Economic Botany & Pharmacognosy and Ethnobotany

(BSCHBOTC402, BSCHBOTSEC302 & BSCPBOTSEC301):

Historically, botany and medicine were closely allied subjects as most medicines were herbal, using plant materials to supply medicinally active drugs. The earliest botanic gardens were dedicated to the production of plants with medicinal properties. Human beings have used plants as medicines for millennia and there is a rapidly growing interest in identifying medicinally active plant products. This involves everything from learning about traditional medicines to the assessment of crops and native floras for the production of new medicines. The study of **ethnobotany**, the study of plant species and their uses in indigenous societies, has been inspired by awareness of rapid loss of species diversity and of the importance of plant derived drugs. Ethnobotany seeks to record the uses of plants by societies and wherever possible, to conserve those species for future use.

Ethnobotany is the science of the relationship between the chemical constituents and properties of native species of plants and their uses by indigenous peoples. As plants contain a wide range of different, biologically active secondary metabolites, the discovery of compounds new to western medicine is an important aspect of this science.

Glycosides

The cardiac glycosides or carnolides based on digitoxin and digoxin inhibit the heart Na+/K+-pump. Applied at appropriate dose, they stabilize the heart rhythm and are used to treat heart failure and similar conditions.

Alkaloids

Alkaloids are a wide range of compounds with many applications. The quinoline alkaloid quinine, the isoquinolines morphine and codeine, and the indole alkaloids vinblastine and vincristine, are all widely used medicinals.

Terpenes

The terpene taxol, from the bark of the Pacific yew, stabilizes microtubules and thereby inhibits cell division in tumor cells. It is therefore a potent chemotherapy agent in cancer treatment.

Medicines based on plant products include many different compounds with many different uses. The **cardiac glycosides**, based on the compound**digitonin** from foxglove (*Digitalis purpurea*) are widely used to treat heart disease. Drugs based on the plant **alkaloids**, the **opiates**, derived from the opium poppy (*Papaver somniferum*) are

amongst the most effective pain-relievers known. Many **anti-cancer agents** such as **taxol** (derived from the pacific yew, *Taxus brevifolia*)and **vincristine** and **vinblastine** (derived from the periwinkle, *Vinca rosea*) are also plant products. Plant-derived medicinal compounds are plant secondary products.

Glycosides

Glycosides are a very diverse group of compounds. The **cardiac glycosides** (or **cardenolides**) contain sugar residues bonded to sterols; in one example (**digitoxin**, from the foxglove *Digitalis purpurea*), the sugar residues are one glucose molecule, two digitoxose molecules and one molecule of 1-acetyl digitoxose. Digitoxose is a rare 6-carbon sugar. A second cardiac glycoside, **digoxin** is alsopresent in the foxglove.

Cardiac glycosides are extremely toxic compounds that inhibit the heart Na+/K+-pump. At a suitable dose, they slow and strengthen the rhythm of the heart and are very effective in the treatment of heart failure and other heart conditions.

Alkaloids

Alkaloids are also a diverse group of compounds, all of which contain nitrogen, usually as part of a heterocyclic ring. They are synthesized from amino acids. Many alkaloids are extremely poisonous; others, including **codeine** and **morphine** are very effective **pain killers**, while others are addictive drugs (nicotine, cocaine). *Table 1* presents some of the alkaloids and their effects.

Terpenes

Terpenes are synthesized either from acetyl coenzyme A (CoA) or from 3-phosphoglycerate and pyruvate and are based on the 5-carbon isoprene unit . Complex terpenes are generally believed to be anti-herbivory defenses in plants; however, amongst the very diverse range of terpenes are **essential oils** such as the **menthols** (used as insect repellants and in proprietry remedies for colds and coughs). The most significant medicinal terpene of recent years has been the diterpene **taxol**, isolated initially from the bark of the **Pacific yew**, *Taxus brevifiolia*. Taxol causes a blockage of cell division in tumor cells by stabilizing and polymerizing microtubules. Taxol is effective against solid tumors. Its initial discovery led to a considerable effort to secure sufficient supplies of the compound, as its production (like

many plant secondary products) is limited to one tissue (the bark) of a single species. Application of plant tissue culture was less successful than attempts at organic (chemical) synthesis and taxol-based drugs are now produced by this means.

