also may serve as "magic" bullets to target toxic agents to cancer tumors. However, the large size of MAb's has limited their ability to penetrate some tumors. Antibody fragments can be used instead; these products can be made in nonmammalian cells.

12.4.2. Immunobiological Regulators

Interferon (an anticancer glycoprotein secreted by animal cells upon exposure to cancer-causing agents) is an example of an immunoregulator produced by mammalian cells. Interferon can be produced by either animal cells or recombinant (genetically engineered) bacteria. Other immunoregulators are lymphokines (hormonal proteins regulating immune responses of human body), interleukines (anticancer agents), tissue plasminogen activator (a compound preventing blood clotting), and thymosin. The production of immunoregulators is a very promising area with a great potential for growth in the near future.

12.4.3. Virus Vaccines

Various virus vaccines (prophylactics) have been produced for animal and human use. In some cases live virus is propagated in animal cells. Virus is then collected and inactivated ("killed" virus) and used as a vaccine. In other cases a weakened or *attenuated* form of the virus is used that will induce a protective response but no disease. However, most vaccines now under development are *subunit vaccines*. Typically a protein displayed on the surface of the virus particle is produced. An *epitope* or small region of the protein is recognized by the immune system and induces a protective immune response. For the epitope to be displayed properly, the protein may need to assemble into a *viruslike particle*. Such a particle is an empty capsid that contains no nucleic acid. The absence of viral DNA or RNA increases the safety of the product.

12.4.4. Hormones

Some animal hormones are large molecules (50 to 200 amino acids) and are glycosylated. These hormones can be produced by using cell cultures of the hormone-synthesizing organ.

Some potential hormone products from animal cells are follicle-stimulating hormone, chorionic hormone, and erythropoetin. Some animal hormones are relatively small polypeptides (20 to 30 amino acids) and may be produced by chemical synthesis. Erythropoetin is a very successful commercial product useful in treating anemia in a wide range of disorders from patients on artificial kidneys to those with AIDS.

12.4.5. Enzymes

A number of enzymes can be produced by animal cell cultures. The synthesis and excretion of these enzymes are targets of genetic engineering. Glycosylation, posttranslational modification, and excretion from the host organism are potential problems. Some potential enzyme products from animal cell cultures are urokinase, rennin, asparaginase, collagenase, pepsin, trypsin, hyaluronidase, and blood-clotting compounds such as factor VII,