China, lard was often consumed mixed into cooked rice along with soy sauce to make "lard rice" (豬油拌飯 or 豬油撈飯). This is less commonly served in modern times due to concerns with saturated fats.

Other uses

Rendered lard can be used to produce biofuel and soap. Lard is also useful as a cutting fluid in machining. Its use in machining has declined since the mid-20th century as other specially engineered cutting fluids became prominent. However, it is still a viable option.

Chemical properties

Pigs that have been fed different diets will have lard with a significantly different fatty acid content and iodine value. Peanut-fed hogs or the acorn-fed pigs raised for Jamón ibérico therefore produce a somewhat different kind of lard compared to pigs raised in North American farms that are fed corn.

Similar fats

Cooking fat obtained from cattle or sheep is known as suet or tallow. The fat of chickens, ducks, or geese has no special English name, except in Jewish cuisine, where it is known as schmaltz. Bacon grease is sometimes also used in a culinary capacity.

Chapter 11

Honey

Jars of honey and honeycomb

Honey in honeycombs

Traditional honey pot from North Korea

A honey bee on calyx of goldenrod

Honey is a sweet food made by bees using nectar from flowers. The variety produced by honey bees (the genus *Apis*) is the one most commonly referred to and is the type of honey collected by beekeepers and consumed by humans. Honey produced by other bees and insects has distinctly different properties.

Honey bees form nectar into honey by a process of regurgitation and store it as a primary food source in wax honeycombs inside the beehive. Beekeeping practices encourage overproduction of honey so that the excess can be taken without endangering the bee colony.

Honey gets its sweetness from the monosaccharides fructose and glucose and has approximately the same relative sweetness as that of granulated sugar. It has attractive chemical properties for baking, and a distinctive flavor that leads some people to prefer it over sugar and other sweeteners. Most microorganisms do not grow in honey because of its low water activity of 0.6. However, honey sometimes contains dormant endospores of the bacterium *Clostridium botulinum*, which can be dangerous to infants as the endospores can transform into toxin-producing bacteria in the infant's immature intestinal tract, leading to illness and even death.

Honey has a long history of human consumption and is used in various foods and beverages as a sweetener and flavoring. It also has a role in religion and symbolism. Flavors of honey vary based on the nectar source, and various types and grades of honey are available. It is also used in various medicinal traditions to treat ailments. The study of pollens and spores in raw honey (melissopalynology) can determine floral sources of honey. Because bees carry an electrostatic charge, and can attract other particles, the same techniques of melissopalynology can be used in area environmental studies of radioactive particles, dust or particulate pollution.

Formation

Honey is created by bees as a food source. In cold weather or when fresh food sources are scarce, bees use their stored honey as their source of energy. By contriving for bee swarms to nest in artificial hives, people have been able to semi-domesticate the insects, and harvest excess honey. In the hive (or in a wild nest) there are three types of bee: a single female queen bee, a seasonally variable number of male drone bees to fertilize new queens, and some 20,000 to 40,000 female worker bees. The worker bees raise larvae and collect the nectar that will become honey in the hive. Leaving the hive, they collect sugar-rich flower nectar and return.

In the hive the bees use their "honey stomachs" to ingest and regurgitate the nectar a number of times until it is partially digested. The bees work together as a group with the regurgitation and digestion until the product reaches a desired quality. It is then stored in honeycomb cells. After the final regurgitation, the honeycomb is left unsealed. However, the nectar is still high in both water content and natural yeasts, which, unchecked, would cause the sugars in the nectar to ferment. The process continues as bees inside the hive fan their wings, creating a strong draft across the honeycomb, which enhances evaporation of much of the water from the nectar. This reduction in water content raises the sugar concentration and prevents fermentation. Ripe honey, as removed from the hive by a beekeeper, has a long shelf life and will not ferment if properly sealed.

Physical properties

The physical properties of honey vary, depending on water content, the type of flora used to produce it, temperature, and the proportion of the specific sugars it contains. Fresh honey is a supersaturated liquid, containing more sugar than the water can typically dissolve at ambient temperatures. At room temperature, honey is a supercooled liquid, in which the glucose will precipitate in order to crystalize into solid granules. This forms a semi-solid solution of solidified sugars mixed with liquid sugars and other ingredients.

The melting point of crystalized honey is between 40 and 50 °C (104 and 122 °F), depending on its composition. Below this temperature, honey can be either in a metastable state, meaning that it will not crystalize until a seed crystal is added, or, more often, it is in a "labile" state, being saturated with enough sugars to crystalize spontaneously. The rate of crystalization is affected by the ratio of the main sugars, fructose to glucose, as well as the dextrin content. Temperature also affects the rate of crystalization, which is fastest between 13 and 17 °C (55 and 63 °F). Below 5 °C, the honey will not crystalize and, thus, the original texture and flavor can be preserved indefinitely.

Since honey normally exists below its melting point, it is a supercooled liquid. At very low temperatures, honey will not freeze solid (crystalize). Instead, as the temperatures become colder, the viscosity of honey increases. Like most viscous liquids, the honey will become thick and sluggish with decreasing temperature. While appearing or even feeling solid, it will continue to flow at very slow rates. Honey has a glass transition between -42 and -51 °C (-44 and -60 °F). Below this temperature, honey enters a glassy state and will become a non-crystalline amorphous solid.

The viscosity of honey is affected greatly by both temperature and water content. The higher the humidity, the easier honey will flow. Above its melting point, however, water has little effect on viscosity. Aside from water content, the composition of honey also has little effect on viscosity, with the exception of a few types. At 25 °C (77 °F), honey with 14% humidity will generally have a viscosity of around 400 poise, while a honey containing 20% humidity will have a viscosity of around 20 poise. Viscosity increase due to temperature occurs very slowly at first. A honey containing 16% humidity, at 70 °C (158 °F), will have a viscosity of around 2 poise, while at 30 °C (86 °F), the viscosity will be around 70 poise. As cooling progresses, honey will become more viscous at an increasingly rapid rate, reaching 600 poise around 14 °C (57 °F). However, while honey is very viscous, it has rather low surface tension.

A few types of honey have unusual viscous properties. Honey from heather or manuka display thixotropic properties. These types of honey enter a gel-like state when motionless, but then liquify when stirred.

Unlike many other liquids, honey has very poor thermal conductivity. Melting crystalized honey can easily result in localized caramelization if the heat source is too hot, or if it is not evenly distributed. However, honey will take substantially longer to liquify when just above the melting point than it will at elevated temperatures.

Since honey contains electrolytes, in the form of acids and minerals, it exhibits varying degrees of electrical conductivity. Measurements of the electrical conductvity are used to determine the quality of honey in terms of ash content.

The effect honey has on light is useful for determining the type and quality. Variations in the water content alter the refractive index of honey. Water content can easily be measured with a refractometer. Typically, the refractive index for honey will range from 1.504 at 13% humidity, to 1.474 at 25%. Honey also has an effect on polarized light, in that it will rotate the polarization plane. The fructose will give a negative rotation, while the glucose will give a positive one. The overall rotation can be used to measure the ratio of the mixture.

Honey has the ability to absorb moisture directly from the air, a phenomenon called hygroscopy. The amount of water the honey will absorb is dependent on the relative humidity of the air. This hygroscopic nature requires that honey be stored in sealed containers to prevent fermentation. Honey will tend to absorb more water in this manner than the individual sugars would allow on their own, which may be due to other ingredients which it contains.

In history, culture, and folklore

Honey use and production has a long and varied history. In many cultures, honey has associations that go beyond its use as a food. Honey is frequently used as a talisman and symbol of sweetness.

Ancient times

Honey collection is an ancient activity. Eva Crane's *The Archaeology of Beekeeping* states that humans began hunting for honey at least 10,000 years ago. She evidences this with a cave painting in Valencia, Spain. The painting is a Mesolithic rock painting, showing two female honey-hunters collecting honey and honeycomb from a wild bee nest. The two women are depicted in the nude, carrying baskets, and using a long wobbly ladder in order to reach the wild nest.

In ancient Egypt, honey was used to sweeten cakes and biscuits, and was used in many other dishes. Ancient Egyptian and Middle Eastern peoples also used honey for embalming the dead. Pliny the Elder devotes considerable space in his book *Naturalis Historia* to the bee and honey, and its many uses. The fertility god of Egypt, Min, was offered honey.

The art of beekeeping appeared in ancient China for a long time and hardly traceable to its origin. In the book "Golden Rules of Business Success" written by Fan Li (or Tao Zhu Gong) during the Spring and Autumn Period, there are some parts mentioning the art of beekeeping and the importance of the quality of the wooden box for bee keeping that can affect the quality of its honey.

Honey was also cultivated in ancient Mesoamerica. The Maya used honey from the stingless bee for culinary purposes and continue to do so today. The Maya also regard the bee as sacred.

Some cultures believed honey had many practical health uses. It was used as an ointment for rashes and burns, and used to help soothe sore throats when no other medicinal practices were available.

Religious significance

In Hinduism, honey (Madhu) is one of the five elixirs of immortality (Panchamrita). In temples, honey is poured over the deities in a ritual called Madhu abhisheka. The Vedas and other ancient literature mention the use of honey as a great medicinal and health food.

In Jewish tradition, honey is a symbol for the new year, Rosh Hashanah. At the traditional meal for that holiday, apple slices are dipped in honey and eaten to bring a sweet new year. Some Rosh Hashanah greetings show honey and an apple, symbolizing the feast. In some congregations, small straws of honey are given out to usher in the new year.

The Hebrew Bible contains many references to honey. In the Book of Judges, Samson found a swarm of bees and honey in the carcass of a lion (14:8). The Book of Exodus famously describes the Promised Land as a "land flowing with milk and honey" (33:3). However, the claim has been advanced that the original Hebrew (*devash*) actually refers to the sweet syrup produced from the juice of dates. Pure honey is considered kosher even though it is produced by a flying insect, a non-kosher creature; other products of non-kosher animals are non-kosher.

