A **grain** or **caryopsis** is a seed or a seed-like fruit of plants, particularly members of the grass family, **Poaceae**.

These fruits are unique because their seed coats are completely fused to the ovary walls.

**Cereals** are edible grains produced by annual grasses.

The word **cereal** is derived from the name of the Roman goddess of agriculture, **Ceres**.

Cereal grains were some of the first cultivated crops.

The grass family contains more than 10,500 species distributed worldwide.

Only 35 have been cultivated as cereals.

### TABLE 6.1 Major Grains of the Old World

<table>
<thead>
<tr>
<th>COMMON NAME</th>
<th>SPECIES</th>
<th>NATIVE REGION</th>
<th>FAMILY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>Hordeum vulgare</td>
<td>Southwest Asia</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Buckwheat</td>
<td>Fagopyrum esculentum</td>
<td>China</td>
<td>Polygonaceae</td>
</tr>
<tr>
<td>Goat grass</td>
<td>Triticum speltoides</td>
<td>Southwest Asia</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Millet</td>
<td>Panicum miliaceum</td>
<td>China</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Broomcorn</td>
<td>Elymus coracanum</td>
<td>Africa</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Finger</td>
<td>Setaria italica</td>
<td>China</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Foxtail</td>
<td>Pennisetum glaucum</td>
<td>Africa</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Pearl</td>
<td>Avena sativa</td>
<td>Europe</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Oats</td>
<td>Oriza sativa</td>
<td>China</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Rice, common</td>
<td>Sorgnium bicolor</td>
<td>Tropical Africa</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Sorghum</td>
<td>Triticum</td>
<td>Manamade</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Triticale</td>
<td>T. aestivum</td>
<td>Southwest Asia</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Wheat</td>
<td>T. monococum</td>
<td>Southwest Asia</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Bread</td>
<td>T. turidum</td>
<td>Southwest Asia</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Einkorn</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emmer</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 7.1 Grains Discussed in Chapter 7

<table>
<thead>
<tr>
<th>COMMON NAME</th>
<th>SCIENTIFIC NAME</th>
<th>AREA OF DOMESTICATION</th>
<th>FAMILY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amaranth, grain</td>
<td>Amaranthus spp.</td>
<td>Mexico</td>
<td>Amaranthaceae</td>
</tr>
<tr>
<td>Corn</td>
<td>Zea mays</td>
<td>Southern Mexico</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Quinoa</td>
<td>Chenopodium quinoa</td>
<td>Central Andes</td>
<td>Amaranthaceae</td>
</tr>
<tr>
<td>Rice, wild</td>
<td>Zizania aquatica</td>
<td>Northern United States</td>
<td>Poaceae</td>
</tr>
</tbody>
</table>

The important characteristics of grasses are:
The Grass Plant

Mature grasses have a fibrous root system.

Some grasses have 1 or a few major stems called culms.

Other grasses branch at the base and produce tillers.

Grasses are monocots.

The grass leaf consists of a sheath, which forms part of the stem, and a flattened, upper portion called a blade.

The base of the sheath attaches to the stem at the node (solid).

The section between the two nodes, internode (hollow).

Vegetative production is common in perennial grasses.

Some produce rhizomes or stolons.

The flowers are borne on compound inflorescences consisting of a few to many spikelets.

Each spikelet contains 1 to several florets.

The floret is composed of a minute flower enclosed in 2 bracts, the palea and the lemma.
The Grass Plant

At the base of each spikelet are additional bracts called the glumes.

The tip of the lemma can extend beyond the bract and form a long structure called an awn.

The single ovary matures into a fruit with a seed coat and ovary wall (pericarp) fused into the bran.

The aleuronic layer is rich in proteins and fats.

The aleuronic layer plays a key role in the germination of grains.

It secretes enzymes that break down the endosperm starch into sugar for the germinating embryo (germ).

Grasses store energy for germination and seedling establishment in the endosperm.

Whole grains contain carbohydrates, proteins, fats and vitamins.