PLANTS AS FOOD

The range of food crops

Numerous species are edible but we rely on only 20 species for 90% of our plant food and wheat, rice and maize for over half. Seeds and roots or tubers, mainly providing starch, are the staple plant foods. Leaf crops provide mainly vitamins and roughage and some seeds and fruits are rich in protein or fat.

Origin of staple crops

Wheat, oats and barley all originate in south-west Asia and were the main crops of the earliest civilizations. Rice comes from China and maize from Mexico. Ephemeral grasses have many qualities suitable for cultivation such as self-fertility, easy germination and quick growth. Certain regions of the world have been the sources of many crops.

Potatoes originate in the Andes and needed much selection to be suitable for long days. Cassava is from lowland South America and other staple grain and root crops come from various tropical areas. Most of these crops have reached their present form through hybridization of related species and often polyploidy, and there are many varieties.

Other food crops

Brassicas all derive from a wild Mediterranean species and there are numerous crops from different areas. Breeding has often involved production of polyploids and, for example cultivated bananas are all sterile triploids. Some varieties such as pink grapefruit derive from somatic mutation.

Plants for flavour

Herbs are leaves deriving particularly from Lamiaceae of the Mediterranean. Spices belong to numerous families and derive from fruits, seeds, flower buds, roots or bark. They are mainly tropical and were much sought after for flavoring food in the early days of exploration in the 15th and 16th centuries.

Alcohol

All alcoholic beverages derive from plant sugar fermented by yeasts. Grapes, native to central Asia, provide sugar-rich fruit and have been fermented in a controlled way for

millennia. Germinating barley is fermented for beer and barley can tolerate short summers. Numerous other plants are used.

Crops in the twentieth century

Concentration on yield led to a reduction in the number of varieties grown in the western world. With the rise in environmental consciousness more emphasis is beginning to be placed on wild sources particularly for disease resistance. Some wild crop ancestors are rare. Destruction of the ecology of agricultural soils has resulted from monocultures with high input of fertilizer and pesticide and some areas are losing their potential for agricultural production.

The range of food crops

Plants form the bulk of our food. Many plant species are edible and prior to the advent of agriculture in the meso- to neolithic period, numerous species were eaten. One of the few remaining hunter-gatherer peoples of the world, the !Kung San (bushmen) of the Kalahari, still regularly eat over 80 species of plant native to that region and use a great many more as flavors or medicines. Throughout the world over 30 000 species of plant have some edible parts, 12% of all flowering plants, and at least 7000 have been collected or grown as food at some time. In sharp contrast, a mere 20 species currently supply 90% of the world's food and just three grass species, **wheat**, **rice** and **maize**, supply about half of it. The potential for plant foods is being seriously underutilized.

The main importance of plants as food has been as providers of **starch**, the seeds of the three staple grasses being mostly starch. Other staple crops provide starchy **tubers** (swollen underground stems) such as **potatoes**, or **roots** such as **cassava** and **yams**. Leaves, stems and flowers have much less starch but supply vital vitamins and roughage, most importantly the **brassicas** (cabbage, cauliflower, sprouts, etc). Many **fruits** are sugary energy sources. Proteins and fats are present in small quantities in some of these organs although traditionally animals have been our main sources. Some seeds are rich in proteins, particularly **beans** and **pulses** connected with the fact that their root nodules have bacteria that fix nitrogen, and certain fruits, e.g. **olive**, **avocado**, are rich in fats. Oil-rich seeds have become widely planted for margarines, animal feed and non-food uses, particularly oil-seed rape (or canola), sunflowers and flax (linseed oil). Fruits and seeds come from a wide range of woody and

herbaceous plants but, with occasional minor exceptions, all the vegetative parts of plants that we eat come from herbaceous plants.

Origin of staple crops

Wheat and barley are responsible for the rise of the first civilization in the Tigris/Euphrates valley, both species originating in the '**Fertile Crescent**' of mountains just north of it, ranging from northern Syria through Turkey to northern Iraq. The wild relatives of wheat, oats and barley are all ephemeral grasses of this region. Rice and maize also derive from ephemeral grasses, rice originating in **China** and maize in **Mexico**, these two species being responsible for the rise of the civilizations in these regions separately from that in the Fertile Crescent. Some of the features that characterize ephemeral grasses are those that make them good crop plants: many are self-fertile, guaranteeing seed set; they produce many seeds within a year of planting; they are characteristic of disturbed ground; they have no innate seed dormancy but can germinate as soon as conditions are favorable; in comparison with other grasses their seeds are large and rich in starch favoring rapid germination. It is likely that these plants were noticed as particularly good food sources and subsequently encouraged and cultivated. Before human intervention the seeds will have dropped from the stems to be dispersed, but, for humans, those that retained ripe seeds would have been easiest to gather for subsequent sowing so there will have been unconscious selection for seed retention.