In Buddhism, honey plays an important role in the festival of Madhu Purnima, celebrated in India and Bangladesh. The day commemorates Buddha's making peace among his disciples by retreating into the wilderness. The legend has it that while he was there, a monkey brought him honey to eat. On Madhu Purnima, Buddhists remember this act by giving honey to monks. The monkey's gift is frequently depicted in Buddhist art.

In the Christian New Testament, Matthew 3:4, John the Baptist is said to have lived for a long period of time in the wilderness on a diet consisting of locusts and wild honey.

In Islam, there is an entire Surah in the Qur'an called al-Nahl (the Honey Bee). According to hadith, Prophet Muhammad strongly recommended honey for healing purposes. Qur'an promotes honey as a nutritious and healthy food. Below is the English translation of those specific verses.

And your Lord inspired the bees, saying: "Take you habitations in the mountains and in the trees and in what they erect. (68) Then, eat of all fruits, and follow the ways of your Lord made easy (for you)." There comes forth from their bellies, a drink of varying colour wherein is healing for men. Verily, in this is indeed a sign for people who think.

In Western culture

A jar of honey with honey dipper

The word "honey", along with variations like "honey bun" and the abbreviation "hon", has become a term of endearment in most of the English-speaking world. In some places it is used for loved ones; in others, such as the Southern United States and Baltimore, Maryland, it is used when addressing casual acquaintances or even strangers.

Also, in many children’s books bears are depicted as eating honey, (e.g., Winnie the Pooh) even though most bears actually eat a wide variety of foods, and bears seen at beehives are usually more interested in bee larvae than honey. In some European languages even the word for 'bear' (e.g. in Russian 'medvéd', in Czech 'medvěd, in

Serbian 'medved', in Croatian 'medvjed') is coined from the noun meaning 'honey' and the verb meaning 'to eat'. Honey is sometimes sold in bear-shaped jars or squeeze bottles.

Collecting honey

Honey is collected from wild bee colonies, or from domesticated beehives. Wild bee nests are sometimes located by following a honeyguide bird.

Collecting honey is typically achieved by using smoke from a bee smoker to pacify the bees; this causes the bees to attempt to save the resources of the hive from a possible forest fire, and makes them far less aggressive. The honeycomb is removed from the hive and the honey is extracted from that, often using a honey extractor. The honey is then filtered.

Modern uses

As a food and in cooking

The main uses of honey are in cooking, baking, as a spread on bread, and as an addition to various beverages such as tea and as a sweetener in some commercial beverages. According to international food regulations, "honey stipulates a pure product that does not allow for the addition of any other substance...this includes, but is not limited to, water or other sweeteners". Honey barbecue and honey mustard are common and popular sauce flavors.

Honey is the main ingredient in the alcoholic beverage mead, which is also known as "honey wine" or "honey beer". Historically, the ferment for mead was honey's naturally occurring yeast. Honey is also used as an adjunct in some beers.

Nutrition

Honey

Nutritional value per 100 g (3.5 oz)

Energy	1,272 kJ (304 kcal)
Carbohydrates	82.4 g
Sugars	82.12 g
Dietary fiber	0.2 g
Fat	0 g
Protein	0.3 g
Water	17.10 g
Riboflavin (Vit. B_2)	0.038 mg (3%)

Niacin (Vit. B_3)	0.121 mg (1%)
Pantothenic acid (B_5)	0.068 mg (1%)
Vitamin B_6	0.024 mg (2%)
Folate (Vit. B_9)	2 μg (1%)
Vitamin C	0.5 mg (1%)
Calcium	6 mg (1%)
Iron	0.42 mg (3%)
Magnesium	2 mg (1%)
Phosphorus	4 mg (1%)
Potassium	52 mg (1%)
Sodium	4 mg (0%)
Zinc	0.22 mg (2%)

Honey is a mixture of sugars and other compounds. With respect to carbohydrates, honey is mainly fructose (about 38.5%) and glucose (about 31.0%), making it similar to the synthetically produced inverted sugar syrup, which is approximately 48% fructose, 47% glucose, and 5% sucrose. Honey's remaining carbohydrates include maltose, sucrose, and other complex carbohydrates. As with all nutritive sweeteners, honey is mostly sugars and contains only trace amounts of vitamins or minerals. Honey also contains tiny amounts of several compounds thought to function as antioxidants, including chrysin, pinobanksin, vitamin C, catalase, and pinocembrin. The specific composition of any batch of honey depends on the flowers available to the bees that produced the honey.

Typical honey analysis.

- Fructose: 38.2%
- Glucose: 31.3%
- Sucrose: 1.3%
- Maltose: 7.1%
- Water: 17.2%
- Higher sugars: 1.5%
- Ash: 0.2%
- Other/undetermined: 3.2%

Its glycemic index ranges from 31 to 78, depending on the variety.

Honey has a density of about 1.36 kilograms per litre (36% denser than water).

Isotope ratio mass spectrometry can be used to detect addition of corn syrup or sugar cane sugars by the carbon isotopic signature. Addition of sugars originating from corn or sugar cane (C4 plants, unlike the plants used by bees, which are predominantly C3 plants) skews the isotopic ratio of sugars present in honey, but does not influence the isotopic ratio of proteins; in an unadulterated honey the carbon isotopic ratios of sugars and proteins should match. As low as 7% level of addition can be detected.

Classification

Honey is classified by its floral source, and there are also divisions according to the packaging and processing used. There are also regional honeys. Honey is also graded on its color and optical density by USDA standards, graded on a scale called the Pfund scale, which ranges from 0 for "water white" honey to more than 114 for "dark amber" honey.

Floral source

Generally, honey is classified by the floral source of the nectar from which it was made. Honeys can be from specific types of flower nectars, from indeterminate origin, or can be blended after collection.

Blended

Most commercially available honey is blended, meaning that it is a mixture of two or more honeys differing in floral source, color, flavor, density or geographic origin.

Polyfloral

Polyfloral honey, also known as wildflower honey, is derived from the nectar of many types of flowers. The taste may vary from year to year, and the aroma and the flavor can be more or less intense, depending on which bloomings are prevalent.

Monofloral

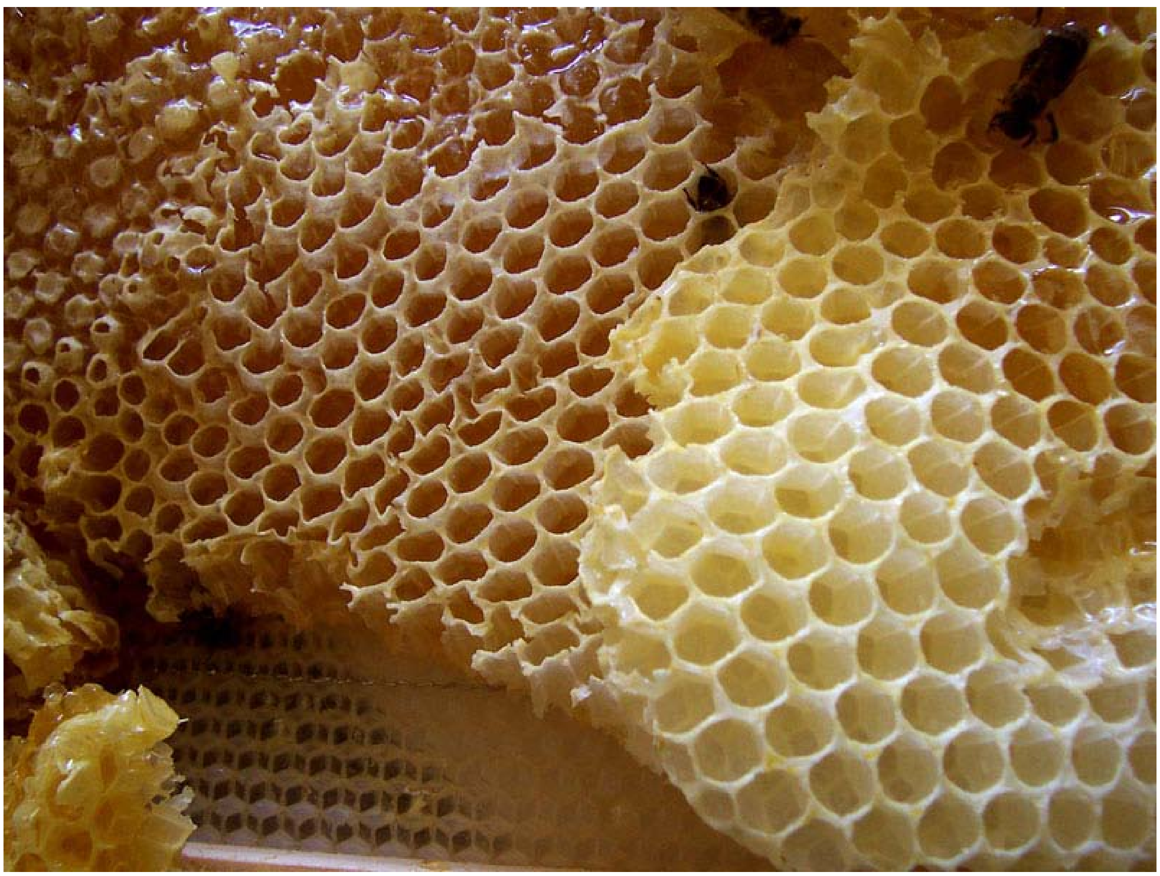
Monofloral honey is made primarily from the nectar of one type of flower. Different monofloral honeys have a distinctive flavor and color because of differences between their principal nectar sources. To produce monofloral honey, beekeepers keep beehives in an area where the bees have access to only one type of flower. In practice, because of the difficulties in containing bees, a small proportion of any honey will be from additional nectar from other flower types. Typical examples of North American monofloral honeys are clover, orange blossom, sage, tupelo, buckwheat, fireweed, and sourwood. Some typical European examples include thyme, thistle, heather, acacia, dandelion, sunflower, honeysuckle, and varieties from lime and chestnut trees. In North Africa, such as Egypt, examples include clover, cotton, and citrus (mainly orange blossoms).