<p>| TABLE 6.2 Nutritional Composition of Cereal Grains, Based on a 100-gm, Dry, Uncooked Edible Portion |
|----------------------------------|--------|--------|--------|--------|----------|</p>
<table>
<thead>
<tr>
<th>GRAIN</th>
<th>WATER, gm</th>
<th>CALORIES, Cal</th>
<th>PROTEIN, gm</th>
<th>FAT, gm</th>
<th>CARBOHYDRATE, gm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley, pearled</td>
<td>10</td>
<td>352</td>
<td>10</td>
<td>1.2</td>
<td>78</td>
</tr>
<tr>
<td>Corn, dry</td>
<td>8</td>
<td>386</td>
<td>9.8</td>
<td>5.2</td>
<td>75</td>
</tr>
<tr>
<td>Oats, rolled</td>
<td>8</td>
<td>389</td>
<td>17</td>
<td>7.0</td>
<td>76</td>
</tr>
<tr>
<td>Rice, brown</td>
<td>12</td>
<td>362</td>
<td>7.5</td>
<td>2.7</td>
<td>66</td>
</tr>
<tr>
<td>Sorghum</td>
<td>9</td>
<td>339</td>
<td>11.3</td>
<td>3.3</td>
<td>75</td>
</tr>
<tr>
<td>Wheat, whole grain</td>
<td>11</td>
<td>339</td>
<td>13.7</td>
<td>2.5</td>
<td>71</td>
</tr>
<tr>
<td>Durum</td>
<td>10</td>
<td>340</td>
<td>10.7</td>
<td>2.0</td>
<td>75</td>
</tr>
<tr>
<td>Soft, white</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Data from USDA National Nutritional Database at: http://www.nal.usda.gov/fnic/nutcomp/search/

The process of removing the layers surrounding the endosperm is called polishing or pearling which produces white rice, white flour and pearled barley.
Directions of Selection in Grains

Humans have modified the growth habit of cereal grasses in two ways to increase harvest:

-- agriculturalists selected early for a single-gene trait that led to non-shattering in all domesticated cereals

-- removal of fruit from the bracts (palea, lemma and glumes)

-- natural mutation occurred that caused the bases of these bracts to collapse when dried

-- these “free-threshing” or “naked” grains facilitate the harvest and collection of large quantities of clean fruits.

Additional modifications of grass inflorescences during domestication:

Other lines of early selection involved plant growth form (habit).

Each tiller in wild grains are initiated sequentially, so individual tillers produce mature fruits at different times.

People selected for erect growth of tillers and synchrony of formation.

Other lines of early selection involved plant growth form (habit)

-- ancestral grains had a large central stem and small, lateral branches

-- people selected for reduced branching, a strong central stem, and fruit production on one or a few inflorescences

Modern cultivars of sorghum and pearl millet have large, single unbranched stems.
Directions of Selection in Grains

A major problem for many grains that grow in wet areas is lodging.

*Lodging* refers to the matting of tall stalks that are bent over by wind or rain.

Intensive selection programs for increased stalk strength and dwarf (short) varieties of wheat, rice, and sorghum have increased cultivation, especially in the tropics.

Major Old World Cereal Grain Crops

Rice, *Oryza sativa*, is the world’s most important crop, because it is a major dietary staple for 3 billion people.

*Oryza sativa* has been a major crop in China for millenia.

Recent phytolith data from the Yangtze River suggests that domestication occurred 9,000 to 12,000 ybp.

Rice is considered sacred and a symbol of fertility in much of Asia.

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**Major Old World Cereal Grain Crops**

First mention of rice in Europe by Alexander the Great, 320 B.C.

Rice cultivation spread to the Middle East and Egypt over next 300 years

Spain and Italy cultivated rice in the 15th century

Portuguese introduced rice to Brazil and west Africa

English imported rice in the 16th century from Madagascar

First rice plants in American colonies (South Carolina) in 1695
Recent studies have shown that rice was independently domesticated twice from *Oryza rufipogon*.

- indica type
Recent studies have shown that rice was independently domesticated twice from *Oryza rufipogon*.

- sativa or japonica type

### Rice cultivation:

- upland rice
- paddy rice
- floodplain rice

Upland rice is grown without standing water.

This type of rice is produced in areas with 4.9-6.6 feet of rain per year.

Brazil is the largest producer of upland rice.
Paddy rice is grown in standing water.

Paddy rice can grow partially submerged in water because of the specialized stem and root anatomy.

This structure maintains oxygen to the under water parts of the plant.

If temperatures are favorable, then rice production can occur all year-round.

In Southeast Asia, rice cultivation often involves hand labor, particularly in areas where fields are terraced.

The advent of modern milling procedures about 150 years ago, the world switched from brown rice to polished rice.

The polished rice lacked the vitamin B1 (thiamine) which caused beri-beri, a vitamin deficiency.
Major Old World Cereal Grain Crops

Wheat outranks rice in terms of acreage and tons produced per year.

Fossil evidence shows that wheat was first domesticated in the region of southeastern Turkey between 10,000 and 11,000 ybp.

The domestication of wheat (and barley) was associated with the cultivation of various legumes (lentils; peas) and the rise of the great civilizations of Mesopotamia.
Major Old World Cereal Grain Crops

All wheats and their close relatives (barley and rye) produce proteins known as glutens.

Gluten refers to several particular water-soluble proteins that occur in the endosperm.

