

# Neurologic Electrodiagnostic Testing

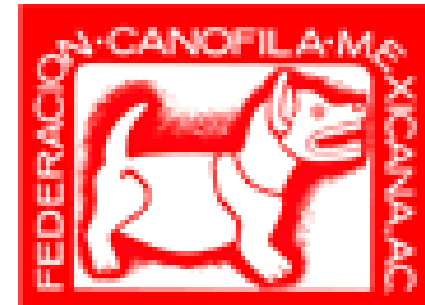
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Pruebas de Electrodiagnóstico Neurológico

Congreso Internacional de Medicina, Cirugía y  
Zootecnia en Perros, Gatos y otras Mascotas

May 2006

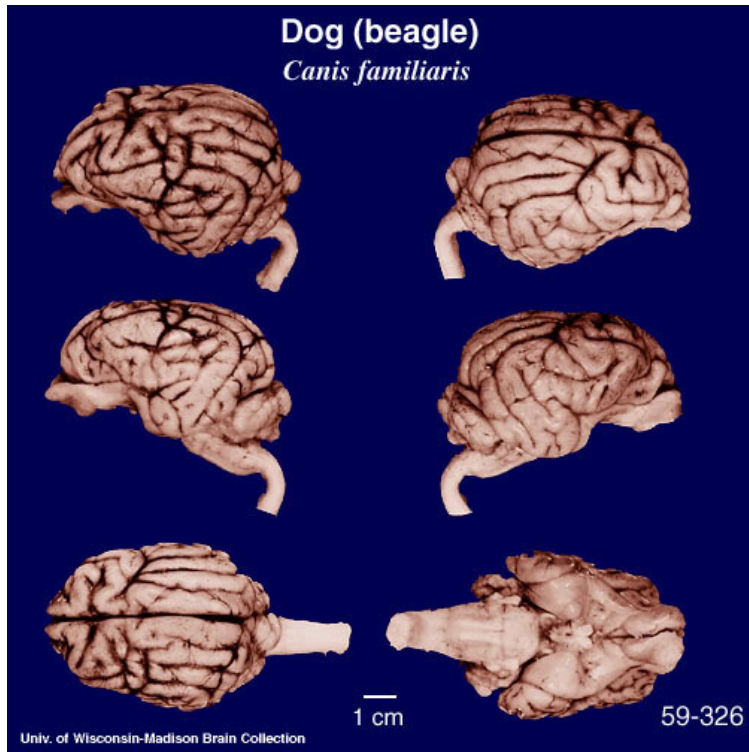
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**Baton Rouge, Louisiana USA**



# Neurologic Electrodiagnostic Testing

- Measurement – from the body surface – of the electrical activity of nerve and muscle
- Necessary because of the inaccessibility of most of the nervous system
- Spontaneous (EEG) or activity evoked by appropriate stimuli – evoked potentials
- Usually only available in veterinary schools or specialty neurology practices

# Outline



- Tests of auditory function
- Tests of visual function
- Tests of somatosensory-motor system function
- Tests of cortical function

# Sensory Evoked Potential (EP)

- Definition: a voltage (potential) produced in some part of the nervous system as a consequence of a sensory stimulus being applied to the appropriate receptors.
- Components of the EP are thought to reflect summated effects at synaptic relays along the afferent paths, so the EP provides a noninvasive technique for examining the integrity of peripheral and CNS sensory pathways.
- Responses are small compared to other electrical signals present on the body.



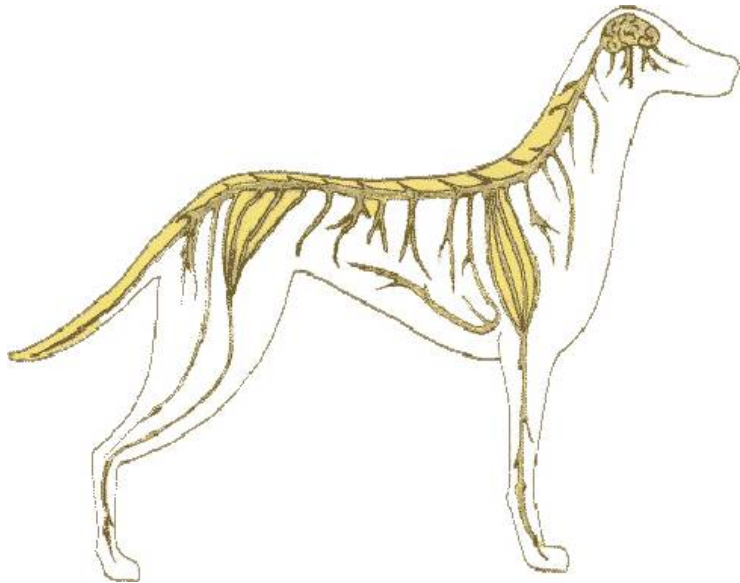
# Averaged Evoked Potentials

- EEG segments after each repeated stimulus are added together numerically.
- Most of the EEG activity is unrelated to the sensory stimulus, so it acts as random noise.
- When many of the EEG segments are summed, the noise components tend to cancel out (some positive, some negative), while the response to the stimulus tends to be reinforced.
- The signal remaining after the noise has been reduced is the averaged evoked potential.