Honeydew honey

Instead of taking nectar, bees can take honeydew, the sweet secretions of aphids or other plant sap-sucking insects. Honeydew honey is very dark brown in color, with a rich fragrance of stewed fruit or fig jam and is not sweet like nectar honeys. Germany's Black Forest is a well known source of honeydew-based honeys, as well as some regions in Bulgaria and Northern California in the United States. In Greece, pine honey (a type of honeydew honey) constitutes 60–65% of the annual honey production. Honeydew honey is popular in some areas, but in other areas beekeepers have difficulty selling the stronger flavored product.

The production of honeydew honey has some complications and dangers. The honey has a much larger proportion of indigestibles than light floral honeys, thus causing dysentery to the bees, resulting in the death of colonies in areas with cold winters. Good beekeeping management requires the removal of honeydew prior to winter in colder areas. Bees collecting this resource also have to be fed protein supplements, as honeydew lacks the protein-rich pollen accompaniment gathered from flowers.

Classification by packaging and processing



Honeycomb

A variety of honey flavors and container sizes and styles from the 2008 Texas State Fair

Generally, honey is bottled in its familiar liquid form. However, honey is sold in other forms, and can be subjected to a variety of processing methods.

- **Crystallized honey** is honey in which some of the glucose content has spontaneously crystallized from solution as the monohydrate. Also called "granulated honey." Honey that has crystallized over time (or commercially purchased crystallized) in the home can be returned to a liquid state if stirred in a container sitting in warm water at 120 °F (approx 49 °C).
- **Pasteurized honey** is honey that has been heated in a pasteurization process. Pasteurization destroys yeast cells. It also liquefies any micro-crystals in the honey, which delays the onset of visible crystallization. However, excessive heat-exposure also results in product deterioration as it increases the level of hydroxymethylfurfural (HMF) and reduces enzyme (e.g. diastase) activity. Heat also affects appearance (darkens the natural honey color) , taste, and fragrance.
- **Raw honey** is honey as it exists in the beehive or as obtained by extraction, settling or straining, without adding heat (although some honey that has been "minimally processed" is often labeled as raw honey). Raw honey contains some pollen and may contain small particles of wax. Local raw honey is sought after by allergy sufferers as the pollen impurities are thought to lessen the sensitivity to hay fever.

- **Strained honey** is honey that has been passed through a mesh material to remove particulate material (pieces of wax, propolis, other defects) without removing pollen, minerals or valuable enzymes.
- **Ultrafiltered honey** is honey processed by very fine filtration under high pressure to remove all extraneous solids and pollen grains. The process typically heats honey to 150–170 °F (approx. 65–77 °C) to more easily pass through the fine filter. Ultrafiltered honey is very clear and has a longer shelf life, because it crystallizes more slowly because of the high temperatures breaking down any sugar seed crystals, making it preferred by the supermarket trade.
- **Ultrasonicated honey** is honey that has been processed by ultrasonication, a nonthermal processing alternative for honey. When honey is exposed to ultrasonication, most of the yeast cells are destroyed. Yeast cells that survive sonication generally lose their ability to grow. This reduces the rate of honey fermentation substantially. Ultrasonication also eliminates existing crystals and inhibits further crystallization in honey. Ultrasonically aided liquefaction can work at substantially lower temperatures of approximately 35 °C (95 °F) and can reduce liquefaction time to less than 30 seconds.
- **Whipped honey**, also called creamed honey, spun honey, churned honey, candied honey, and honey fondant, is honey that has been processed to control crystallization. Whipped honey contains a large number of small crystals in the honey. The small crystals prevent the formation of larger crystals that can occur in unprocessed honey. The processing also produces a honey with a smooth, spreadable consistency.
- **Dried honey** has the moisture extracted from liquid honey to create a completely solid, nonsticky honey. This process may or may not include the use of drying and antibinding agents. Dried honey is commonly used to garnish desserts.
- **Comb honey** is honey still in the honeybees' wax comb. Comb honey traditionally is collected by using standard wooden frames in honey supers. The frames are collected and the comb cut out in chunks before packaging. As an alternative to this labor intensive method, plastic rings or cartridges can be used that do not require manual cutting of the comb, and speed packaging. Comb honey harvested in the traditional manner is also referred to as "cut-comb honey". In India, honey is harvested from forests in bee's natural habitat. It is said that honey will be consumed by the bees on the new moon day, so it is cultivated the day before.
- **Chunk honey** is honey packed in widemouth containers consisting of one or more pieces of comb honey immersed in extracted liquid honey.

Preservation

Sealed frame of honey

Because of its unique composition and chemical properties, honey is suitable for long term storage and is easily assimilated even after long preservation. Honey, and objects immersed in honey, have been preserved for decades and even centuries. The key to preservation is limiting access to humidity. In its cured state, honey has a sufficiently high sugar content to inhibit fermentation. If, however, the honey is exposed to moist air, its hydrophilic properties will pull moisture into the honey, eventually diluting it to the point that fermentation can begin. Honey sealed in honeycomb cells by the bees is considered by many to be the ideal form for preservation.

Honey should also be protected from oxidation and temperature degradation. Honey generally should not be preserved in metal containers because the acids in the honey may promote oxidation of the vessel. Traditionally, honey was stored in ceramic or wooden containers; however, glass and plastic are now the favored materials. Honey stored in wooden containers may be discolored or take on flavors imparted from the vessel. Likewise, honey stored uncovered near other foods may absorb other smells.

Excessive heat can have detrimental effects on the nutritional value of honey. Heating up to 37 °C (98.6 °F) causes loss of nearly 200 components, some of which are antibacterial.

Heating up to 40 °C (104 °F) destroys invertase, an important enzyme. At 50 °C (122 °F), the honey sugars caramelize. Generally any large temperature fluctuation causes decay.

Regardless of preservation, honey may crystallize over time. Crystallization does not affect the flavor, quality or nutritional content of the honey though it does affect color and texture. The pace of crystallization is a function of storage temperature, availability of "seed" crystals and the specific mix of sugars and trace compounds in the honey. Tupelo and acacia honeys, for example, are exceptionally slow to crystallize while goldenrod will often crystallize still in the comb. Most honeys crystallize fastest between about 50 and 70 °F (10 and 21 °C).

The crystals can be redissolved by heating the honey.

Distinguishing honey

Honey grading

In the US, honey grading is performed voluntarily (USDA does offer inspection and grading "*as on-line (in-plant) or lot inspection...upon application, on a fee-for-service basis.*") based upon USDA standards. Honey is graded based upon a number of factors including water content, flavor & aroma, absence of defects and clarity. Honey is also classified by color though color is not a factor in the grading scale. The honey grade scale is:

Grade	Water content	Flavor & Aroma	Absence of Defects	Clarity
A	< 18.6%	Good—has a good, normal flavor and aroma for the predominant floral source and is free from caramelization, smoke, fermentation, chemicals and other odor causes	Practically free—practically no defects that affect appearance or edibility	Clear—may contain air bubbles that do not materially affect the appearance; may contain a trace of pollen grains or other finely divided particles of suspended material that do not affect appearance

B	< 18.6%	Reasonably good—practically free from caramelization; free from smoke, fermentation, chemicals, and other causes	Reasonably free—do not materially affect appearance or edibility	Reasonably clear—may contain air bubbles, pollen grains, or other finely divided particles of suspended material that do not materially affect appearance
C	< 20.0%	Fairly good—reasonably free from caramelization; free from smoke, fermentation, chemicals, and other causes	Fairly free—do not seriously affect the appearance or edibility	Fairly clear—may contain air bubbles, pollen grains, or other finely divided particles of suspended material that do not seriously affect appearance
Substandard	> 20.0%	Fails Grade C	Fails Grade C	Fails Grade C

Other countries may have differing standards on the grading of honey. India, for example, certifies honey grades based on additional factors such as the Fiehes test, as well as other empirical measurements.

Indicators of quality

High quality honey can be distinguished by fragrance, taste, and consistency. Ripe, freshly collected, high quality honey at 20 °C (68 °F) should flow from a knife in a straight stream, without breaking into separate drops. After falling down, the honey should form a bead. The honey when poured should form small, temporary layers that disappear fairly quickly, indicating high viscosity. If not, it indicates excessive water content (over 20%) of the product. Honey with excessive water content is not suitable for long-term preservation.

In jars, fresh honey should appear as a pure, consistent fluid and should not set in layers. Within a few weeks to a few months of extraction, many varieties of honey crystallize into a cream-coloured solid. Some varieties of honey, including tupelo, acacia, and sage, crystallize less regularly. Honey may be heated during bottling at temperatures of 40–49 °C (104–120 °F) to delay or inhibit crystallization. Overheating is indicated by change in enzyme levels, for instance, diastase activity, which can be determined with the Schade method or the Phadebas method. A fluffy film on the surface of the honey (like a white foam), or marble-coloured or white-spotted crystallization on a containers sides, is formed by air bubbles trapped during the bottling process.

A 2008 Italian study determined that nuclear magnetic resonance spectroscopy can be used to distinguish between different honey types, and can be used to pinpoint the area where it was produced. Researchers were able to identify differences in acacia and polyfloral honeys by the differing proportions of fructose and sucrose, as well as differing levels of aromatic amino acids phenylalanine and tyrosine. This ability allows greater ease of selecting compatible stocks.

In medicine

For at least 2700 years, honey has been used by humans to treat a variety of ailments through topical application, but only recently have the antiseptic and antibacterial properties of honey been chemically explained.

In Ayurveda, a 4000-year-old medicine originating from India, honey is considered to positively affect all three primitive material imbalances of the body. "Vaatalam guru sheetam cha raktapittakaphapaham| Sandhatru cchedanam ruksham kashayam madhuram madhu||" "It has sweetness with added astringent as end taste. It is heavy, dry and cold. Its effect on doshas (imbalances) is that it aggravates vata (air / moving forces), scrapes kapha (mucus / holding forces) and normalizes pitta (catabolic fire) and rakta (blood). It promotes the healing process."

Some wound gels which contain antibacterial raw honey and have regulatory approval are now available to help treat drug resistant strains of bacteria MRSA. As an antimicrobial agent honey may have the potential for treating a variety of ailments. One New Zealand researcher says a particular type of honey (Manuka honey) may be useful in treating MRSA infections. Antibacterial properties of honey are the result of the low water activity causing osmosis, hydrogen peroxide effect, high acidity, and the antibacterial activity of methylglyoxal.