In wheat, these proteins are gliadin and glutenin which produce an elastic dough that allows the formation of leavened bread.

Gluten proteins link together and form an elastic matrix when mixed with water and kneaded.

When yeast is added to the flour and water mixture, it uses the sugars in the flour for fermentation and produces CO$_2$.

The CO$_2$ gets trapped in the spongy protein mass and the dough rises.
When the dough is baked, the gas expands and forms large bubbles before the high temperatures kill the yeast.

Durum wheat is known today as hard or macaroni wheat. It is grown in low rainfall areas such as the Mediterranean, central Russia and the Great Plains.

The Spanish brought wheat to the New World in 1520.

Early English colonists failed to grow wheat in early colonial settlements.

In the 1870’s, wheat brought from immigrants from Russia was “Turkey” wheat from Turkey or nearby Crimea.

This wheat variety grew well in dry regions and made farming feasible in the U.S.

Two later developments contributed to the success of wheat in the U.S.:

- alleviation of pest problems
- improved quality of flour
Major Old World Cereal Grain Crops

A single wheat gene confers resistance to wheat rust, *Puccinia graminis*.

The second important event that encouraged wheat production was the development of modern industrial flour mills with steel rollers that replaced traditional millstones.

Sorghum, (*Sorghum bicolor*), is a grain native to tropical Africa.

Sorghum is the third most important Old World cereal grain in terms of production and importance for human nutrition.

It has traditionally been a grain of hot regions with little rainfall.
Sorghum was domesticated about 5000-6000 years ago in Northeastern sub-Saharan Africa.

Anthropological studies indicate that sorghum was used by hunter-gatherers about 10,000 ybp.

In India and Africa, the dried grains are often ground and used to make flatbread.
Almost all U.S. sorghum is used for livestock feed.

Some sorghum is cultivated for syrup production or sorghum “molasses.”

The stalks are crushed and the juice is evaporated to produce syrup.

Barley, *Hordeum vulgare* appears to have been one of the first domesticated cereals.

Charred barley kernels from the Fertile Crescent (southern Turkey, Syria and Iraq), are evidence of early domestication about 10,000 years ago.
Other Important Old World Grains

Researchers suggest the existence of two independent domestcations:

Two-rowed species of barley have clusters of 3 spikelets.

In two-row barley (wild barley), only 1 flower of each spikelet is fertile.

Only 2 grains per node (two-row barley).

During domestication, human selection led to fertility in all three spikelets.

Six-rowed barley appeared in the archeological record in 6000 B.C.

A single gene determined the restoration of fertility.

The major types of cultivated barley, based on combinations of hulled versus naked kernels and spike type, i.e. two-rowed versus six-rowed ears (Fig. 3), appeared during the early phases of plant cultivation in the Old World (Zohary & Hopf, 1993).

In early Egyptian times, barley was an important part of the culture.

The ancient Greeks used barley for bread.
Other Important Old World Grains

They also learned to soak the grains in water before drying and grinding to increase the digestibility.

In the United States, about 51% the barley grown is used to feed livestock and 44% is malted for beer.

Kykeon was a beverage of water and barley (sometimes flavored with mint or thyme) popular among the working, ‘lower’ class of ancient Greece.

Rye, (*Secale cereale*), like barley and wheat, is native to Southwest Asia.

New findings have dated cultivated rye from Syria to 11,050 years old, so the cultivation of rye may have pre-dated other grains.

Beginning in 1800 B.C., rye cultivation spread across Europe.

By the 18th century, it was a major grain in Russia.

Rye is a hardy grain and can germinate at temperatures as low as 1°C (34 F) and mature as low as 12°C (55 F).

Rye is often called the “poor person’s wheat.”

German, Czech, Polish and northern European black breads are a reflection of widespread rye cultivation in those regions.
Other Important Old World Grains

Rye is also used for:

Triticale is a cross between wheat and rye.

Triticale, or *Triticecale* is the first truly man-made cereal.

Oats, *Avena sativa*, was domesticated much later than other Eurasian grains, (3000 years ago).

Domestication probably occurred in Europe rather than the Near East.
Other Important Old World Grains

Oats is historically important because it was used for feed, especially for horses.

After the 8th century, two developments led to the replacement of oxen with horses:

Romans cultivated oats for their animals, but referred to the Germans as the “oat-eating barbarians.”

Oats are high in protein and fat.

Oat cultivation has fueled workhorses and is an integral part of the European agricultural system.

The name millet does not refer to a single cereal, but to several edible grasses.