# Tests of Auditory Function

# Brainstem Auditory Evoked Response (BAER)



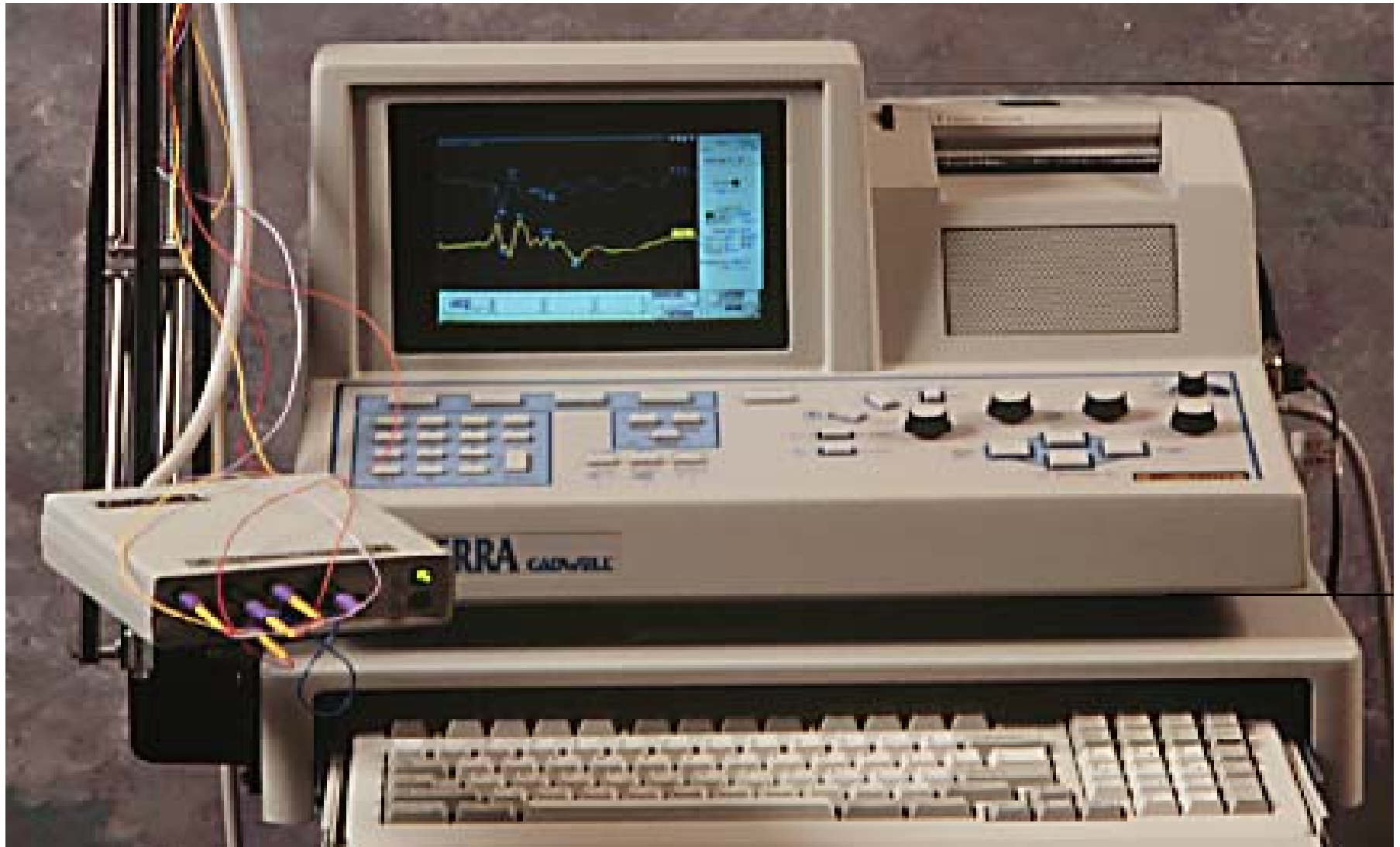
# BAER

- Used as a screening test to identify animals with unilateral or bilateral deafness
- Does not evaluate hearing at different frequencies
- Not used to determine hearing thresholds
- Does not quantify amount of partial hearing loss
- Subjects can be awake or anesthetized
- Results reflect activity of the cochlear nerve and the brainstem in response to click stimuli

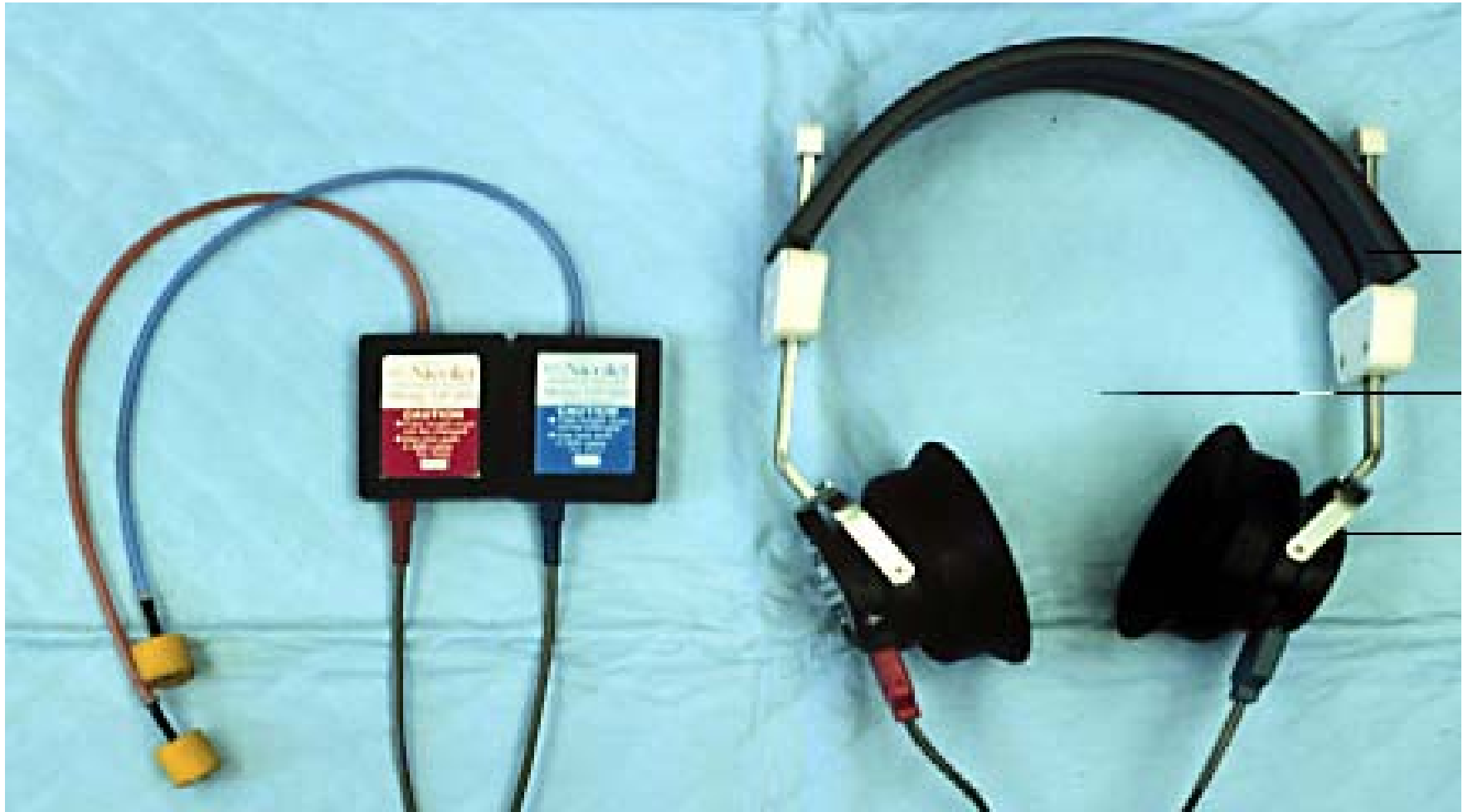
# BAER

- Stimulus: 100  $\mu$ sec air-conducted click,  $\sim 1$  /sec, 55-95 dB amplitude
- Recording electrodes: subdermal needle electrodes, vertex vs. tested ear, with ground over the neck
- Response duration:  $< 10$  msec
- Average  $\sim 1000$  responses
- Response pattern: vertex-positive peaks, named with Roman numerals
  - Peak I: cochlear nerve
  - Peaks II-V: brainstem