Honey appears to be effective in killing drug-resistant biofilms which are implicated in chronic rhinosinusitis.

Osmotic effect

Honey is primarily a saturated mixture of two monosaccharides. This mixture has a low water activity; most of the water molecules are associated with the sugars and few remain available for microorganisms, so it is a poor environment for their growth. If water is mixed with honey, it loses its low water activity, and therefore no longer possesses this antimicrobial property.

Hydrogen peroxide

Hydrogen peroxide is formed in a slow-release manner by the enzyme glucose oxidase present in honey. It becomes active only when honey is diluted, requires oxygen to be available for the reaction (thus it may not work under wound dressings, in wound cavities or in the gut), is active only when the acidity of honey is neutralised by body fluids, can be destroyed by the protein-digesting enzymes present in wound fluids, and is destroyed when honey is exposed to heat and light. Honey chelates and deactivates free iron, which would otherwise catalyze the formation of oxygen free radicals from hydrogen peroxide, leading to inflammation. Also, the antioxidant constituents in honey help clean up oxygen free radicals present.

$$C_6H_{12}O_6 + H_2O + O_2 \rightarrow C_6H_{12}O_7 + H_2O_2 \text{ (glucose oxidase reaction)}$$

When honey is used topically (as, for example, a wound dressing), hydrogen peroxide is produced by dilution of the honey with body fluids. As a result, hydrogen peroxide is released slowly and acts as an antiseptic.

In diabetic ulcers

Topical honey has been used successfully in a comprehensive treatment of diabetic ulcers when the patient cannot use topical antibiotics.

Acidity

The pH of honey is commonly between 3.2 and 4.5. This relatively acidic pH level prevents the growth of many bacteria.

Methylglyoxal

The non-peroxide antibiotic activity is due to methylglyoxal (MGO) and an unidentified synergistic component. Most honeys contain very low levels of MGO, but manuka honey contains very high levels. The presence of the synergist in manuka honey more than doubles MGO antibacterial activity.

Nutraceutical effects

Antioxidants in honey have even been implicated in reducing the damage done to the colon in colitis. Such claims are consistent with its use in many traditions of folk medicine.

For throats

Honey has also been used for centuries as a treatment for sore throats and coughs and, according to recent research, may be an effective soothing agent for coughs.

Other medical applications

Some studies suggest that the topical use of honey may reduce odors, swelling, and scarring when used to treat wounds; it may also prevent the dressing from sticking to the healing wound.

Honey has been shown to be an effective treatment for conjunctivitis in rats.

Unfiltered, pasteurized honey is widely believed to alleviate allergies, though neither commercially filtered nor raw honey was shown to be more effective than placebo in a controlled study of 36 participants with ocular allergies. Nearly 1 in 3 of the volunteers dropped out of the study because they couldn't tolerate eating one tablespoon of honey every day due to the overly sweet taste. The official conclusion: "This study does not confirm the widely held belief that honey relieves the symptoms of allergic rhinoconjunctivitis." A more recent study has shown pollen collected by bees to exert an anti allergenic effect, mediated by an inhibition of IgE immunoglobulin binding to mast cells. This inhibited mast cell degranulation and thus reduced allergic reaction. The risk of experiencing anaphylaxis as an immune system reaction may outweigh any potential allergy relief.

A review in the Cochrane Library suggests that honey could reduce the time it takes for a burn to heal—up to four days sooner in some cases. The review included 19 studies with 2,554 participants. Although the honey treatment healed moderate burns faster than traditional dressings did, the author recommends viewing the findings with caution, since a single researcher performed all of the burn studies.

Health hazards

Botulism

Because of the natural presence of botulinum endospores in honey, children under one year of age should not be given honey. The more developed digestive system of older children and adults generally destroys the spores. Infants, however, can contract botulism from honey. Medical grade honey can be treated with gamma radiation to reduce the risk of botulinum spores being present. Gamma radiation evidently does not affect honey's antibacterial activity, whether or not the particular honey's antibacterial activity is dependent upon peroxide generation.

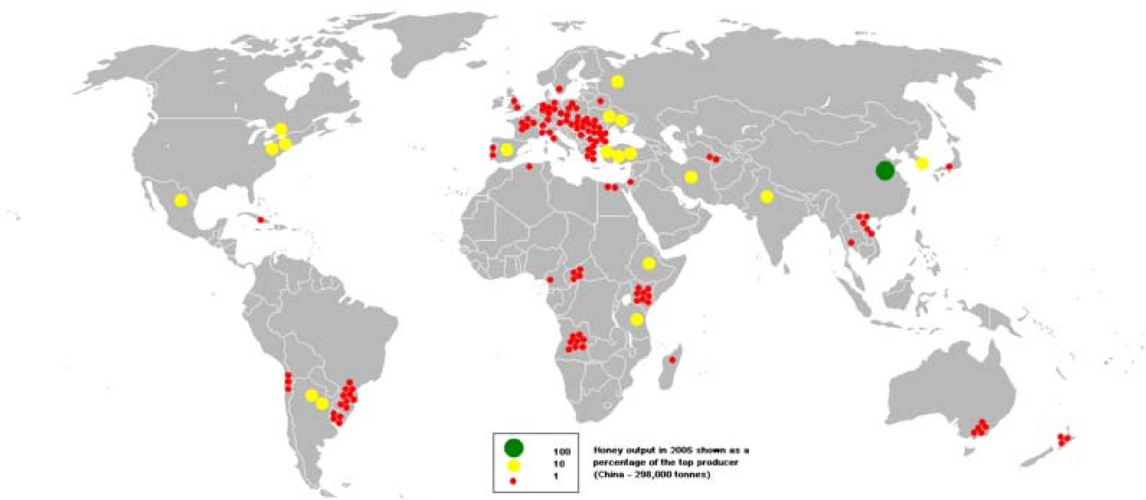
Infantile botulism shows geographical variation. In the UK, there have only been six cases reported between 1976 and 2006, yet the U.S. has much higher rates: 1.9 per 100,000 live births, 47.2% of which are in California. Although honey has been implicated as a risk factor for infection, it is household dust that is the major source of spores. Therefore the risk honey poses to infant health is small, if uncertain.

Toxic honey

Honey produced from the flowers of oleanders, rhododendrons, mountain laurels, sheep laurel, and azaleas may cause honey intoxication. Symptoms include dizziness, weakness, excessive perspiration, nausea, and vomiting. Less commonly, low blood pressure, shock, heart rhythm irregularities, and convulsions may occur, with rare cases resulting in death. Honey intoxication is more likely when using "natural" unprocessed honey and honey from farmers who may have a small number of hives. Commercial processing, with pooling of honey from numerous sources, generally dilutes any toxins.

Toxic honey may also result when bees are proximate to tutu bushes (*Coriaria arborea*) and the vine hopper insect (*Scolypopa australis*). Both are found throughout New Zealand. Bees gather honeydew produced by the vine hopper insects feeding on the tutu plant. This introduces the poison tutin into honey. Only a few areas in New Zealand (Coromandel Peninsula, Eastern Bay of Plenty and the Marlborough Sound) frequently produce toxic honey. Symptoms of tutin poisoning include vomiting, delirium, giddiness, increased excitability, stupor, coma, and violent convulsions. To reduce the risk of tutin poisoning, humans should not eat honey taken from feral hives in the risk areas of New Zealand. Since December 2001, New Zealand beekeepers have been required to reduce the risk of producing toxic honey by closely monitoring tutu, vine hopper, and foraging conditions within 3 km of their apiary.

Honey producing countries



Honey output in 2005

In 2005, China, Argentina, Turkey and the United States were the top producers of natural honey, reports the Food and Agriculture Organization of the United Nations (FAO).

Significant regional producers of honey include Turkey (ranked 3rd worldwide) and Ukraine (ranked 5th worldwide). Mexico is also an important producer of honey, providing about 10% of the world's supply. Much of this (about one-third) comes from the Yucatán Peninsula. Honey production began there when the *Apis mellifera* and the *A. mellifer ligustica* were introduced there early in the 20th century. Most of Mexico's Yucatán producers are small, family operations who use original traditional techniques, moving hives to take advantage of the various tropical and subtropical flowers.

Honey is also one of the gourmet products of the French island of Corsica. Corsican honey is certified as to its origin (Appellation d'origine contrôlée) just as are French wines, like Champagne. Homolje honey (eastern Serbia) is certified as to its origin.