Present-day wheat is derived from at least six wild species by multiple hybridizations. Natural, then artificial, hybridization and selection for large seeds made them the staple crops and 17 000 varieties have been produced. Modern bread wheat is hexaploid and hybridizations between the species have involved polyploidy at several stages . Rice and maize have fewer varieties (a few hundred), although rice derives from at least three species; maize from perhaps two.

A few particular regions of the earth, known as **Vavilov centers** , after the Russian biologist who first described them, have supplied the most useful edible plants including the grain crops. Of our other staple crops, potatoes and cassava are both South American in origin and their cultivation contributed to the rise of civilizations there 6000–7000 years ago. Potatoes came from the Andes, cassava from the lowlands. In the wild, these and other root or tuber crops have poisonous alkaloids that are often bitter

tasting; only years of selectionof less bitter varieties have led to the crops of today. In cassava toxic alkaloids remain, since methods for fermenting and cooking it that remove the toxin are well known and the toxic varieties are more resistant to pests. The potato was imported into Europe in the 16th century and, later, North America, but it did not crop well or only very late in the long days of a temperate summer. It took nearly 200 years, until the late 18th century, to develop clones that produced adequate tubers under these conditions, and these probably came from a narrow genetic base. It rapidly became a staple, but it is prone to disease, the most important being the**potato blight**, the oomycete *Phytophthora infestans*(a fungus-like member of the Protista;). This appeared in Europe in the 1840s with devastating consequences for the potato crop in Ireland, which particularly depended on it, leading to the famous famine. Much potato breeding and selection has been associated with disease resistance.

Other tropical staple crops come from the various regions, the millets and sorghum from Africa, dasheen or cocoyam from Asia, and different species of yams from all three continents Other food crops

One species of wild **cabbage**, *Brassica oleracea*, is the ancestor of all the cabbage, kale, brussels sprout, cauliflower, broccoli and kohlrabi crops. Turnips, swede and oilseed rape (canola) are closely related. The wild cabbage is widespread around the Mediterranean extending into Asia and the different cultivated types have originated in different parts of this range. Many other crops originated in this region including peas and lentils, both of which were first grown as animal feed with their nitrogen-rich foliage and later developed for human consumption.

Soya beans, regarded as one of the world's most important developingcrops because its seeds are rich in protein and oils, originated and was confined to the Far East, mainly China, until the early 20th century. There has been an enormous increase since then in the USA and elsewhere, and there have been extensive breeding programmes for its use in the short days of the tropics. Exploration of South America in the 16th to 18th centuries led to tomatoes and capsicums appearing in Europe in addition to potatoes. Cocoa, pineapples and some other tropical crops were exported from South America to other tropical colonies. South-east Asia is the native home of such pantropical crops such as bananas, sugar cane, mangoes and breadfruit, and is the center of distribution of citrus species. Apples and pears come from central Asia.

Frequently, hybridization between two or more species has resulted in varieties that are larger or more suitable for human consumption, and often polyploids. Crop **bananas** are triploid and sterile giving rise to seedless fruits that reproduce purely by clones, although all wild species are diploid.**Apples**, **pears** and **citrus fruits** are reproduced mainly by cuttings and grafts with each named variety usually being a single clone. Citrus fruits are, in addition, prone to somatic mutations, changes within the plant body that happen spontaneously without any seeds . One such mutation gave rise to the pink grapefruit, clones of which are now distributed in many areas.

Plants for flavour

A great variety of plants are used as flavorers in addition to those eaten as food crops. Culinary '**herbs**' are the leaves, usually dried, of various herbs and shrubs of several families, most importantly the Lamiaceae many of which are native to the Mediterranean, providing thyme, sage, mint, basil and others. The Apiaceae (umbellifers) provide parsley, caraway and aniseed. The aromatic oils and other compounds derived from these plants originate as secondary compounds, which protect the plants from herbivore attack owing to their indigestibility and, frequently, bitterness. In small quantities, it is this aspect that is desirable.

