Table 4–1. Late Responses: F Response and H Reflex

	F Response	H Reflex
Afferent	Motor	Sensory (Ia muscle spindle)
Efferent	Motor	Motor
Synapse	No	Yes
Nerves studied	All	Tibial–soleus (median-FCR, femoral-quads)
Stimulation	Supramaximal	Submaximal, long duration pulse (1 ms)
Configuration	Usually polyphasic Amplitude 1–5% CMAP Varies with each simulation	Triphasic and stable At low stimulation intensity, H is present without M As stimulation is increased, H and M increase At high stimulation, H decreases and M increases
Measurements	Minimal latency Chronodispersion Persistence	Minimal latency H/M ratio (maximal H/maximal M amplitude)
Major uses	Early Guillain–Barré syndrome C8–T1, L5–S1 radiculopathy Polyneuropathy Internal control (entrapment neuropathy)	Early polyneuropathy S1 radiculopathy Early Guillain–Barré syndrome Tibial and sciatic neuropathy, sacral plexopathy
Normal values	≤32 ms median/ulnar* ≤56 ms peroneal/tibial* Compare to F estimate Compare symptomatic to asymptomatic side Chronodispersion <4 ms (median/ulnar) <6 ms (peroneal/tibial) Persistence >50%	≤34 ms* Leg length nomogram Height nomogram ≤1.5 ms difference side to side H/M ratio ≤50%
Miscellaneous	In normals, peroneal F waves may be absent or impersistent F responses may be absent in sleeping or sedated patients F responses may be absent with low-amplitude distal CMAPs May be enhanced by Jendrassik maneuver	Electrical correlate of the ankle jerk Must be present if ankle jerk is present May be present even if ankle jerk is absent May be enhanced by Jendrassik maneuver

CMAP, compound muscle action potential. FCR, flexor carpi radialis.

*Assumes median height, normal conduction velocity and distal latency.

Nerve conduction studies are most often used to assess distal nerve segments, with routine stimulation seldom done above the elbow or knee. Few studies can be easily performed to assess the more proximal nerve segments (plexus and roots). In the arm, surface stimulation can be performed proximally in the axilla and at Erb's point, although technical factors limit these studies, especially at Erb's point. Needle stimulation or high-voltage stimulators, both of which have technical limitations, often are needed to study proximal nerve segments at the root level. In the electromyography (EMG) laboratory, two late responses, the F response and the H reflex, are used routinely to study the more proximal nerve segments. Each has its advantages and limitations (Table 4–1). Although both are usually thought of as assessing only the proximal nerve segments, in reality they travel the entire nerve segment from distal to proximal and back. Thus, they are most useful when routine nerve conduction studies, which assess distal segments, are normal and the late responses are abnormal, a situation that implies a proximal lesion.

F RESPONSE

The F response is a late motor response that occurs after the compound muscle action potential (CMAP, also known as the direct motor [M] potential) (Figure 4–1). The F response derives its name from the word "foot" because it was first recorded from the intrinsic foot muscles. In the upper extremity, when the median or ulnar nerves are stimulated at the wrist, the F response usually occurs at a latency of 25 to 32 ms. In the lower extremity, when the peroneal or tibial nerves are stimulated at the ankle, the F response usually occurs at a latency of 45 to 56 ms. If the stimulator is moved proximally, the latency of the CMAP increases as expected, but the latency of the F response actually decreases (Figure 4–2). This is due to the circuitry of the F response, which is initially antidromic toward the spinal cord. Thus, with more proximal stimulation, the action potential has less distance to travel, hence the shorter latency. During a routine motor nerve conduction study, one usually thinks of the action potential as traveling down the nerve across the neuromuscular junction (NMJ) to subsequently depolarize the muscle. When stimulated,