# Typical Electrodiagnostics System



# Insert Earphones (left) Work Better Than Headphones



# Testing Configuration



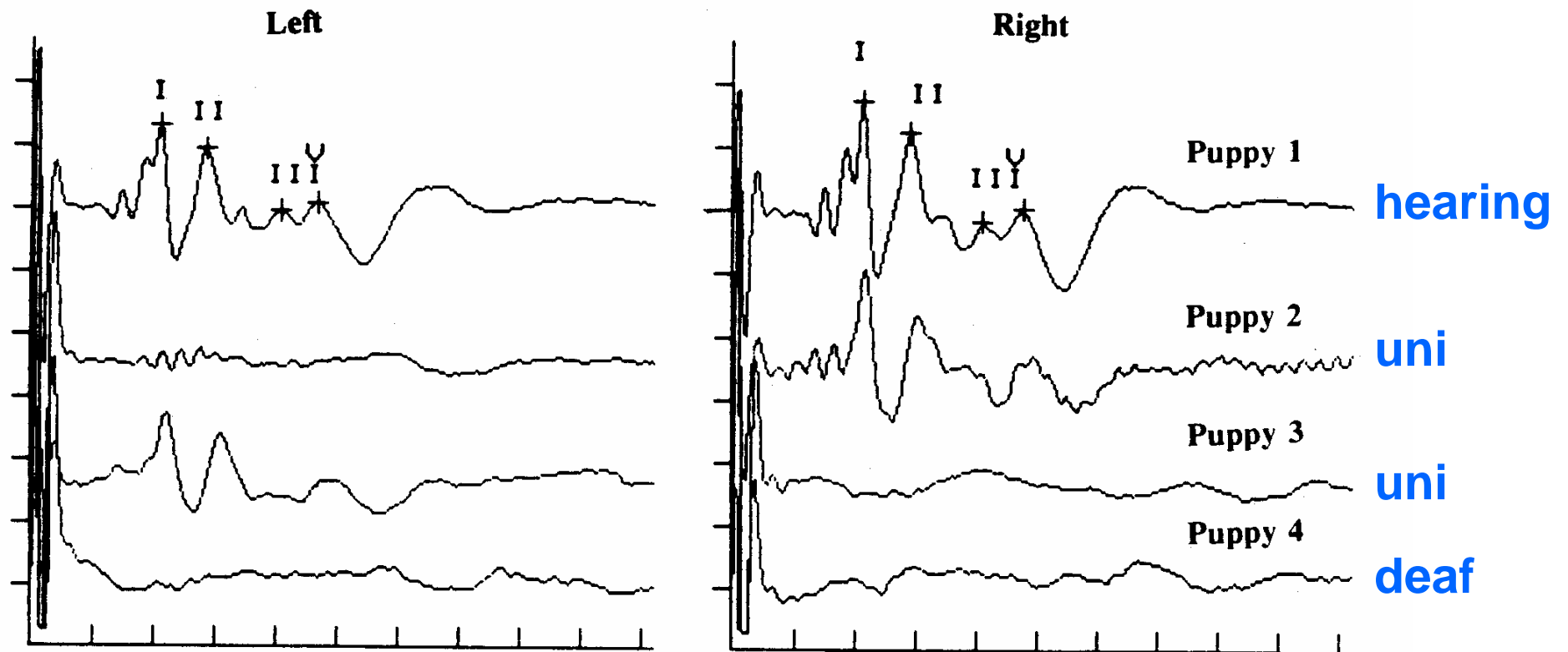


# Cats Usually Require A Restraint Bag





# Brainstem Auditory Evoked Responses





# Bone Transducer Used To Distinguish Conduction and Nerve Deafness

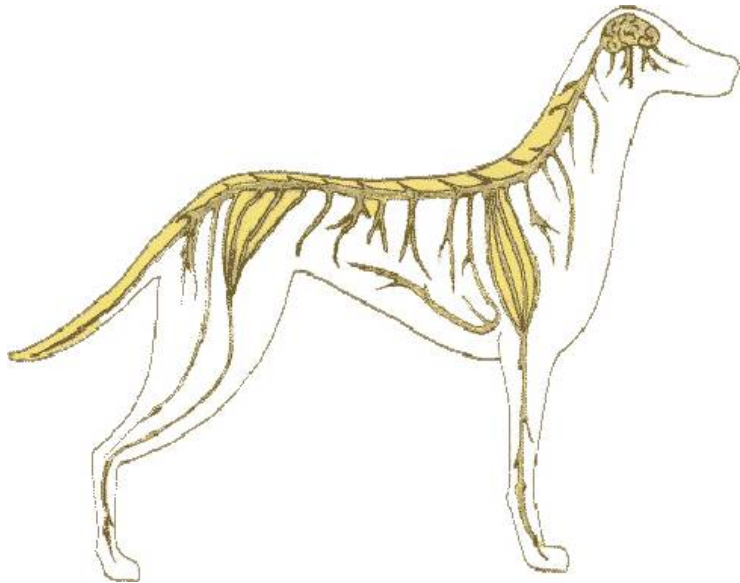


**Bone stimulus  
transducer**

# BAER Uses in Veterinary Medicine

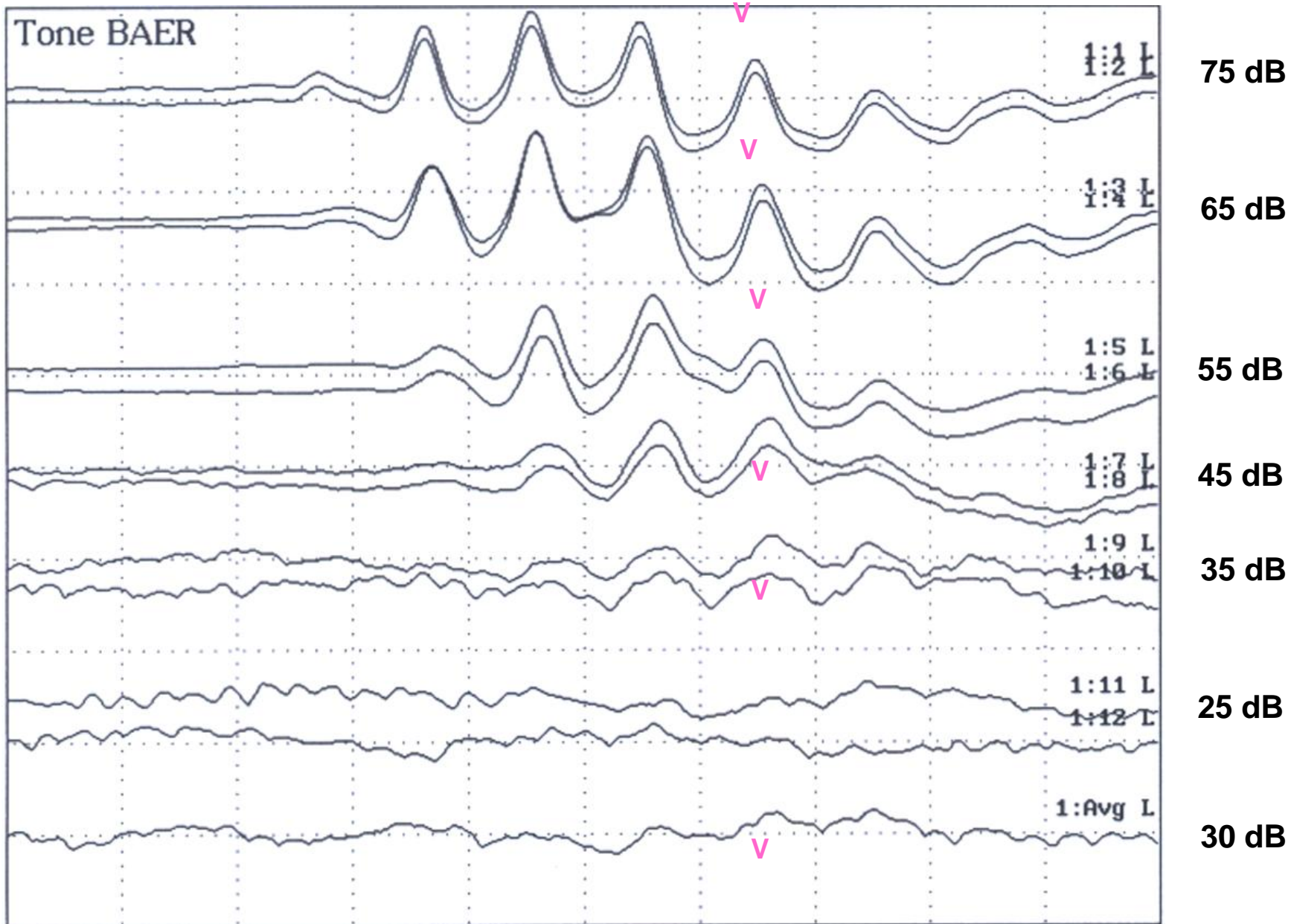
- Identifying peripheral deafness in puppies (or kittens) from breeds with congenital hereditary sensorineural deafness – Dalmatians, English setters, English cockers, bull terriers, etc. – for breeding decisions and puppy sale price (show quality vs. pet quality)
- Confirming late-onset sensorineural deafness – presbycusis, ototoxicity, noise damage (gun fire)
- Distinguishing between sensorineural and conduction deafness – bone transducer stimulator

