TABLE 3.6 Some Industrially Important Enzymes

Name	Example of Source	Application
Amylase	*Bacillus subtilis, Aspergillus niger*	Starch hydrolysis, glucose production
Glucoamylase	*A. niger, Rhizopus niveus, Endomycopsis*	Saccharification of starch, glucose production
Trypsin	Animal pancreas	Meat tenderizer, beer haze removal
Papain	Papaya	Digestive aid, meat tenderizer, medical applications
Pepsin	Animal stomach	Digestive aid, meat tenderizer
Rennet	Calf stomach/recombinant *E. coli*	Cheese manufacturing
Glucose isomerase	*Flavobacterium arborescens, Bacillus coagulans, Lactobacillus brevis*	Isomerization of glucose to fructose
Penicillinase	*B. subtilis*	Degradation of penicillin
Glucose oxidase	*A. niger*	Glucose → gluconic acid, dried-egg manufacture
Lignases	Fungal	Biopulping of wood for paper manufacture
Lipases	*Rhizopus,* pancreas	Hydrolysis of lipids, flavoring and digestive aid
Invertase	*S. cerevisiae*	Hydrolysis of sucrose for further fermentation
Pectinase	*A. oryzae, A. niger, A. flavus*	Clarification of fruit juices, hydrolysis of pectin
Cellulase	*Trichoderma viride*	Cellulose hydrolysis

Pectinases are produced mainly by *A. niger*. The major components in pectinases are pectin esterase, polygalacturonase, and polymethylgalacturonatelyase. Pectinases are used in fruit juice processing and wine making to increase juice yield, reduce viscosity, and clear the juice.

Lipases hydrolyze lipids into fatty acids and glycerol and are produced from animal pancreas, some molds, and yeasts. Lipases may be used to hydrolyze oils for soap manufacture and to hydrolyze the lipid-fat compounds present in waste-water streams. Interesterification of oils and fats may be catalyzed by lipases. Lipases may also be used in the cheese and butter industry to impart flavor as a result of the hydrolysis of fats. Lipase-containing detergents are an important application of lipases.

Amylases are used for the hydrolysis of starch and are produced by many different organisms, including *A. niger* and *B. subtilis*. Three major types of amylases are α-amylase, β-amylase, and glucoamylase. α-amylase breaks α-1,4 glycosidic bonds randomly on the amylose chain and solubilizes amylose. For this reason, α-amylase is known as the starch-liquefying enzyme. β-amylase hydrolyzes α-1,4 glycosidic bonds on the nonreducing ends of amylose and produces maltose residues. β-amylase is known as a saccharifying enzyme. α-1,6 glycosidic linkages in the amylopectin fraction of starch are hydrolyzed by glucoamylase, which is also known as a saccharifying enzyme. In the United States on the average, nearly 1.3×10^9 lb/yr of glucose is produced by the enzymatic hydrolysis of starch. The enzyme pullulanase also hydrolyzes α-1,6 glycosidic linkages in starch selectively.