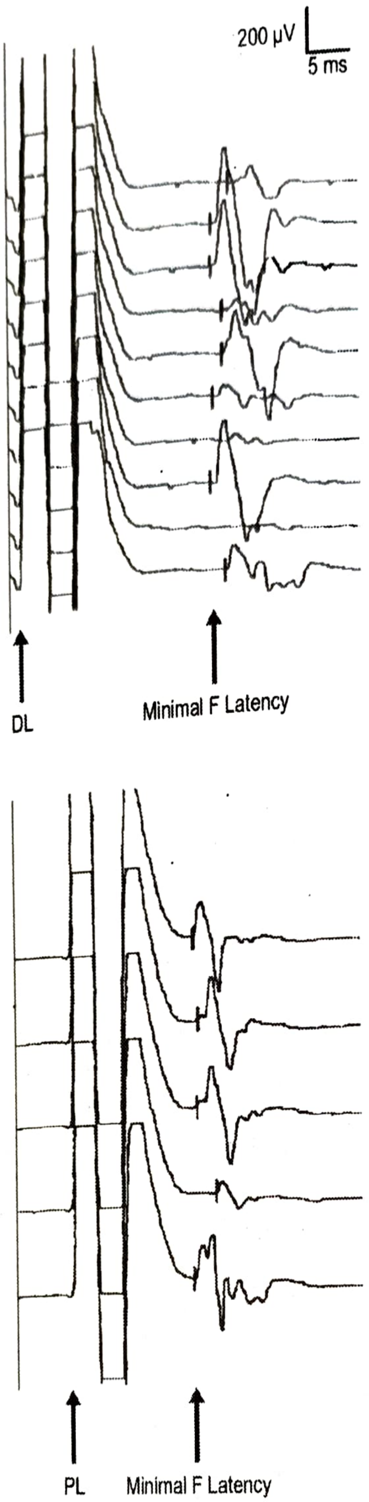

FIGURE 4–2 Normal F responses, distal and proximal stimulation. Median F responses recording abductor pollicis brevis, stimulating wrist **(top trace)** and elbow **(bottom trace)**. DL, distal compound muscle action potential (CMAP) latency; PL, proximal CMAP latency. Note with proximal stimulation, the proximal CMAP latencies increase as expected, but the F response latencies decrease, due to the F response traveling a shorter distance antidromically to the spinal cord.

however, the nerve conducts well in both directions. The F response is derived by antidromic travel up the nerve to the anterior horn cell, with backfiring of a small population of anterior horn cells, resulting in orthodromic travel back down the nerve past the stimulation site to the muscle (Figure 4–3). The F response is actually a small CMAP, representing 1 to 5% of the muscle fibers. The F response

H REFLEX

The H reflex derives its name from Paul Hoffmann, who first evoked the response in 1918. The H response is distinctly different from the F response in that it is a true reflex with a sensory afferent, a synapse, and a motor efferent segment. Likewise, several other properties differentiate the H and F responses (Table 4–1). Unlike the F response that can be elicited from all motor nerves, the distribution of the H reflex is much more limited. In newborns, H reflexes are widely present in motor nerves, but beyond the age of two, they can only be routinely elicited by stimulating the tibial nerve in the popliteal fossa and recording the gastroc–soleus muscle. Although there are techniques for obtaining an H reflex from the femoral nerve recording the quadriceps muscle and from the median nerve recording the flexor carpi radialis muscle, both of these have significant limitations.

The circuitry of the H reflex involves the Ia muscle spindles as sensory afferents and the alpha motor neurons and their axons as efferents (Figure 4–8). If a low submaximal stimulus with a long duration pulse is applied to a nerve, it is possible to relatively selectively activate the Ia fibers. Several adjustments must be made to the EMG machine to record an H reflex, similar to those made for the F response. The gain must be increased initially to 200 to 500 µV. The typical H reflex latency is approximately 30 ms, so the sweep speed must be increased to 10 ms.