# Frequency-Specific BAER



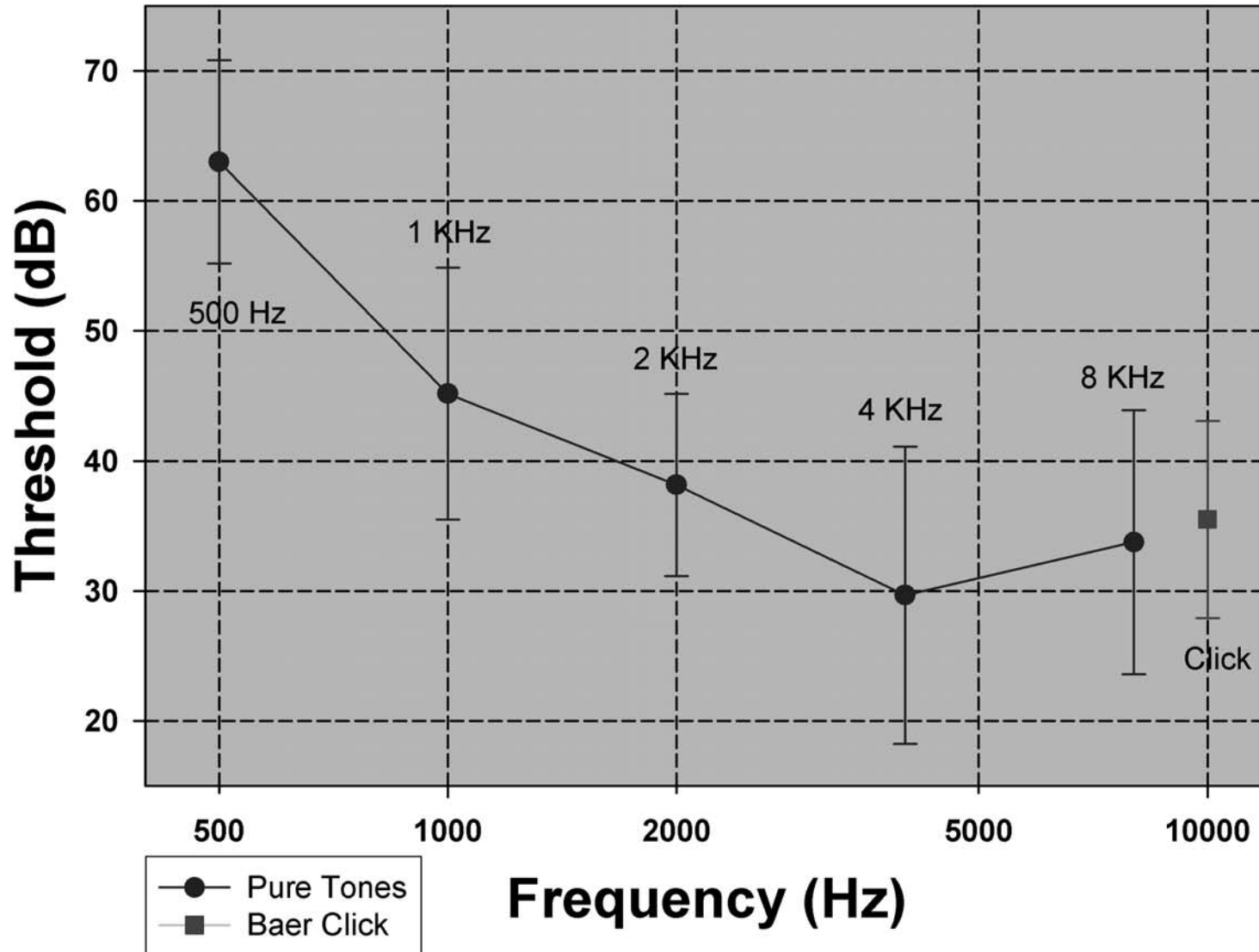
# FBAER

- Similar to BAER but using pure tone stimuli
- Hearing thresholds determined under anesthesia
- Specific frequencies tested from 500 Hz to 8 kHz, based on equipment capacity
- Testing requires several hours, so not used routinely in the clinic

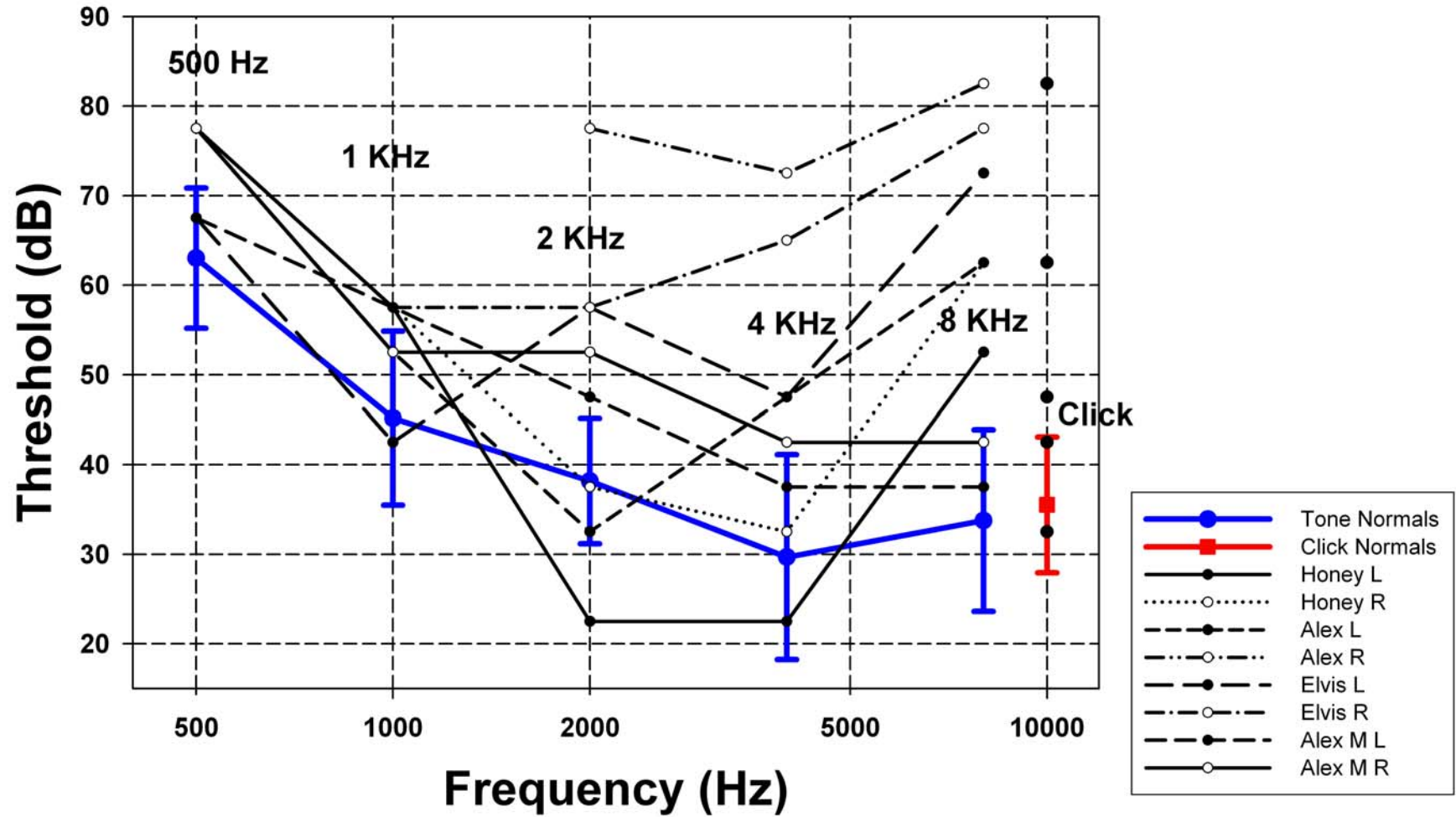




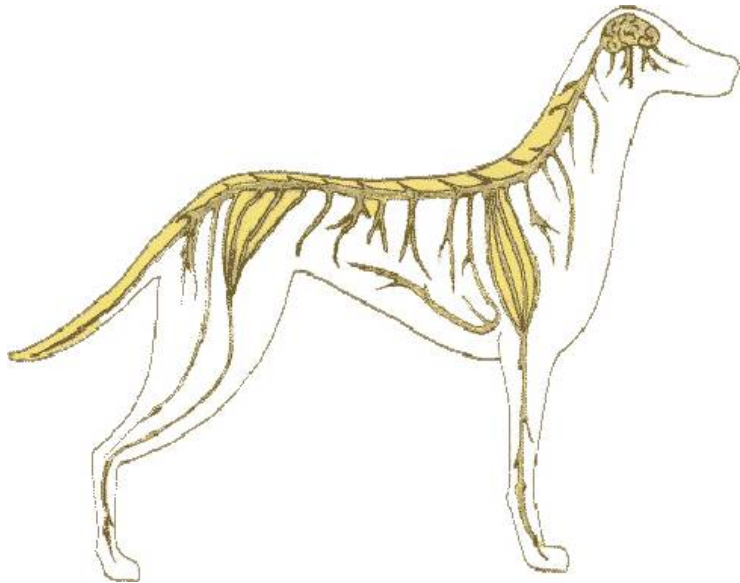
# Hearing Threshold by Frequency (n=30 ears)