Spices, prized for their strong, often 'hot' taste, derive from parts of the plant other than leaves and come from a wide range of plant families. Nearly all are tropical and spices, most importantly **black pepper**, became much sought after in the 15th century. Spices were seen as highly desirable, some as mild **preservatives**, but mainly to cover the flavor of old or decaying food and they fetched extremely high prices. Columbus's voyages to America were a by-product of the search for spices. Black pepper is native to south Asia but is now planted throughout the tropics in small quantities. Black pepper is a dried fruit, and other spicy fruits and seeds include cardamoms, allspice, nutmeg and vanilla. Spices from other plant parts include ginger deriving from a root, turmeric from a rhizome, cinnamon from bark and cloves from flower buds

Alcohol

Alcoholic beverages are all made, at least initially, from the **anaerobic fermentation** of sugars by yeasts, unicellular ascomycete fungi. Most fruits and manynectar-rich flowers have yeasts occurring naturally, fermenting some of the sugar. Any animal may become **intoxicated** including bees feeding on alcoholic nectar which may then be

unable to fly, and numerous mammals that feed on fallen fermenting fruit. The two most important crops are the **grape** with its sugar-rich fruit making wines and brandy, and **barley**, whose germinating seed is rich in sugars, the basis of most beers and whiskies. Grape vines are naturally distributed from Afghanistan to the eastern Black Sea and were taken to the eastern Mediterranean 5000 years ago. When introduced outside its native range it has sometimes hybridized with related species of each region to produce new varieties suited to the area. It is naturally dioecious but most cultivated forms are hermaphrodite, an advantage as a crop since all will produce fruits. Seedless varieties, used for consumption as grapes, appeared first by somatic mutation.

Barley originated in the fertile crescent and was one of the staple crops of early civilizations. It matures quickly which makes it adaptable to short summers and is somewhat more tolerant of salt in the soil than wheat. It was formerly an important grain staple, but today it is mainly used for alcoholic drinks and animal fodder. Other grain crops such as rice and rye are used for similar drinks and many other plants are used for making alcoholic drinks including numerous fruits, potatoes (vodka) and the pith of *Agave* (tequila) and palms (arak). Some are distilled to increase alcohol content.

Crops in the twentieth century

During the last 100 years and particularly the last 50 years there has been **intensive breeding** for increased yield in many crops . In the westernworld, the advent of apparently limitless inorganic fertilizer and a great number of pesticides, along with highly selective breeding has achieved yields unimaginable in 1900. During much of this time only the highest yielding varieties were planted and, overall, there has been a serious reduction in the number of varieties. In poorer countries, including many tropical countries, breeding has been less intensive and inorganic fertilizer is not so readily available. Crops in these countries are receiving more attention since the advent of serious famines in the 1980s and 1990s, and some genetic modification is specifically targeted at tropical countries, e.g. vitamin A in rice.

With increasing **mechanization** of farming, monocultures, often over large uninterrupted areas, have become widespread. All monocultures are prone to pests and diseases and, in farming, these crops rely on the input of large quantities of pesticide. In the 1960s, the first evidence of environmental damage came to light in relation to persistent organochlorines such as DDT and they were banned in many countries, but are still used in others. Many other pesticides, including herbicides and fungicides, are

in wide use. With the rise in environmental consciousness there has been renewed interest in wild ancestors of crops where there is often genetic variation for disease resistance. These are now being used in crop breeding programmes. Some of these wild relatives have a highly restricted distribution, the most extreme example being the closest relative of maize, *Zea perennis*, found for the first time during the 1980s on a range of less than 1 hectare in Mexico.

The high-yielding varieties grown utilize many soil nutrients and to grow them for greatest yield requires high input. One tonne of grain requires about 10 kg of nitrogen, 5 kg of phosphorus and other nutrients. At present, under intensive agriculture, most of this is replaced from inorganic sources. The combination of pesticide and fertilizer input damages the ecology severely, losing the soil structure and most of its microorganisms, beneficial as well as damaging, and this will continue to be a problem under existing agricultural regimes. In environments prone to drought there have been many problems of soil loss altogether and resulting loss of possibility for growing further crops or a natural vegetation cover, and these will undoubtedly become more widespread. Throughout the history of agriculture, using the soil too heavily for crops, particularly grain, has led to infertility. In addition, a covering of plants of any kind can affect the climate locally and some climates in dry areas have become drier overall in the depleted areas. The combination of lowered soil fertility and a drier climate has allowed deserts to spread.