Modern beehives

Smoking the hive

Using a blower to remove bees from honey prior to removal to honey house

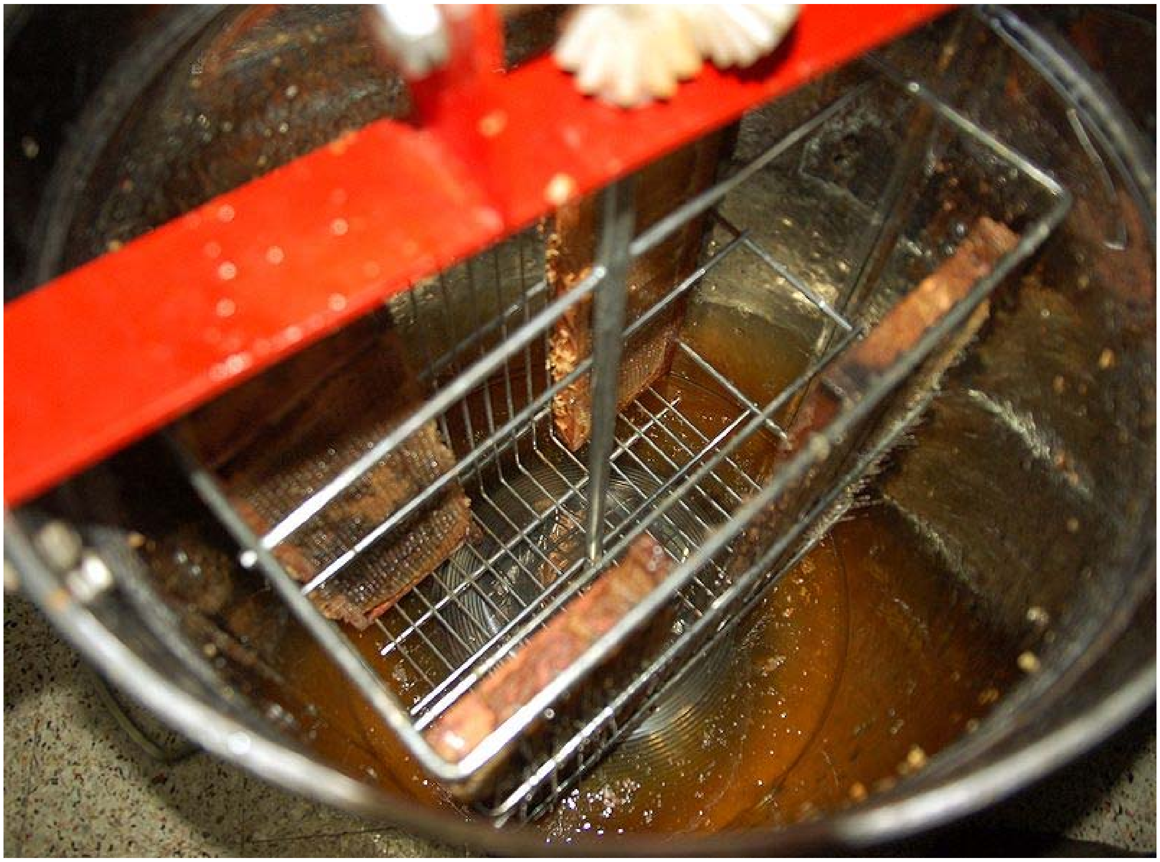
A beekeeper removing frames from the hive

A capped honey super frame

Opening the cells: Uncapping

An uncapping fork

Uncapping the cells by hand using an uncapping knife



Extracting the honey

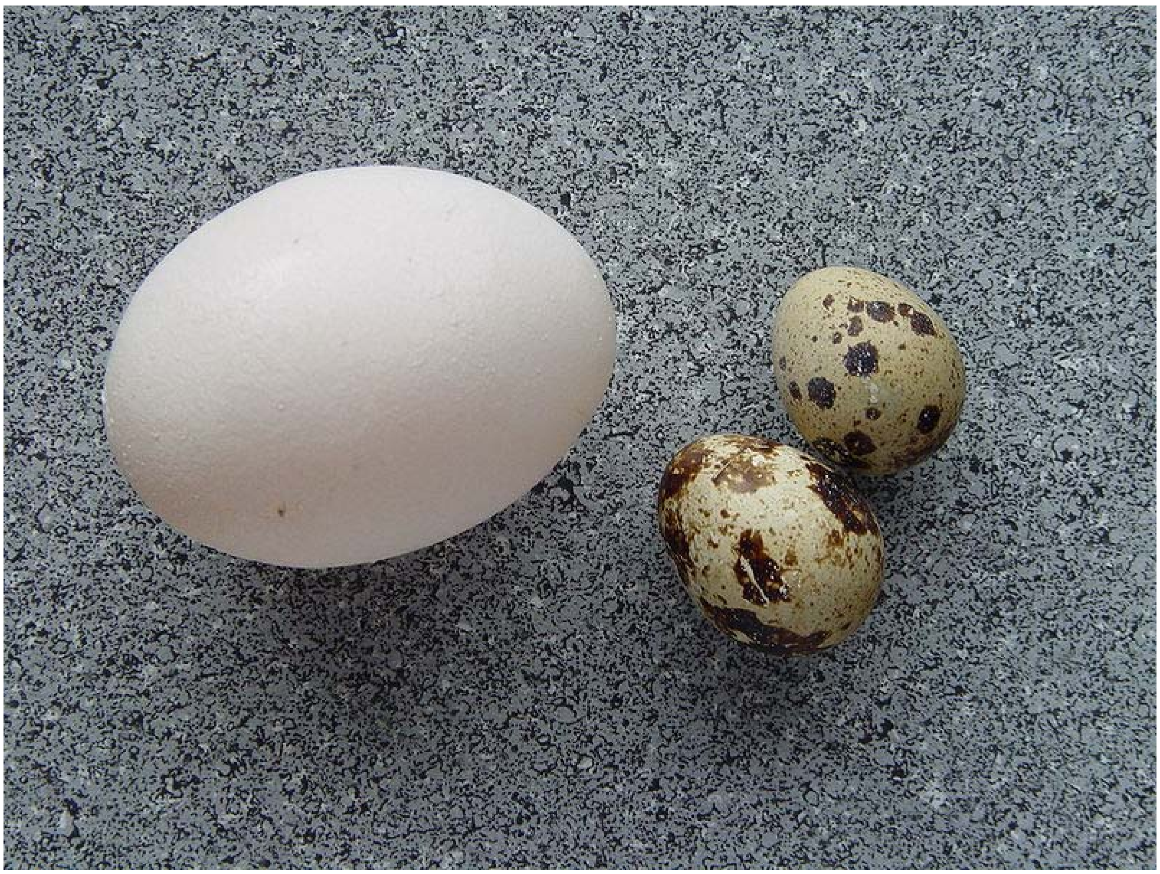
Filtering the honey

Pouring in pots

View Honey Al Jabal Alkhdar near the city of Al Bayda, Libya

Chapter 12

Egg (Food)



On the left a chicken egg, the egg most commonly eaten by humans, and on the right two quail eggs

Eggs laid by females of many different species, including birds, reptiles, amphibians, and fish, have probably been eaten by mankind for millennia. Bird and reptile eggs consist of a protective eggshell, albumen (egg white), and vitellus (egg yolk), contained within various thin membranes.

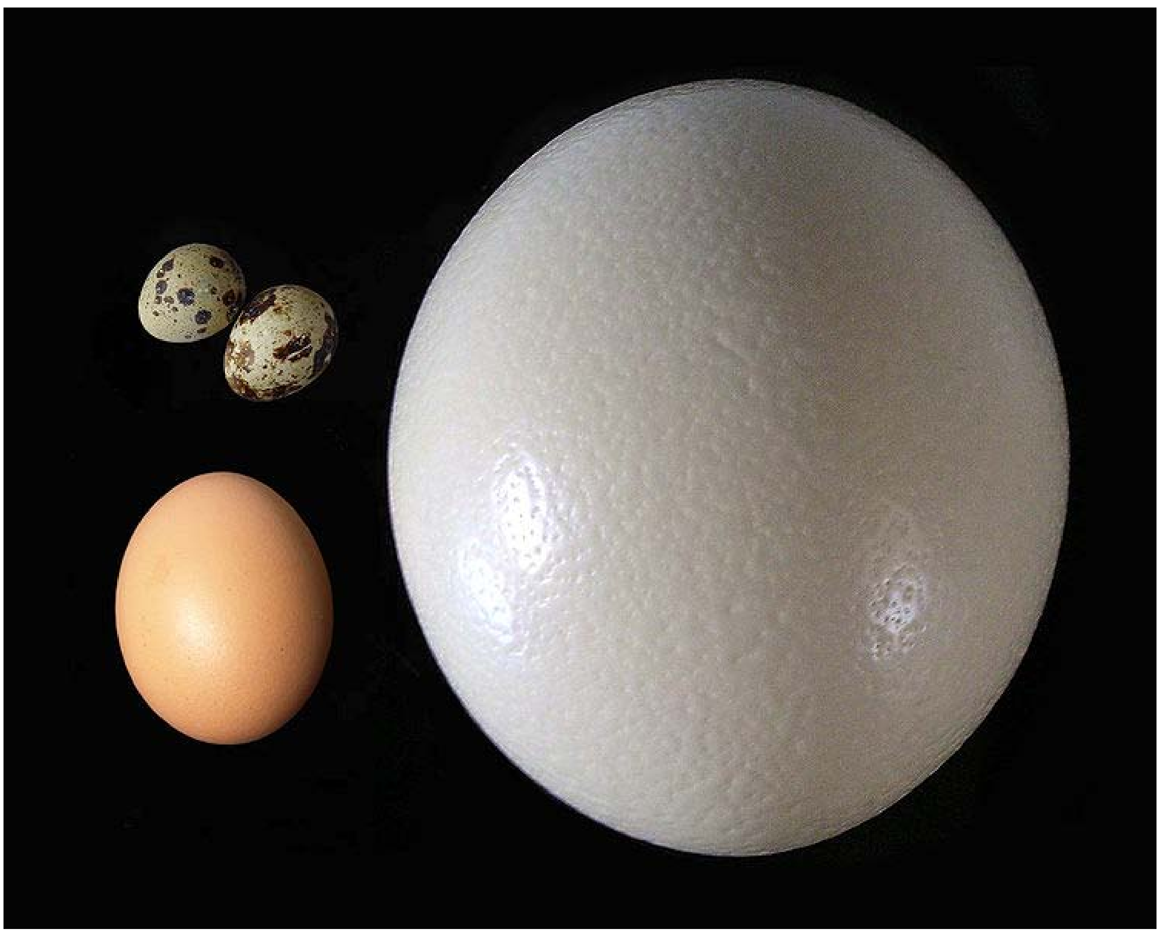
Egg yolks and whole eggs store a lot of protein and choline. For this reason, the USDA (United States Department of Agriculture) categorizes eggs as *Meats* within the Food Guide Pyramid.

Popular choices for egg consumption are chicken, duck, roe, and caviar. The egg most often humanly consumed by far is the produce of the chicken.

Production

Most commercially produced chicken eggs intended for human consumption are unfertilized, since the laying hens are kept without roosters. Fertile eggs can be purchased and eaten as well, with little nutritional difference. Fertile eggs will not contain a developed embryo, as refrigeration prohibits cellular growth for an extended amount of time (although sometimes the embryo is allowed to develop on purpose, as in balut).