# Hearing Threshold For Frequency And Click Stimuli In Geriatric Dogs



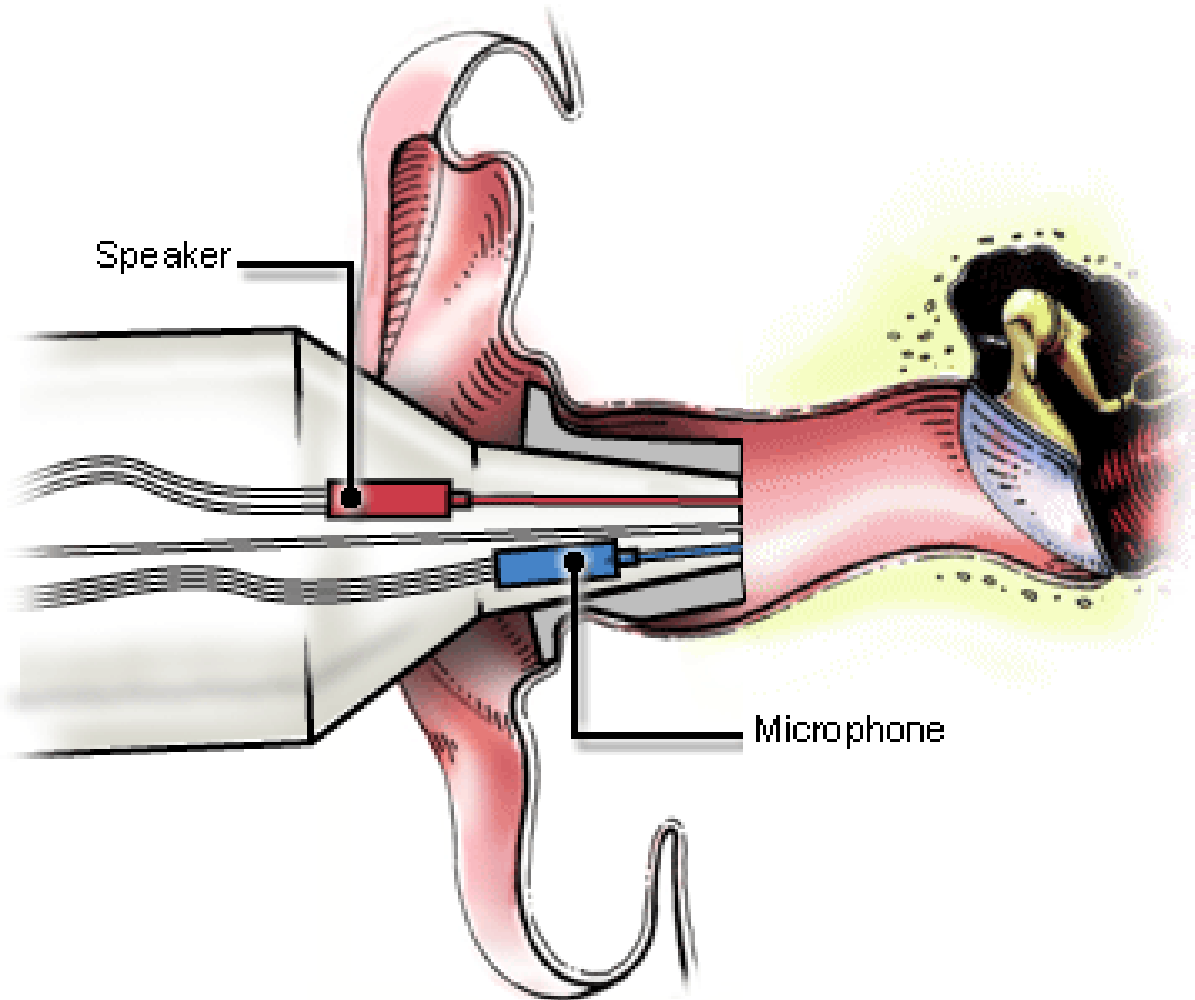
# **Distortion Product Otoacoustic Emission (DPOAE)**



# DPOAEs

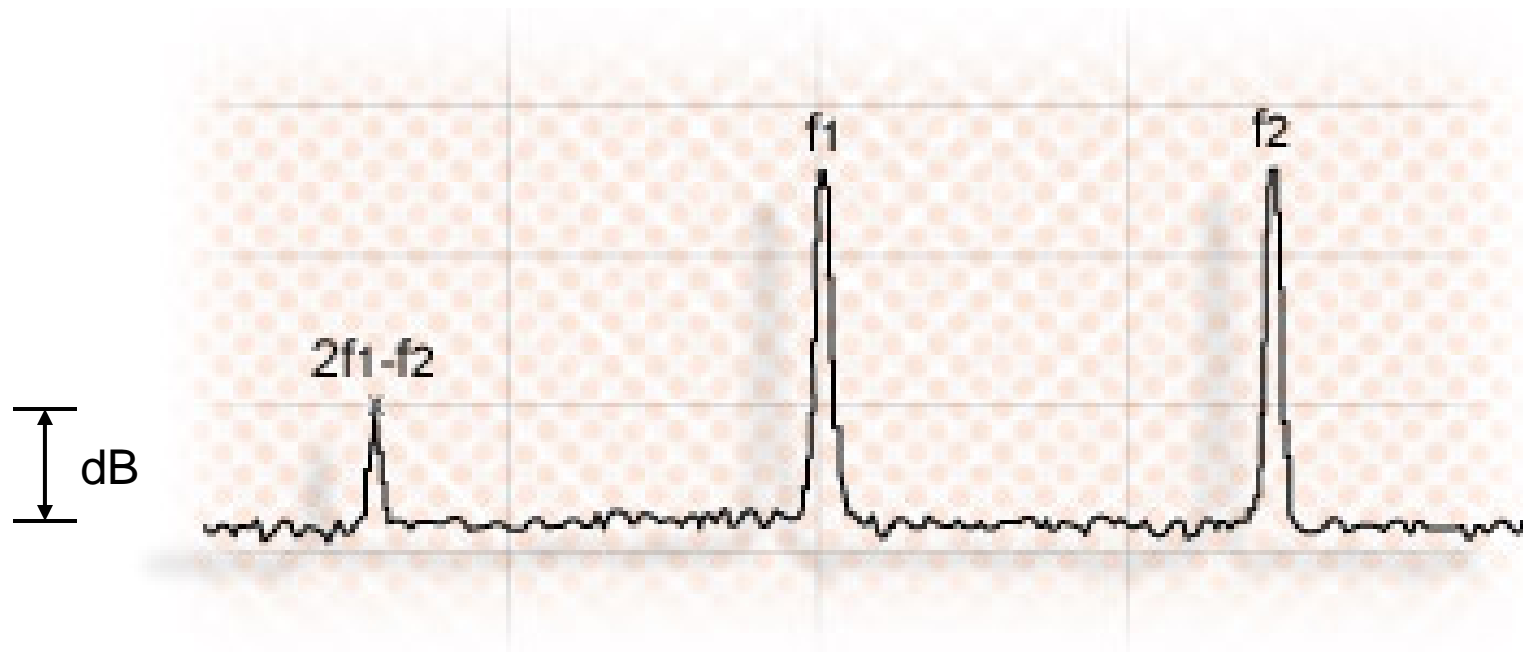
- Information about hearing at different frequencies can now be obtained with non-invasive tests without using sedation
- When a pure tone is presented into an ear, all normal ears produce a tone in response: an evoked otoacoustic emission (OAE)
- If two tones are presented, a different third tone is produced: the distortion product OAE
- OAE are generated by cochlear outer hair cells
- Cochlea is tested by varying the frequencies from 1-12 kHz

