solutes into different peaks that exit at a characteristic retention time (which will change if operating conditions are altered).

Elution chromatography is similiar to fixed-bed adsorption (Section 11.4.4). However, in fixed-bed adsorption (sometimes called frontal chromatography) the solute is captured in the adsorbent and then eluted as a concentrate. In elution chromatography you purify the product even while it is being diluted.

When large amounts of material are being processed, *displacement chromatography* may be attractive. In this method the column is subjected to sequential step changes in inlet conditions (e.g., nature of solvent). In this method the feed mixture is introduced, followed by a constant infusion of displacer solution. The displacer must have a higher affinity for the stationary phase than any compound in the feed solution. The displacer "pushes" solute off the stationary phase and back into the mobile phase. If conditions are chosen correctly, the feed components are forced into adjacent square-wave-like zones of concentrated, pure solutes. These zones then break through the end of the column with the zone having the solute with the lowest affinity for the stationary phase exiting first. The primary advantage of displacement chromatography over elution chromatography is the potential for higher throughput, but operation is more difficult, and high *resolution* (separation of solutes) can be difficult to obtain in some situations.

These chromatographic processes are almost always run as batch operations, although schemes for continuous or semicontinuous operation have been proposed. For the remainder of our discussion we focus on elution chromatography as a batch process. Some important types of chromatographic methods are:

1. *Adsorption chromatography* (ADC) is based on the adsorption of solute molecules onto solid particles, such as alumina and silica gel, by weak van der Waals forces and steric interactions.
2. *Liquid–liquid partition chromatography* (LLC) is based on the different partition coefficients (solubility) of solute molecules between an adsorbed liquid phase and passing solution. Often the adsorbed liquid is nonpolar.
3. *Ion-exchange chromatography* (IEC) is based on the adsorption of ions (or electrically charged compounds) on ion-exchange resin particles by electrostatic forces.
4. *Gel-filtration (molecular sieving) chromatography* is based on the penetration of solute molecules into small pores of packing particles on the basis of molecular size and the shape of the solute molecules. It is also known as size exclusion chromatography.
5. *Affinity chromatography* (AFC) is based on the specific chemical interactions between solute molecules and ligands (a functional molecule covalently linked to a support particle). Ligand–solute interaction is very specific, such as enzyme–substrate interaction, which may depend on covalent, ionic forces or hydrogen-bond formation. Affinity binding may be molecular size and shape specific.
6. *Hydrophobic chromatography* (HC) is based on hydrophobic interactions between solute molecules (e.g., proteins) and functional groups (e.g., alkyl residues) on support particles. This method is a type of *reverse phase chromatography* which requires that the stationary phase is less polar than the mobile phase.
7. *High-pressure liquid chromatography* (HPLC) is based on the general principles of chromatography, the only difference being high liquid pressure applied to the