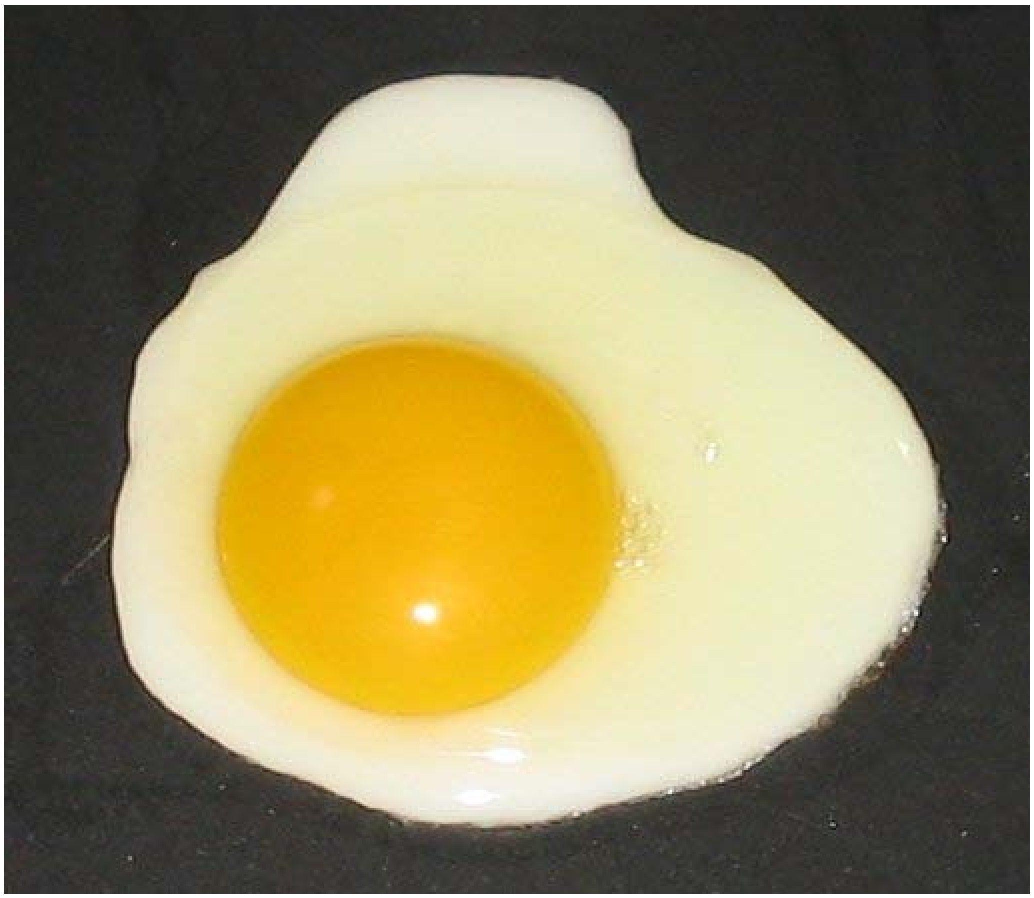
Varieties



Ostrich egg (right), compared to chicken egg (lower left) and quail eggs (upper left)

Bird eggs are a common food and one of the most versatile ingredients used in cooking. They are important in many branches of the modern food industry. The most commonly used bird eggs are those from the chicken. Duck and goose eggs, and smaller eggs such as quail eggs are occasionally used as a gourmet ingredient, as are the largest bird eggs, from ostriches. Gull eggs are considered a delicacy in England, as well as in some Scandinavian countries, particularly in Norway. In some African countries, guineafowl eggs are commonly seen in marketplaces, especially in the spring of each year. Pheasant eggs and emu eggs are perfectly edible but less widely available. Sometimes they are obtainable from farmers, poulterers, or luxury grocery stores. Most wild birds' eggs are protected by laws in many countries, which prohibit collecting or selling them, or permit these only during specific periods of the year.

Uses



A fried chicken egg, "sunny side up".

Chicken eggs are widely used in many types of dishes, both sweet and savory, including many baked goods. Eggs can be scrambled, fried, hard-boiled, soft-boiled, pickled, and refrigerated. They can also be eaten raw, though this is not recommended for people who may be especially susceptible to salmonella, such as the elderly, the infirm, or pregnant women. In addition, the protein in raw eggs is only 51% bio-available, whereas that of a cooked egg is nearer 91% bio-available, meaning the protein of cooked eggs is nearly twice as absorbable as the protein from raw eggs. As an ingredient, egg yolks are an important emulsifier in the kitchen, and the proteins in egg white allow it to form foams and aerated dishes.

Soft-boiled quail eggs, with potato galettes

The albumen, or egg white, contains protein but little or no fat, and can be used in cooking separately from the yolk. Egg whites may be aerated or whipped to a light, fluffy consistency and are often used in desserts such as meringues and mousse. Ground egg shells are sometimes used as a food additive to deliver calcium. Every part of an egg is edible, although the eggshell is generally discarded.

Flavor

Although the age of the egg and the conditions of its storage have a greater influence, the bird's diet does affect the flavor of the egg. For example, when a brown-egg chicken breed eats rapeseed or soy meals, its intestinal microbes metabolize them into fishy-smelling triethylamine, which ends up in the egg. The unpredictable diet of free-range hens will produce unpredictable eggs.

Cooking

Shopping for chicken eggs in a grocery store.

Egg white coagulates, or solidifies, when it reaches temperatures between 144 °F and 149 °F (62.2 °C-65 °C). Egg yolk coagulates at slightly higher temperatures, between 149 °F and 158 °F (65 °C-70 °C).

If a boiled egg is overcooked, a greenish ring sometimes appears around egg yolk. This is a manifestation of the iron and sulfur compounds in the egg. It can also occur when there is an abundance of iron in the cooking water. The green ring does not affect the egg's taste; overcooking, however, harms the quality of the protein Chilling the egg for a few minutes in cold water until the egg is completely cooled prevents the greenish "ring" from forming on the surface of the yolk.

Cooking also increases the risk of atherosclerosis due to increased oxidization of the cholesterol contained in the egg yolk.

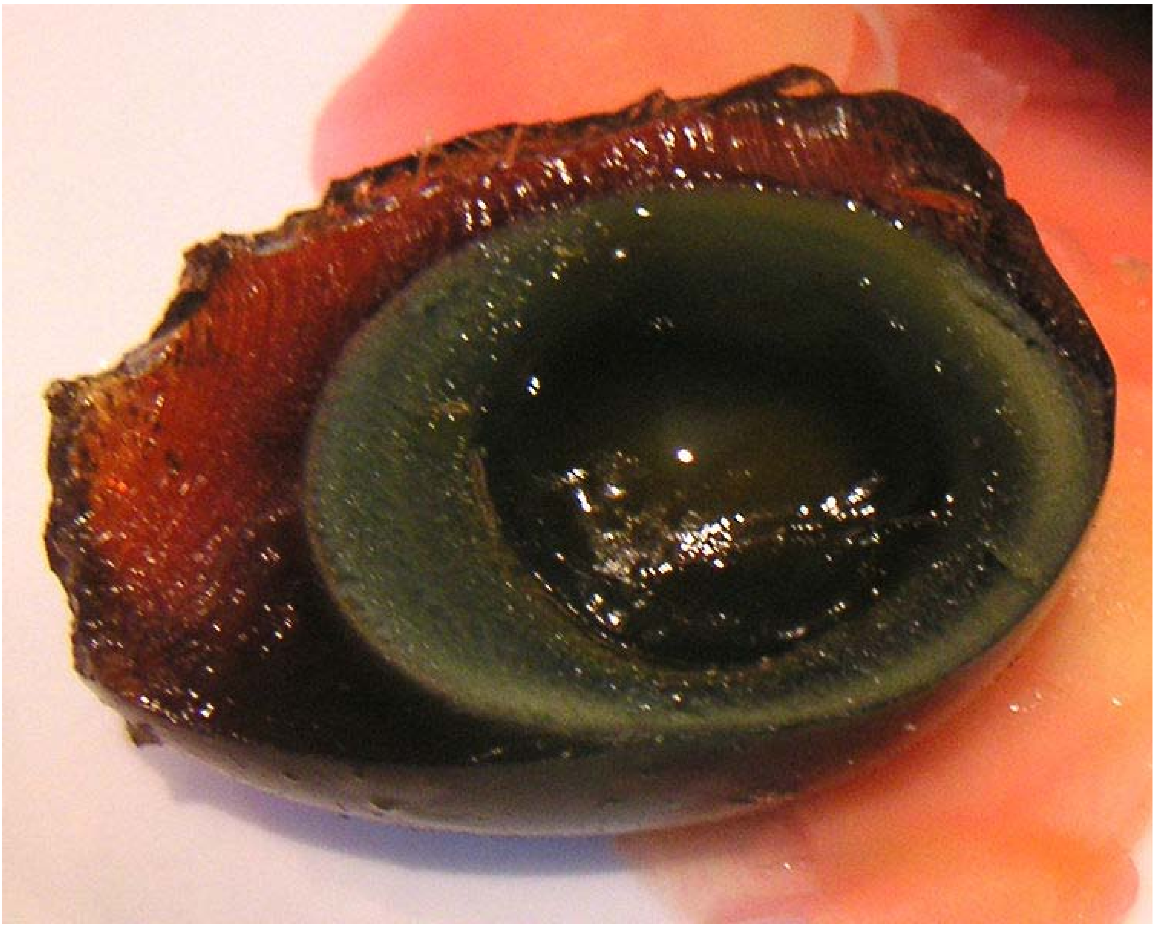
Preservation

Salted duck egg

Careful preservation of edible eggs is extremely important, as an improperly handled egg can contain elevated levels of *Salmonella*, bacteria that can cause severe food poisoning. The simplest method to preserve an egg is to treat it with salt. Salt draws water out of bacteria and molds, which prevents their growth. The Chinese salted duck egg is made by immersing duck eggs in brine, or coating them individually with a paste of salt and mud or clay. The eggs stop absorbing salt after about a month, having reached chemical equilibrium. Their yolks take on an orange-red color and solidify, but the white remains liquid. They are boiled before consumption and often served with rice congee.