# Otoacoustic Emissions



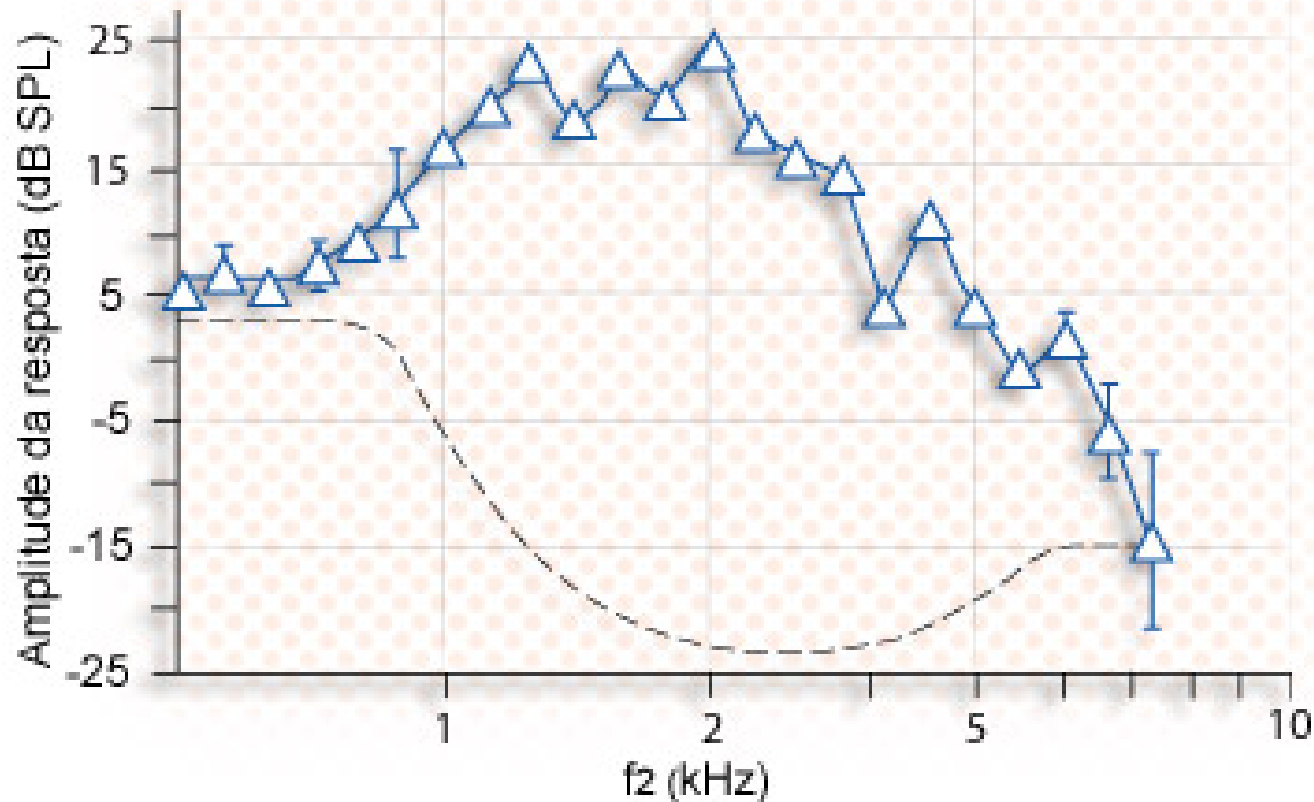
Probe for OAE recordings, with a speaker emitting the stimulating sounds and a microphone to record the returning OAEs.

# Distortion Product = $2f_1 - f_2$



Distortion products (DP) reflect the non-linearity of a normal cochlea. In response to sound stimulation by two frequencies ( $f_1$  and  $f_2$ ), different DPOAEs can be recorded: the most frequently used in clinics and research is  $2f_1 - f_2$ . DP amplitude in dB is measured.

# Distortion Product Audiogram



$2f_1-f_2$  amplitude plotted as a function of  $f_2$  frequency.

**Note a clearly identifiable response (against the noise, bottom dotted line) for frequencies between 1 and 6 kHz. Below 1 kHz, active mechanisms, if any, are not strong enough to allow any recording. Above 6 kHz, the lack of DPOAEs reflects equipment limitations.**

# DPOAE Test Probe



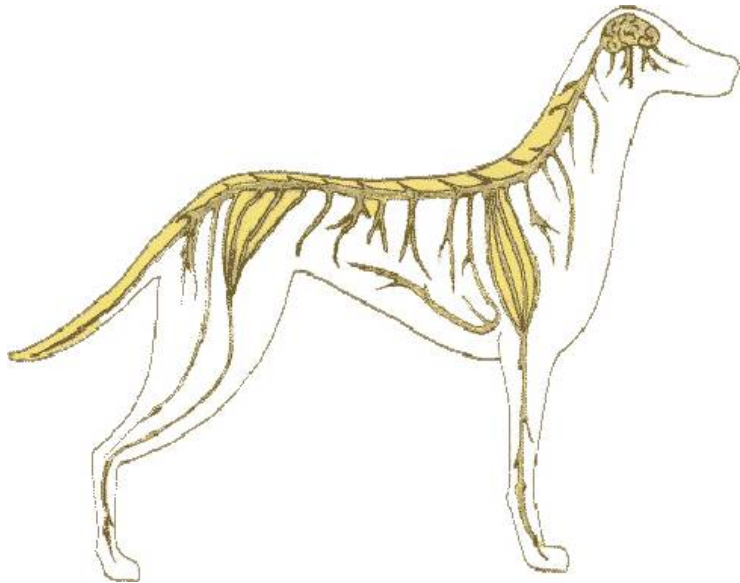


DPOAEs are currently being evaluated for use in dogs and cats as a possible replacement for the BAER.



# Tests of Visual Function

# Electroretinogram (ERG)



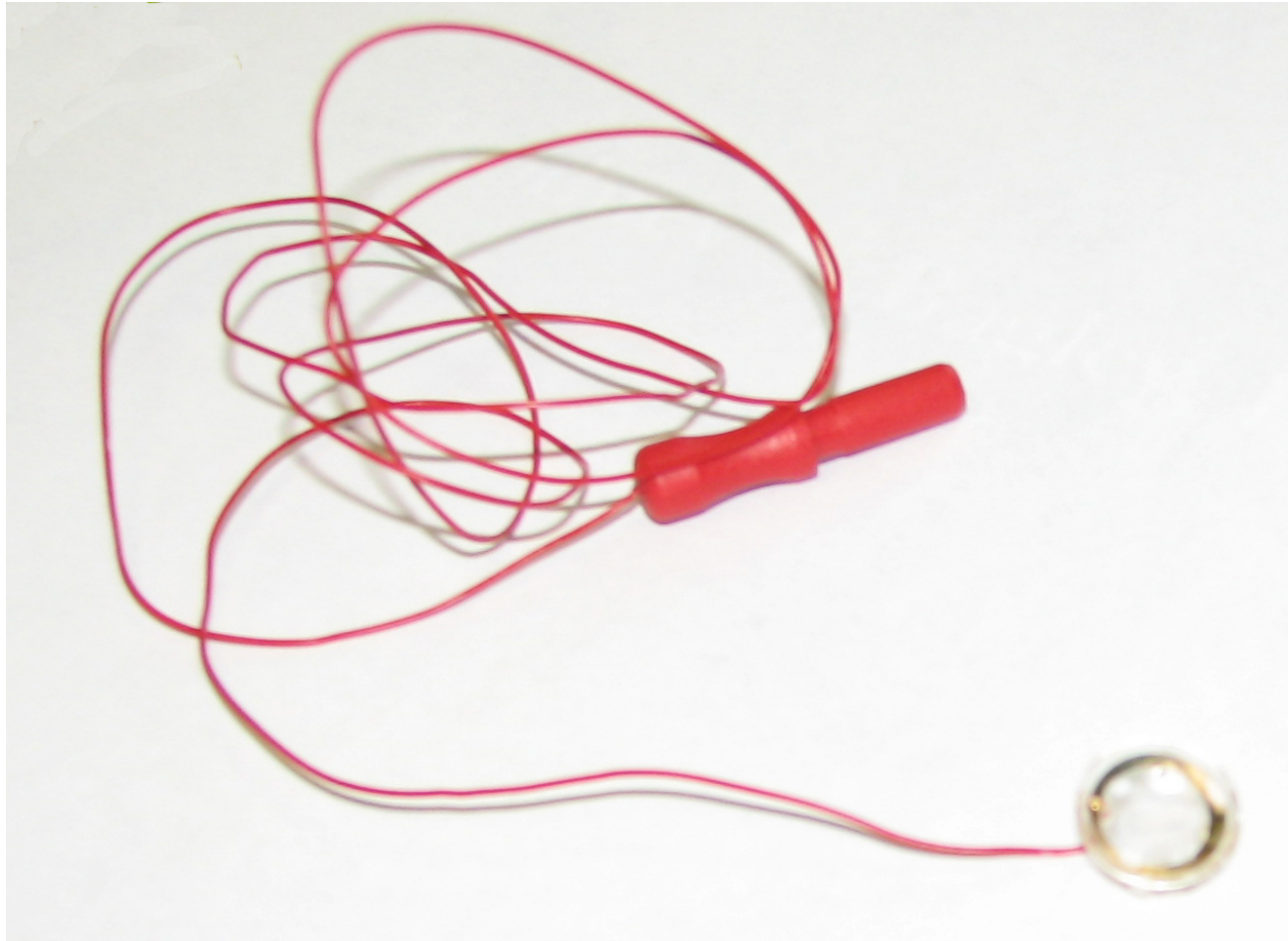
# Electroretinogram (ERG)

