Enzymes are proteins that catalyze chemical reactions, many of which affect the flavor and mouthfeel of foods. Individual enzymes can be applied to foods to achieve effects like tenderization of meat (by proteases like papain and bromelain), adhesion of protein-containing foods (using transglutaminase, aka "meat glue"), aggregation of caseins in milk (by rennin, a protein found in calf stomachs), or the breakdown of potential digestive irritants like lactose and raffinose (e.g. by lactase and α-galactosidase, the active ingredients in Lactaid and Bean-O). The cultivation of microbes on foods like cheese, bread, and wine exposes these foods to many enzymes at once, contributing to flavor development, leavening, and/or resistance to spoilage.

Reaction rates

Enzymes increase the rates at which reactions occur by decreasing the activation energy, the energy required for the chemical reaction to start. Enzymes achieve this by containing sites that bind the substrates (reactants) and prime them for reaction. While enzymes can speed up reactions, they cannot alter the equilibrium constant to make an unfavorable reaction become favorable.

The rates of many reactions approximately double with every 10°C increase in temperature. The Arrhenius equation describes more precisely how reaction rates vary with temperature:

$$k = k_0 e^{-\Delta E / k_B T}$$

where k_0 is the theoretical maximum reaction rate and ΔE is the activation energy. Like other proteins, enzymes denature at roughly 50-70°C, so higher temperatures cannot be used.

Enzymatic browning

Many fruits contain polyphenol oxidase, an enzyme that reacts with phenolic compounds in the presence of oxygen to produce brown pigments. Polyphenol oxidase is normally separated from phenolics, but cellular damage caused by bruising or cutting brings them into contact, resulting in browning. Any treatment that causes the enzyme to denature (extreme pH, very high temperature) or become less active (e.g., limited oxygen exposure, high salt concentration, or low temperature) will decrease the rate of browning.

Another reaction triggered by cellular damage is the production of pungent and flavorful sulfur-containing molecules by alliinase, an enzyme present in garlic and onions. Some recipes call for the garlic/onions to be minced (chopped finely) to increase flavor development by maximizing cell damage, while others call for the garlic/onions to be roasted or sautéed at high temperatures, decreasing flavor development by inactivating the enzyme.

Microbes

Many microbes are purposefully cultivated on food, as you saw in last week's discussion of baking. Brewer's yeast[1] ferment sugar, producing carbon dioxide gas and ethanol. During vinegar production (and sometimes accidentally in wine-making), acetic acid bacteria in turn convert ethanol to acetic acid. Acidifying microbes are also used in cheese and yogurt production, where the environment they create is reponsible for the denaturation of caseins and thus the increased viscosity or solidity of the finished products. Both high ethanol concentration and low pH caused by cultivated microbes prevent many less desirable species from growing, thus limiting food spoilage.

The number of microbes present in a food can be predicted using the exponential growth equation,

$$N(t) = N_0 e^{kt}$$

where N_0 is the initial number of microbes and k is the rate of growth (or, if negative, of death). Federal regulations often require that microbial contaminants be reduced but not necessarily eliminated, and the equation above is effective for determining the number of microbes remaining after a given treatment.

[1] *Saccharomyces cerevisiae* is known as both baker's yeast and brewer's yeast, depending on the context.