Several factors affect filter efficiency in microbial and particle retention (1).

1. Type of particle—Source, shape, charge, size.
2. Filter material (type of polymer)—Filter composition plays a role in charge-related attraction of particles, including microorganisms, with zeta potential van der Waals forces, hydrogen bonding, and hydrophobic attraction properties of the filter all involved.
3. Filter membrane thickness—Filter thickness slows the flow characteristics and affects the particle adsorption mechanism although a coarse and thick membrane can be just as efficient as a fine, thin one.
4. Filter porosity—Obviously the smaller the porosity, the greater the retention of microorganisms and particles, but flow rates are retarded. Also potential incompatibilities with liquids being filtered are greater with smaller porosities.
5. Temperature—influences microbial proliferation and viability and affects the Brownian motion of suspended organisms, increasing possibility of their adsorptive contact with the pore walls. The smaller the organism or particle, the greater the Brownian-motion effect upon it.
6. Type of fluid/solution being filtered—Increasing the viscosity of the solution will require some increase in applied pressure that, in turn, will increase the shear force on any bacterial cells present. Increased viscosity will disrupt adsorption interactions on the filter membrane, but will have no effect on size exclusion properties of the membrane. Surface-active agents in the solution formulation will decrease the surface tension of the solution and lower the bubble point of the filter (explained later). Surface-active agents normally will bind to solid surfaces and may reduce or eliminate bacterial adsorption in the filter, but will have no effect on membrane structure or changing the size of the bacterial cell.
7. Applied pressure, flow rate, and time—While it seems intuitive that increasing pressure or flow rate or time will have adverse effects on the integrity of the filter and perhaps affect microbial cell size, there are no compelling data to support this. Commercially used membrane sterilizing filters can be used for up to one week without changes in retention characteristics according to filter manufacturers' technical literature.

Filter manufacturers publish many technical articles and data sheets (most available on their web sites) describing and explaining the properties and functionalities of all their commercially available filters.

APPLICATIONS

Membrane filters are used exclusively for sterilizing solutions because of their particle-retention effectiveness, nonshedding property, nonreactivity, and disposable characteristics. However, it should be noted that nonreactivity does not apply in all cases. For example, polypeptide products may show considerable adsorption through some membrane filters, but those composed of polysulfone and polyvinylidine difluoride (PVDF) have been developed to be essentially nonadsorptive for these products. The most common membranes are composed of cellulose esters, nylon, polysulfone, polycarbonate, PVDF, or polytetrafluoroethylene (Teflon) (Table 18-2).

Filters are available as flat membranes or pleated into cylinders or cartridge filters (Fig. 18-2) to increase surface area and, thus, flow rate (suppliers: *Cuno, Gelman, Meissner, Millipore, Pall, Sartorius, Schleicher, perhaps others*). Fluid enters the outside of the filter cartridge with applied positive pressure forcing the fluid inward through the filter with the sterile effluent exiting from the center of the cartridge (Fig. 18-3).

The filter is assembled in the stainless steel housing by first wetting the O-rings, making certain that the filter is oriented properly within the housing, then the clamps are hand tightened. There must be no direct hand contact with the cartridge during assembly. The filter and housing are then steam sterilized, typically by steam-in-place (SIP) systems. Inlet pressure must be matched to the maximum cartridge temperature with differential pressure controlled to ensure filter integrity. Both pressurization before and depressurization after sterilization must be gradual to protect filter integrity. Like other steam sterilization processes, there must be assurance that air is replaced by steam. Validation of the sterilization of filters occurs with thermocouples and spore strips located at identified "cold spots" within the filter assembly. After sterilization the filter cartridges are dried with filtered compressed gas.