Pickled egg, colored with beetroot juice

Another method is to make pickled eggs, by boiling them first and immersing them in a mixture of vinegar, salt, and spices like ginger or allspice. Frequently, beetroot juice is added to impart a red color to the eggs. If the eggs are immersed in it for a few hours, the distinct red, white, and yellow colors can be seen when the eggs are sliced. If marinated for several days or more, the red color will reach the yolk. If the eggs are marinated in the mixture for several weeks or more, the vinegar will dissolve much of the shell's calcium carbonate and penetrate the egg, making it acidic enough to inhibit the growth of bacteria and molds. Pickled eggs made this way will generally keep for a year or more without refrigeration.



Century egg

A century egg or hundred-year-old egg is preserved by coating an egg in a mixture of clay, wood ash, salt, lime, and rice straw for several weeks to several months, depending on the method of processing. After the process is completed, the yolk becomes a dark green, cream-like substance with a strong odor of sulfur and ammonia, while the white becomes a dark brown, transparent jelly with a comparatively mild, distinct flavor. The transforming agent in a century egg is its alkaline material, which gradually raises the pH of the egg from around 9 to 12 or more. This chemical process breaks down some of the complex, flavorless proteins and fats of the yolk into simpler, flavorful ones, which in some way may be thought of as an "inorganic version" of fermentation.

Substitutes

For those who do not consume eggs, alternatives used in baking include other rising agents or binding materials, such as ground flax seeds or potato starch flour. Tofu can also act as a partial binding agent, since it is high in lecithin due to its soy content. Applesauce can be used, as well as arrowroot and banana. Extracted soybean lecithin, in turn, is often used in packaged foods as an inexpensive substitute for egg-derived lecithin.

Other egg substitutes are made from just the white of the egg for those who worry about the high cholesterol and fat content in eggs. These products usually have added vitamins and minerals as well as vegetable-based emulsifiers and thickeners such as xanthan gum or guar gum. These allow the product to maintain the nutrition and several culinary properties of real eggs, making possible foods like Hollandaise sauce, custard, mayonnaise, and most baked goods with these substitutes.

History

Bird eggs have been valuable foodstuff since prehistory, in both hunting societies and more recent cultures where birds were domesticated. The chicken was probably domesticated for its eggs from jungle fowl native to tropical and subtropical Southeast Asia and India before 7500 BCE. Chickens were brought to Sumer and Egypt by 1500 BCE, and arrived in Greece around 800 BCE, where the quail had been the primary source of eggs. In Thebes, Egypt, the tomb of Haremhab, built about 1420 BCE, shows a depiction of a man carrying bowls of ostrich eggs and other large eggs, presumably those of the pelican, as offerings. In ancient Rome, eggs were preserved using a number of methods, and meals often started with an egg course. The Romans crushed the shell in their plate to prevent evil spirits from hiding there. In the Middle Ages, eggs were forbidden during Lent because of their richness. It is possible that the word *mayonnaise* was derived from *moyeu*, the medieval French word for the yolk meaning *center* or *hub*.

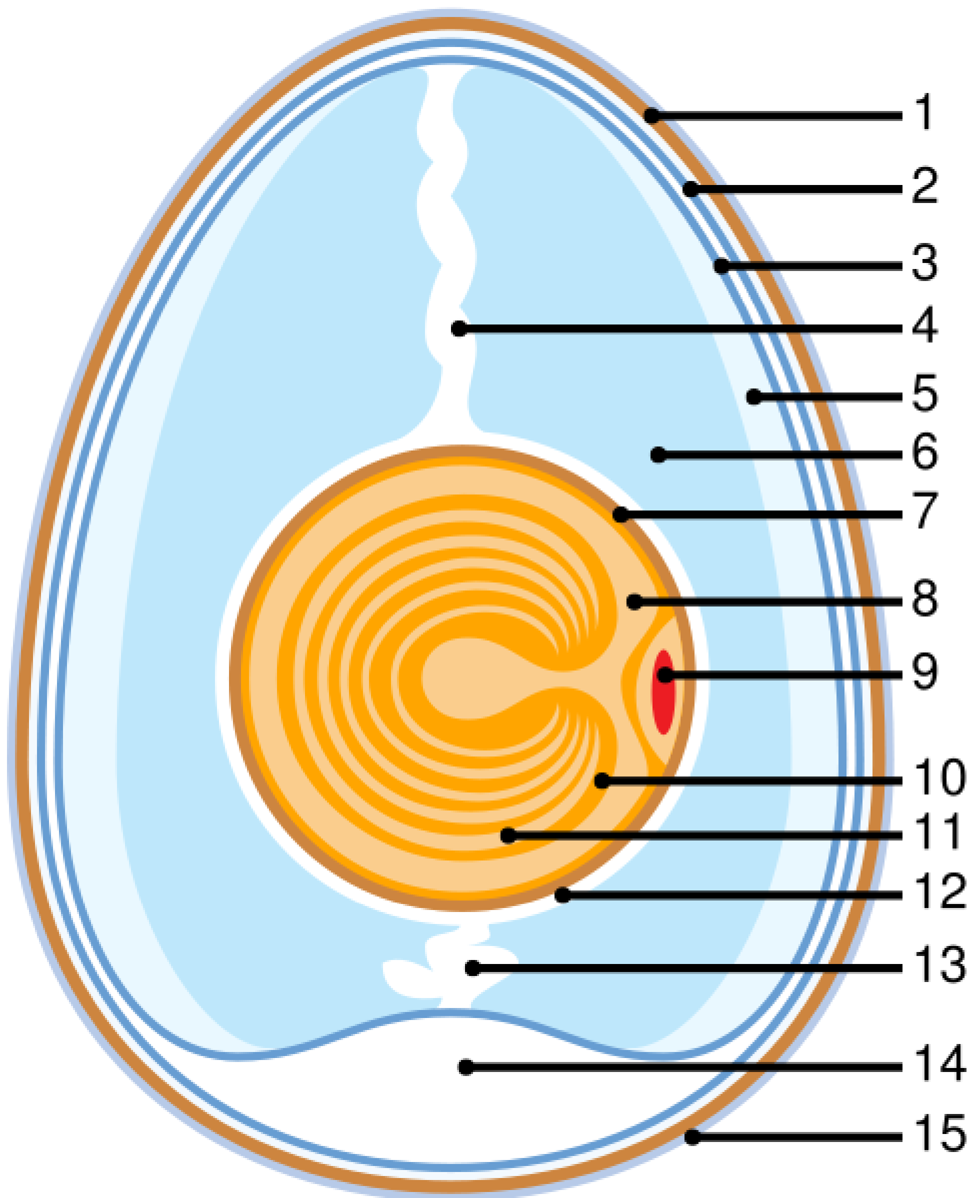
Egg scrambled with acidic fruit juices were popular in France in the 17th century; this may have been the origin of lemon curd.

The dried egg industry developed in the 19th century, before the rise of the frozen egg industry. In 1878, a company in St. Louis, Missouri started to transform egg yolk and white into a light-brown, meal-like substance by using a drying process. The production of dried eggs significantly expanded during World War II, for use by the United States Armed Forces and its allies.

The egg carton was invented by Joseph Coyle in Smithers, British Columbia, to solve a dispute about broken eggs between a farmer in Bulkley Valley and the owner of the Aldermere Hotel. Early egg cartons were made of paper.

Anatomy and characteristics

A raw chicken egg with the shell removed by soaking in vinegar



Schematic of a chicken egg:
1. Eggshell
2. Outer membrane
3. Inner membrane
4. Chalaza
5. Exterior albumen
6. Middle albumen
7. Vitelline membrane
8. Nucleus of pander
9. Germinal disc (nucleus)
10. Yellow yolk
11. White yolk
12. Internal albumen

13. Chalaza
14. Air cell
15. Cuticula

The shape of an egg is an ovate spheroid with one end larger than the other end. The egg has cylindrical symmetry along the long axis.

An egg is surrounded by a thin, hard shell. Inside, the egg yolk is suspended in the egg white by one or two spiral bands of tissue called the chalazae (from the Greek word *khalazi*, meaning hailstone or hard lump.)

Air cell

The larger end of the egg contains the air cell that forms when the contents of the egg cool down and contract after it is laid. Chicken eggs are graded according to the size of this air cell, measured during candling. A very fresh egg has a small air cell and receives a grade of AA. As the size of the air cell increases, and the quality of the egg decreases, the grade moves from AA to A to B. This provides a way of testing the age of an egg: as the air cell increases in size, the egg becomes less dense and the larger end of the egg will rise to increasingly shallower depths when the egg is placed in a bowl of water. A very old egg will actually float in the water and should not be eaten.

Shell

Egg shell color is caused by pigment deposition during egg formation in the oviduct and can vary according to species and breed, from the more common white or brown to pink or speckled blue-green. In general, chicken breeds with white ear lobes lay white eggs, whereas chickens with red ear lobes lay brown eggs. Although there is no significant link between shell color and nutritional value, there is often a cultural preference for one color over another. For example, in most regions of the United States, chicken eggs are generally white; while in the northeast of that country, and in countries as diverse as Costa Rica, Ireland, and the United Kingdom, they are generally light-brown. In Brazil and Poland, white chicken eggs are generally regarded as industrial, and brown or reddish ones are preferred.

Yolk

The yolk in a newly laid egg is round and firm. As the yolk ages it absorbs water from the albumen, which increases its size and causes it to stretch and weaken the vitelline membrane (the clear casing enclosing the yolk). The resulting effect is a flattened and enlarged yolk shape.

Yolk color is dependent on the diet of the hen; if the diet contains yellow/orange plant pigments known as xanthophylls, then they are deposited in the yolk, coloring it. Lutein is the most abundant pigment in egg yolk. A colorless diet can produce an almost colorless yolk. Yolk color is for example enhanced if the diet includes products such as yellow corn and marigold petals. In the US, the use of artificial color additives is forbidden.

