products such as lactate and ammonium can be removed from intracapsule culture media, and high-MW products such as MAb's or lymphokines can be concentrated inside capsules. Moreover, cells are protected from hydrodynamic shear by encapsulation, providing a suitable environment for direct aeration. However, the growth and product-formation rate inside capsules may be limited by the diffusion of nutrients such as dissolved oxygen or glucose, especially at large capsule sizes. The reduction of capsule size to eliminate mass transfer limitations (down to 200 μm) and the control of pore size to concentrate desired products within the capsule are two promising approaches to solve some of the problems associated with encapsulated cells. By varying the concentration and average MW of poly-L-lysine (PPL), the pore size of the capsule membrane can be controlled within certain limits (30 to 80 kda). Monitoring and control of microenvironmental conditions within capsules (pH, DO level, nutrient–product gradient) are major problems that impose limitations on growth and product formation inside capsules. The fragile nature of the microcapsule also limits the scale-up potential of this system.

12.4. PRODUCTS OF ANIMAL CELL CULTURES

Animal cell products usually consist of high-molecular-weight proteins with or without glycosidic groups. A number of enzymes, hormones, vaccines, immunobiologicals (monoclonal antibodies, lymphokines) and anticancer agents can be produced using animal cell culture technology (see Table 12.4).

The major types of immunobiologicals produced by animal cells are (1) monoclonal antibodies, (2) immunobiological regulators (interleukins, lymphokines), and (3) virus vaccines (prophylactics).

12.4.1. Monoclonal Antibodies

Among the most important products of animal cell culture have been monoclonal antibodies (MAb's). MAb's are produced by hybridoma cells and are used in diagnostic assay systems, for therapeutic purposes, and for biological separations (e.g., affinity chromatography). MAb's have been used as diagnostic agents to determine hundreds of drugs, toxins, vitamins, and other biological compounds. MAb's are also used for chromatographic separations to purify protein molecules. Purification of interferon by affinity chromatography is an example of the use of MAb's for protein purification purposes. MAb's

TABLE 12.4 Major Categories of Products of Animal Cell Cultures

Immunobiologicals	Hormones
Monoclonal antibodies	Enzymes
Lymphokines and interleukines	Insecticides
Virus vaccines	Growth factors
Cell surface antigens	Whole cells
	Tissues
	Organs