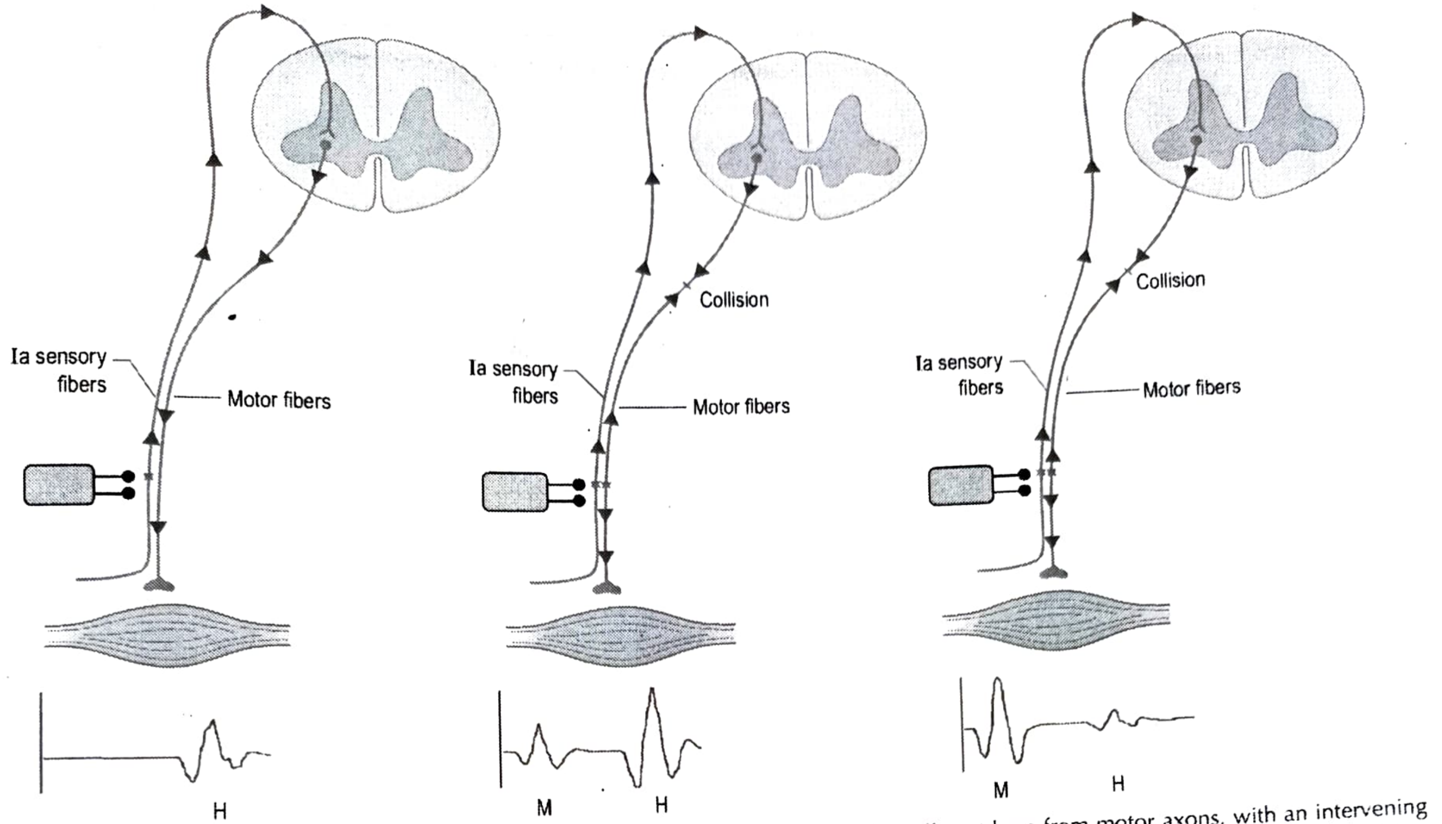

FIGURE 4–8 **H reflex circuitry.** The afferent loop is formed from Ia sensory fibers and the efferent loop from motor axons, with an intervening synapse in the spinal cord. At low stimulation intensity **(left),** the Ia sensory fibers are selectively activated, yielding an H reflex without a direct motor (M) potential. With increasing stimulation **(middle),** more Ia sensory fibers are activated, as are some of the motor fibers. The motor fiber stimulation results in a small M potential and some collision proximally of the descending H reflex by the antidromic motor volley. At higher stimulation **(right),** the selective activation of the Ia sensory fibers is lost. Both sensory and motor fibers are stimulated at high levels. The higher motor stimulation results in an increasingly larger M potential. However, the H reflex decreases in size as there is greater collision proximally of the descending H reflex from the antidromic motor volley.

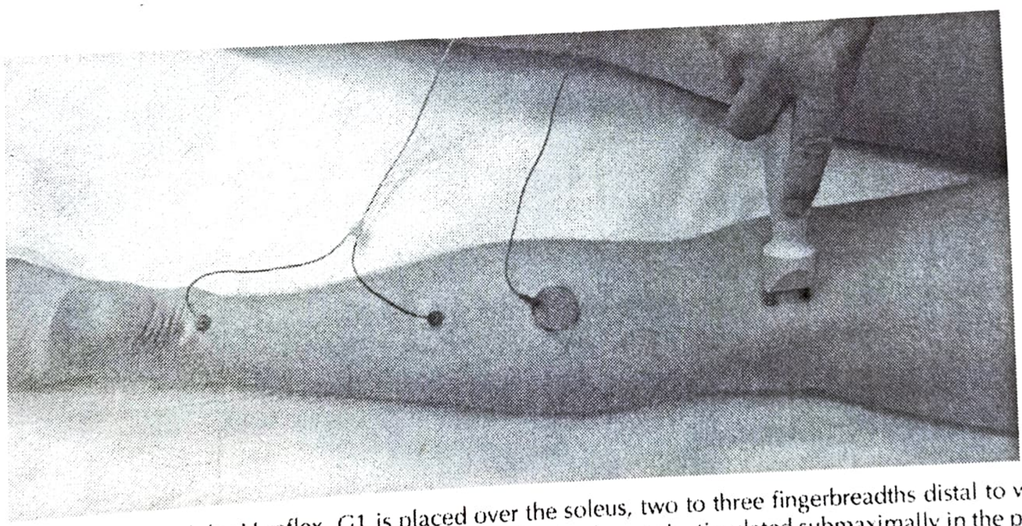

FIGURE 4–9 **H reflex setup.** To record the H reflex, G1 is placed over the soleus, two to three fingerbreadths distal to where it meets the two bellies of the gastrocnemius muscle, with G2 over the Achilles tendon. The tibial nerve is stimulated submaximally in the popliteal fossa, with the cathode placed proximal to the anode.

Most important, the stimulus duration must be increased to 1 ms in order to selectively stimulate the Ia fibers. The recording montage consists of G1 placed over the soleus and G2, the reference electrode, placed over the Achilles tendon (Figure 4–9). Although the H reflex can be recorded over any portion of the gastrocnemius and soleus muscles, the optimal location that yields the largest H reflex has been studied. If one draws a line from the popliteal fossa posteriorly to the Achilles tendon where the medial malleolus flares out and then divides that line into eight equal parts, the optimal location is at the fifth or sixth segment distally, over the soleus (Figure 4–10). This location is approximately two to three fingerbreadths distal to where the soleus meets the two bellies of the gastrocnemius. The