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**TABLE 6.1 Major Grains of the Old World**

<table>
<thead>
<tr>
<th>COMMON NAME</th>
<th>SPECIES</th>
<th>NATIVE REGION</th>
<th>FAMILY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td><em>Hordeum vulgare</em></td>
<td>Southwest Asia</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Buckwheat</td>
<td><em>Fagopyrum esculentum</em></td>
<td>China</td>
<td>Polygonaceae</td>
</tr>
<tr>
<td>Goat grass</td>
<td><em>Triticum spelta</em></td>
<td>Southwest Asia</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Millet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broomcorn</td>
<td><em>Panicum miliaceum</em></td>
<td>China</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Finger</td>
<td><em>Eleusine coracana</em></td>
<td>Africa</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Foxtail</td>
<td><em>Setaria italica</em></td>
<td>China</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Pearl</td>
<td><em>Pennisetum glaucum</em></td>
<td>Africa</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Oats</td>
<td><em>Avena sativa</em></td>
<td>Europe</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Rice, common</td>
<td><em>Oryza sativa</em></td>
<td>China</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Sorghum</td>
<td><em>Sorghum bicolor</em></td>
<td>Tropical Africa</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Triticale</td>
<td><em>Triticosecale</em></td>
<td>Manmade</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Wheat</td>
<td><em>Triticum</em></td>
<td>Southwest Asia</td>
<td>Poaceae</td>
</tr>
<tr>
<td>Bread</td>
<td><em>T. aestivum</em></td>
<td></td>
<td>Poaceae</td>
</tr>
<tr>
<td>Einkorn</td>
<td><em>T. monococcum</em></td>
<td></td>
<td>Poaceae</td>
</tr>
<tr>
<td>Emmer</td>
<td><em>T. turgidum</em></td>
<td></td>
<td>Poaceae</td>
</tr>
</tbody>
</table>
Other Important Old World Grains

Two of the species that are important for human food:

-Pennisetum glaucum (pearl, bullrush, spiked or cattail millet)

--originally domesticated in sub-Saharan West Africa about 4000 years ago

--very drought resistant

--pearl millet is an important food staple for millions of Africans living on the edge of the Sahara

-Setaria italica (foxtail millet)

--domesticated in China more than 8000 years ago

--important food for poorer areas of northern China and Korea

-broomcorn millet (Panicum miliaceum)

--also domesticated in China about 10,000 years ago

--most commonly grown millet in developed countries including the U.S.

- finger millet (Eleusine coricana)

--domesticated in eastern tropical Africa

--food staple in this region

--ground into flour for flatbread or eaten as porridge
Other Important Old World Grains

Buckwheat (*Fagopyrum esculentum*) is not technically a cereal and is in the family Polygonaceae.

It was domesticated in Asia as early as 6000 B.C.

Buckwheat has been an important food source in Russia and parts of Europe.

Cultivation of buckwheat was popular because it can prosper in poor, nitrogen-deficient soil.

The tetrahedral fruits are actually achenes.

The hulled seeds (groats), often called kasha, can be cooked like rice.

Buckwheat is used for several different foods around the world:
Define grain or caryopsis.

Define cereals. Where did the word cereal originate?

What are the important characteristics of grasses?

Know the different parts of a grass plant: (Fig. 6.2)

- root: fibrous roots
- shoot: culms; tillers
- leaf: sheath; blade; node; internode
- vegetative reproduction: rhizome; stolon
- flowers: spikelets; floret; palea; lemma; glumes; awn
- fruit: bran; aleuronic layer; germ

What is the general nutritional composition of cereal grains? (Table 6.2)

How does pearling or polishing change the nutritional composition of cereal grains?

What are 2 main ways that humans have modified the growth habit of cereal grasses?

List other modifications of grass inflorescences during domestication.

Define lodging. What are the problems with lodging?

What are the major Old World cereal grains? (Table 6.1)

**Rice, Oryza sativa**
- Know origin/history and information about cultivation/domestication and uses.
- What is the nutritional difference between brown rice and polished rice (white rice)?
- How is the nutritional content of white rice related to the disease beri-beri?

**Wheat, Triticum aestivum**
- Know origin/history and information about cultivation/domestication and uses.
- What is gluten? How is it important for bread-making?
- What is durum wheat used for?

**Sorghum, Sorghum bicolor**
- Know origin/history and information about cultivation/domestication and uses.
- What are the 4 types of “sorghums” and their general uses?

**Other Important Old World Grains**

**Barley (Hordeum vulgare)**
- Know origin/history and information about cultivation/domestication and uses.

**Rye (Secale cereale)**
- Know origin/history and information about cultivation/domestication and uses.

What is triticale?

**Oats (Avena sativa)**
- Know origin/history and information about cultivation/domestication and uses.

**Millet**
- Know 4 types of millet and uses. (Table 6.1)

**Buckwheat (Fagopyrum esculentum) (Polygonaceae)**
- Know origin/history and information about cultivation/domestication and uses.