- The ERG is a non-invasive measure of the response of retinal photoreceptors to light flashes
- Multiple responses can be averaged for clarity, but photo-bleaching of the receptors reduces the response amplitude, so a single flash is typical
- In some cases scotopic components (rods – dark adapted) and photopic components (cones – light adapted) can be differentiated

# Electroretinogram (ERG)

- Stimulus: stroboscopic light flash in a darkened room (or alternating pattern)
- Recording site: contact lens electrode on the cornea vs. vertex
- Duration: <100 msec
- a, b, and c waves; measure a-b amplitude

# Contact Lens Electrode



# Flash Photostimulator

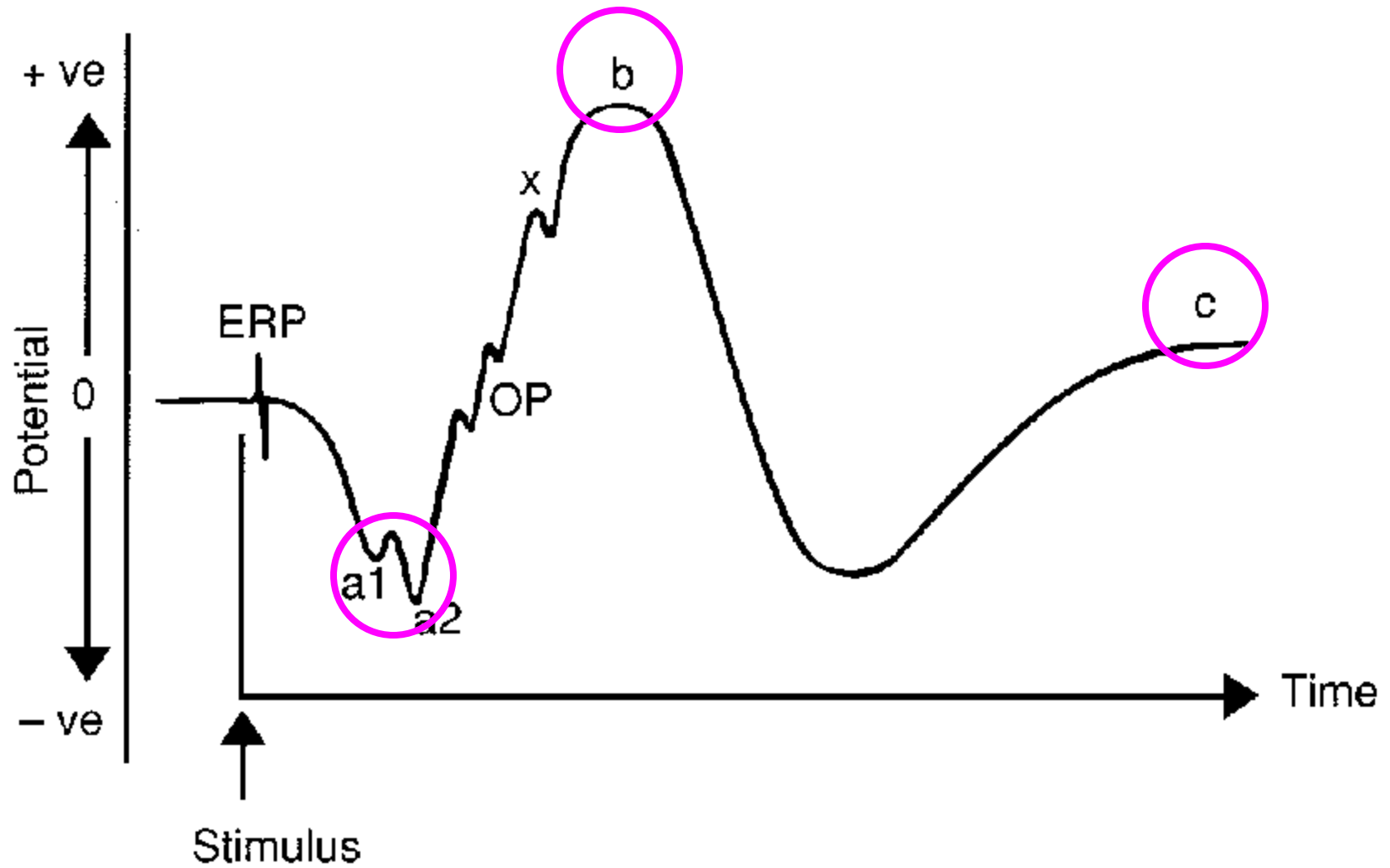




# ERG Testing







ERP – early receptor potential  
OP – oscillatory potentials

# Electroretinogram (ERG)

- The a-wave is thought to originate in the photoreceptors (rods and cones)
- The b-wave is thought to originate in the retinal inner nuclear layer, from bipolar cells or Müller glial cells
- The c-wave is produced by the pigmented epithelial cells; it is only seen with dark adaptation (rod-specific)
- No component from ganglion cells/optic nerve

# ERG In a Dog With Glaucoma

OWNER'S NAME:: [REDACTED]

SEX:: F

DATE:: 01/27/87

CASE HISTORY::

