Chapter 4

Neuromuscular Junctions and Electric Organs

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1. INTRODUCTION

The neuromuscular junction has been much studied anatomically and physiologically, not only because of its influence on muscle action, but also because of its ready accessibility as a peripheral synapse and the significant information that it contributes to synaptic morphology and function in general. Fine structural studies employing the electron microscope and histochemical studies, usually involving the localization of cholinesterase, have contributed most significantly in recent times to our knowledge of the anatomy of the neuromuscular junction. These studies have dealt not only with the structure of the myoneural junction itself, but also with the distribution and location of the nerve terminals on the muscle fibers. Variations have been found, both in the structure and in the disposition of the nerve terminals, and these varieties of endings have attracted attention because they are correlated in many instances with functional variations in the action of the muscle fibers.

2. THE TYPICAL NEUROMUSCULAR JUNCTION

The most common kind of myoneural junction typical of most endings of the vertebrate muscle fiber will be described first and then variations on this theme will be discussed.
2.1. Distribution and Location of Nerve Terminals

Most muscle fibers are individually innervated by a single end plate which usually occurs in the mid-length of the muscle fiber. Hence a band of innervation occurs, located in the middle of the muscle and differing in shape depending on the mode of origin and insertion of the muscle fibers (Coërs, 1967).

2.2 The Axon

2.2.1. Internal Structure and Organelles

The terminal axon arborizes over the surface of the muscle fiber in the synaptic gutter. The axoplasm contains numerous mitochondria of typical structure, a dearth of neurofilaments (although some can be found), and synaptic vesicles about 300 Å in diameter containing a lightly electron dense material enclosed by a membrane (Fig. 1). The vesicles are usually distributed randomly in the terminal axoplasm near the muscle fiber, but recently "active zones" of accumulated vesicles near the presynaptic cleft have been described (Couteaux and Pécot-Dechavassine, 1970). The synaptic vesicles have received much attention because they might represent the storage form of the neuromuscular transmitter and release acetylcholine (ACh) in quantal amounts. Exocytosis of the content of the vesicles into the synaptic space has been suggested (Couteaux and Pécot-Dechavassine, 1970). Increased ACh release at the neuromuscular junction produces a fall in vesicle numbers, while an increase in synaptic vesicle numbers adjacent to the presynaptic cleft occurs in preparations fixed at various times following a long period of nerve stimulation (Jones and Kwanbunbumpen, 1970). A process of endocytosis may also occur, and "coated" vesicles have been found in nerve terminals. These are best seen with peroxidase treatment (Zacks and Saito, 1969), where this reagent gains access to the synaptic space and attaches to the nerve terminal membrane, which apparently then pinches off to form a vesicle within the terminal coated by peroxidase. "Coated" vesicles can also be found normally in the terminal axon, and these are supposedly coated by amorphous material found in the synaptic space. There has been much speculation regarding the changes which must occur in the length of the terminal axonal membrane, since exocytosis implies that the membrane of the synaptic vesicle fuses with the terminal axonal membrane to extrude its contents into the synaptic space causing increase in membrane length, and endocytosis demands that the terminal axonal membrane pinch off to form a vesicle which passes into the axon causing decrease in membrane length [see Chapter 7(i)].