NERVE MUSCLE PHYSIOLOGY:

1.Nerve Action Potential (p. 60)

Nerve signals are transmitted by action potentials, which are rapid changes in the membrane potential. Each action potential begins with a sudden change from the normal resting negative potential to a positive membrane potential and then ends with an almost equally rapid change back to the resting negative potential. The successive stages of the action potential are as follows:

• Resting stage. This is the resting membrane potential before the action potential occurs.

• Depolarization stage. At this time, the membrane suddenly becomes permeable to sodium ions, allow-ing tremendous numbers of positively charged sodium ions to flow to the interior of the axon, and the potential rises rapidly in the positive direction.

• Repolarization stage. Within a few 10,000ths of a second after the membrane becomes highly permeable to sodium ions the sodium channels begin to close and the potassium channels open more than they normally do. Then rapid diffusion of potassium ions to the exterior re-establishes the normal negative resting membrane potential.

Voltage-Gated Sodium and Potassium Channels Are Activated and Inactivated during the Course of an Action Potential. The necessary factor for both depolarization and repolarization of the nerve membrane during the action potential is the voltage-gated sodium channel. The voltage-gated potassium channel also plays an important role in increasing the rapidity of repolarization of the membrane. These two voltage-gated channels are present in addition to the Naþ-Kþ pump and the Naþ-Kþ leak channels that establish the resting permeability of the membrane.

The Events That Cause the Action Potential Can Be Summarized as Follows

• During the resting state, before the action potential begins, the conductance for potassium ions about 100 times as great as the conductance for sodium ions. This is caused by much greater leakage of potassium ions than sodium ions through the leak channels.

• At the onset of the action potential, the sodium channels instantaneously become activated and allow up to a 5000-fold increase in sodium permeability (also called sodium conductance). Then the inactivation process closes the sodium channels within a few fractions of a millisecond. The onset of the action potential also causes voltage gating of the potassium channels, causing them to begin opening more slowly.

• At the end of the action potential, the return of the membrane potential to the negative state causes the potassium channels to close back to their original status but, again, only after a delay.

A Positive-Feedback, Vicious Circle Opens the Sodium Channels. If any event causes the membrane potential to rise from 90 millivolts toward the zero level, the rising voltage itself causes many voltage-gated sodium channels to begin opening. This allows rapid inflow of sodium ions, which causes still further rise of the membrane potential, thus opening still more voltage- gated sodium channels. This process is a positive- feedback vicious circle that continues until all of the voltage-gated sodium channels have become activated (opened).

An Action Potential Does Not Occur until the Threshold Potential Has Been Reached. This happens when the number of sodium ions entering the nerve fiber becomes greater than the number of potassium ions leaving the fiber. A sudden increase in the membrane potential in a large nerve fiber from –90 millivolts to about –65 millivolts usually causes explosive develop- ment of the action potential. This level of –65 millivolts is said to be the threshold of the membrane for stimulation.

A New Action Potential Cannot Occur When the Membrane Is Still Depolarized from the Preceding Action Potential. Shortly after the action potential is initiated, the sodium channels become inactivated, and any amount of excitatory signal applied to these channels at this point does not open the inactivation gates. The only condition that can reopen them is when the membrane potential returns either to or almost to the original resting membrane potential level. Then, within another small fraction of a second, the inactivation gates of the channels open, and a new action potential can then be initiated.

• Absolute refractory period. An action potential cannot be elicited during the absolute refractory period, even with a strong stimulus. This period for large myelinated nerve fibers is about 1/2500 second, which means that a maximum of about 2500 impulses can be transmitted per second.

• Relative refractory period. This period follows the absolute refractory period. During this time, stronger than normal stimuli can excite the nerve fiber, and an action potential can be initiated.