Abnormalities

Nutritional value

Chicken egg, whole, hard-boiled

Nutritional value per 100 g (3.5 oz)

Energy	647 kJ (155 kcal)
Carbohydrates	1.12 g
Fat	10.6 g
Protein	12.6 g
Tryptophan	0.153 g
Threonine	0.604 g
Isoleucine	0.686 g
Leucine	1.075 g
Lysine	0.904 g
Methionine	0.392 g
Cystine	0.292 g
Phenylalanine	0.668 g
Tyrosine	0.513 g
Valine	0.767 g
Arginine	0.755 g
Histidine	0.298 g
Alanine	0.700 g
Aspartic acid	1.264 g
Glutamic acid	1.644 g
Glycine	0.423 g
Proline	0.501 g
Serine	0.936 g
Water	75 g
Vitamin A equiv.	140 µg (16%)

Thiamine (Vit. B_1)	0.066 mg (5%)
Riboflavin (Vit. B_2)	0.5 mg (33%)
Pantothenic acid (B_5)	1.4 mg (28%)
Folate (Vit. B_9)	44 μg (11%)
Calcium	50 mg (5%)
Iron	1.2 mg (10%)
Magnesium	10 mg (3%)
Phosphorus	172 mg (25%)
Potassium	126 mg (3%)
Zinc	1.0 mg (10%)
Choline	225 mg
Cholesterol	424 mg

Eggs add protein to a person's diet, as well as various other nutrients.

Chicken eggs are the most commonly eaten eggs. They supply all essential amino acids for humans, and provide several vitamins and minerals, including vitamin A, riboflavin (vitamin B_2), folic acid (vitamin B_9), vitamin B_6, vitamin B_{12}, choline, iron, calcium, phosphorus and potassium. They are also a single-food source of protein.

All of the egg's vitamin A, D, and E are in the egg yolk. The egg is one of the few foods that naturally contain vitamin D. A large egg yolk contains approximately 60 Calories (250 kilojoules); the egg white contains about 15 Calories (60 kilojoules). A large yolk contains more than two-thirds of the recommended daily intake of 300 mg of cholesterol (although one study indicates that the human body may not absorb much cholesterol from eggs). The yolk makes up about 33% of the liquid weight of the egg. It contains all of the fat, slightly less than half of the protein, and most of the other nutrients. It also contains all of the choline, and one yolk contains approximately half of the recommended daily intake. Choline is an important nutrient for development of the brain, and is said to be important for pregnant and nursing women to ensure healthy fetal brain development.

The diet of the laying hens can greatly affect the nutritional quality of the eggs. For instance, chicken eggs that are especially high in omega 3 fatty acids are produced by feeding laying hens a diet containing polyunsaturated fats and kelp meal. Pastured raised free-range hens which forage largely for their own food also tend to produce eggs with higher nutritional quality in having less cholesterol and fats while being several times higher in vitamins and omega 3 fatty acids than standard factory eggs Focusing on the protein and crude fat content, a 2010 USDA study determined that there were no significant differences of these two macronutrients in consumer chicken eggs.

Cooked eggs are easier to digest, as well as having a lower risk of salmonellosis.

Health issues

Cholesterol and fat

More than half the calories found in eggs come from the fat in the yolk; a large (50 gram) chicken egg contains approximately 5 grams of fat. People on a low-cholesterol diet may need to reduce egg consumption; however, only 27% of the fat in egg is saturated fat (palmitic, stearic and myristic acids) that contains LDL cholesterol. The egg white consists primarily of water (87%) and protein (13%) and contains no cholesterol and little, if any, fat.

There is debate over whether egg yolk presents a health risk. Some research suggests dietary cholesterol increases the ratio of total to HDL cholesterol and, therefore, adversely affects the body's cholesterol profile; whereas other studies show that moderate consumption of eggs, up to one a day, does not appear to increase heart disease risk in healthy individuals. Harold McGee argues that the cholesterol in the yolk is not what causes a problem, because fat (in particular, saturated) is much more likely to raise cholesterol levels than the actual consumption of cholesterol. A 2007 study of nearly 10,000 adults demonstrated no correlation between moderate (6 per week) egg consumption and cardiovascular disease or strokes except in the sub-population of diabetic patients that presented an increased risk of coronary heart disease. Other research supports the idea that a high egg intake increases cardiovascular risk in diabetic patients.

Type 2 diabetes

Consumption of eggs has been linked to an increased risk of type 2 diabetes in both men and women. A 2008 study using data on over 50,000 individuals collected by the Physicians' Health Study I (1982–2007) and the Women's Health Study (1992–2007) determined that the “data suggest that high levels of egg consumption (daily) are associated with an increased risk of type 2 diabetes.” However, a study published in 2010 found no link between egg consumption and type 2 diabetes.

Contamination

Egg cleaning on a farm in in Norway

A health issue associated with eggs is contamination by pathogenic bacteria like *Salmonella enteritidis*. Contamination of eggs exiting a female bird via the cloaca may also occur with other members of the *Salmonella* genus, so care must be taken to prevent the egg shell from becoming contaminated with fecal matter. In commercial practice, eggs are quickly washed with a sanitizing solution within minutes of being laid. The risk of infection from raw or undercooked eggs is dependent in part upon the sanitary conditions under which the hens are kept.

Health experts advise people to refrigerate eggs, use them within two weeks, cook them thoroughly, and never consume raw eggs. As with meat, containers and surfaces that have been used to process raw eggs should not come in contact with ready-to-eat food.

A study by the U.S. Department of Agriculture in 2002 (Risk Analysis April 2002 22(2):203-18) suggests the problem is not as prevalent as once thought. It showed that of the 69 billion eggs produced annually, only 2.3 million are contaminated with *Salmonella* — equivalent to just one in every 30,000 eggs — thus showing that *Salmonella* infection is quite rarely induced by eggs. However, this has not been the case in other countries where *Salmonella enteritidis* and *Salmonella typhimurium* infections due to egg consumptions are major concerns. Egg shells act as hermetic seals that guard against bacteria entering, but this seal can be broken through improper handling or if laid by unhealthy chickens. Most forms of contamination enter through such weaknesses in the shell. In the UK, the British Egg Industry Council award the lions stamp to eggs that, among other things, come from hens that have been vaccinated against *Salmonella*.

Food allergy

One of the most common food allergies in infants is eggs. Infants usually have the opportunity to grow out of this allergy during childhood, if exposure is minimized. Allergic reactions against egg white are more common than reactions against egg yolks.

In addition to true allergic reactions, some people experience a food intolerance to egg whites.

Food labeling practices in most developed countries now include eggs, egg products and the processing of foods on equipment that also process foods containing eggs in a special allergen alert section of the ingredients on the labels.

Antibiotic resistance

Information obtained by the Canadian Integrated Program for Antimicrobial Resistance (CIPARS) “strongly indicates that cephalosporin resistance in humans is moving in lockstep with use of the drug in poultry production.” According to the Canadian Medical Association Journal, the unapproved antibiotic ceftiofur is routinely injected into eggs in Quebec and Ontario to discourage infection of hatchlings. Although the data are contested by the industry, antibiotic resistance in humans appears to be directly related to the antibiotic's use in eggs.

Chicken egg grading

The US Department of Agriculture grade eggs by the interior quality of the egg and the appearance and condition of the egg shell. Eggs of any quality grade may differ in weight (size).

- U.S. Grade AA eggs have whites that are thick and firm; yolks that are high, round, and practically free from defects; and clean, unbroken shells. Grade AA and Grade A eggs are best for frying and poaching, where appearance is important.
- U.S. Grade A eggs have characteristics of Grade AA eggs except the whites are "reasonably" firm. This is the quality most often sold in stores.
- U.S. Grade B eggs have whites that may be thinner and yolks that may be wider and flatter than eggs of higher grades. The shells must be unbroken, but may show slight stains. This quality is seldom found in retail stores because they are usually used to make liquid, frozen, and dried egg products, as well as other egg-containing products.

In other countries, such as Australia and European Union countries, eggs are graded by the hen farming method instead, e.g., from free range hens, battery cages, etc.

Chicken eggs are also graded by size, for the purpose of sales.

Issues in mass production

Commercial factory farming operations often involve raising the hens in small crowded cages, preventing the chickens from engaging in natural behaviors such as wing-flapping, dust-bathing, scratching, pecking, perching and nest-building. Such restrictions can lead to pacing and escape behavior.

Many hens confined to battery cages, and some raised in cage-free conditions, are de-beaked to prevent harming each other and cannibalism. According to critics of the practice, this can cause hens severe pain to the point where some may refuse to eat and starve to death. Some hens may be force molted to increase egg quality and production level after the molting. Molting can be induced by extended feed withdrawal, water withdrawal or controlled lighting programs.

Laying hens are often slaughtered between 100–130 weeks of age, when their egg productivity starts to decline. Due to modern selective breeding, laying hen strains differ from meat production strains. As male birds of the laying strain do not lay eggs and are not suitable for meat production, they are generally culled at the hatchery.

Free-range eggs are considered by some advocates to be an acceptable substitute to factory-farmed eggs. Free-range laying hens are given outdoor access instead of being contained in crowded cages. Questions on the actual living conditions of free-range hens have been raised, as there is no legal definition or regulations for eggs labeled as free-range in the US.

In the US, increased public concern for animal welfare has pushed various egg producers to release eggs under a variety of different standards. The most widespread standard in use is used by United Egg Producers and is a volunteer program known as *United Egg Producers Certified* (UEP Certified). The program includes guidelines with regard to housing, feed, water, air, space allowance, beak trimming, molting, handling, and transportation; however, critics such as The Humane Society have alleged UEP Certification misleadingly allows for a significant amount of animal cruelty. Other standards include "Cage Free", "Natural", "Certified Humane", and "Certified Organic." Of these standards, "Certified Humane", which carries requirements for stocking density and cage-free keeping, among others, and "Certified Organic", which requires hens have outdoor access and are fed only organic, vegetarian feed, among other requirements, are the most stringent.

The European Union will introduce an EU-wide ban on the use of conventional battery cages for egg-laying hens. This ban is expected to come into effect from 1 January 2012, as per EU Directive 1999/74/EC. The EU will instead permit the use of "enriched" cages that must meet certain space and amenity requirements. Egg producers in many member states have objected to the ban.