GLAUCOMA

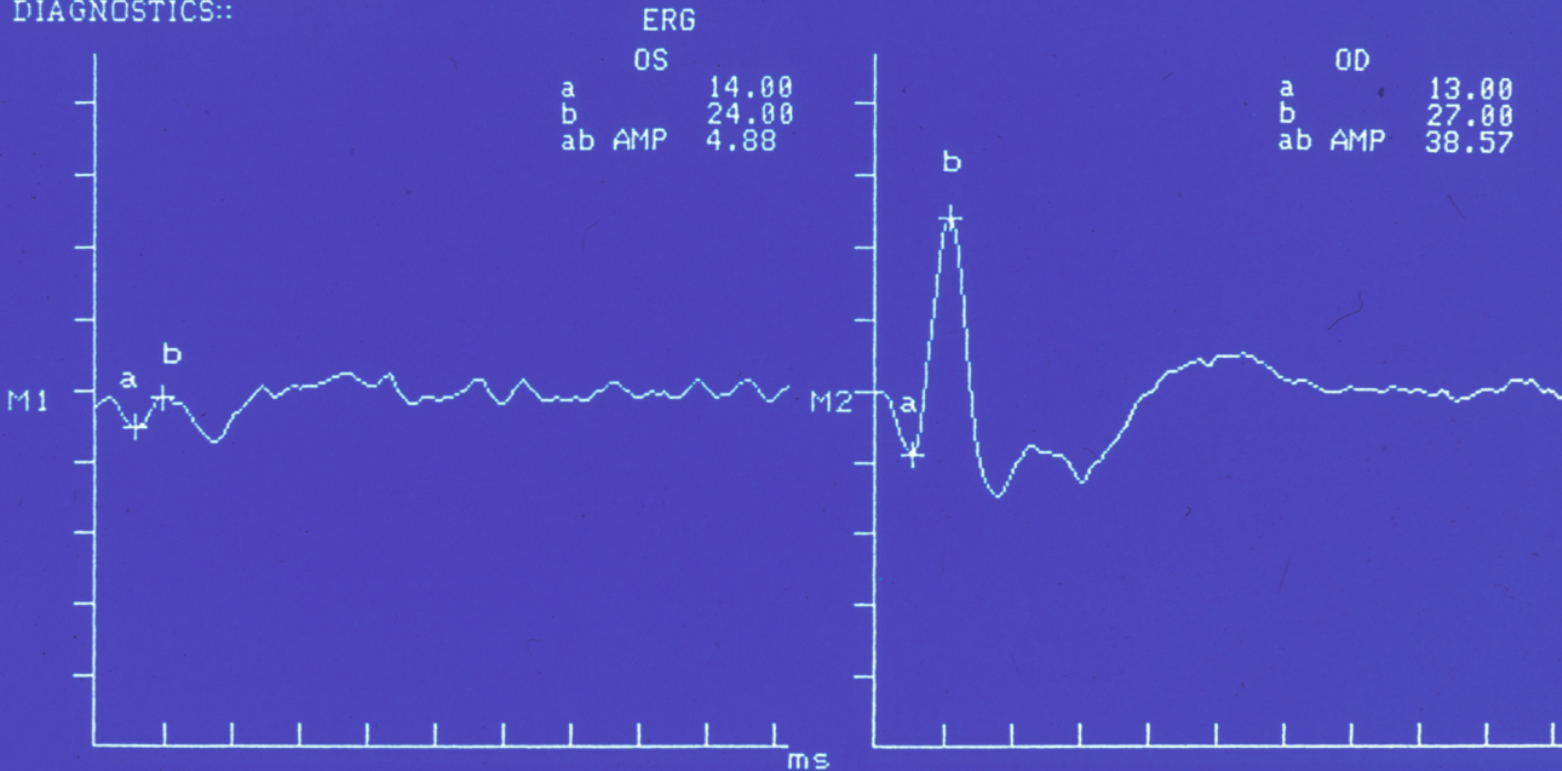
NO DILATION

DIAGNOSTICS::

PATIENT ID:: 31968

SPECIES/BREED:: CAN/CKR

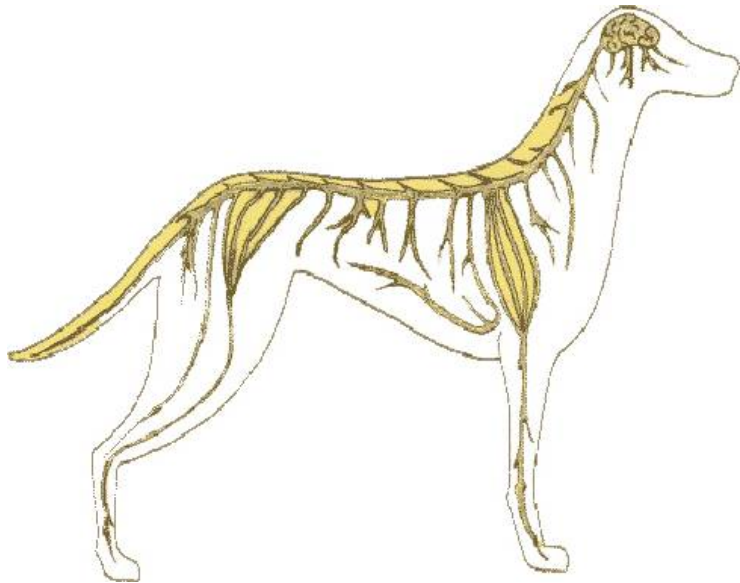
EXAMINER:: DR.G.M. STRAIN



# ERG Uses in Veterinary Medicine

- Testing retinal function prior to cataract surgery, to avoid surgery when no functional retina remains – greatest use
- Useful in evaluating progressive retinal atrophy (PRA)
- Useful in differentiating peripheral vs. central blindness

# Visual Evoked Potential (VEP)



# Visual Evoked Potential (VEP)

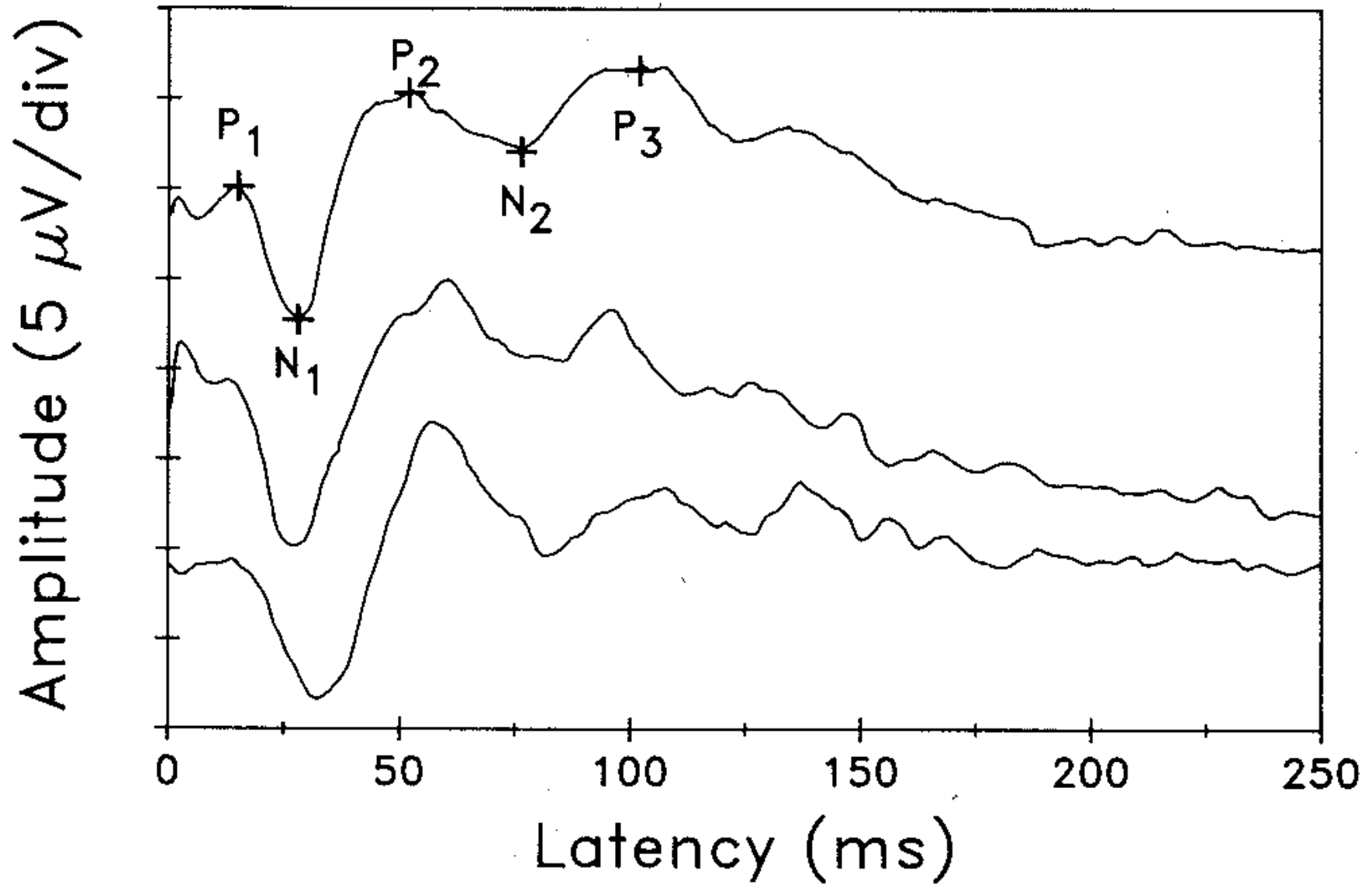
- For assessment of post-retinal visual pathways
- Stimulus: stroboscopic light flash to one eye or alternating stripes or a checkerboard in a darkened room
- Recording site: occipital cortex vs. the forehead
- Duration: 100 - 200 msec
- Average ~ 100 responses



# VEP Testing

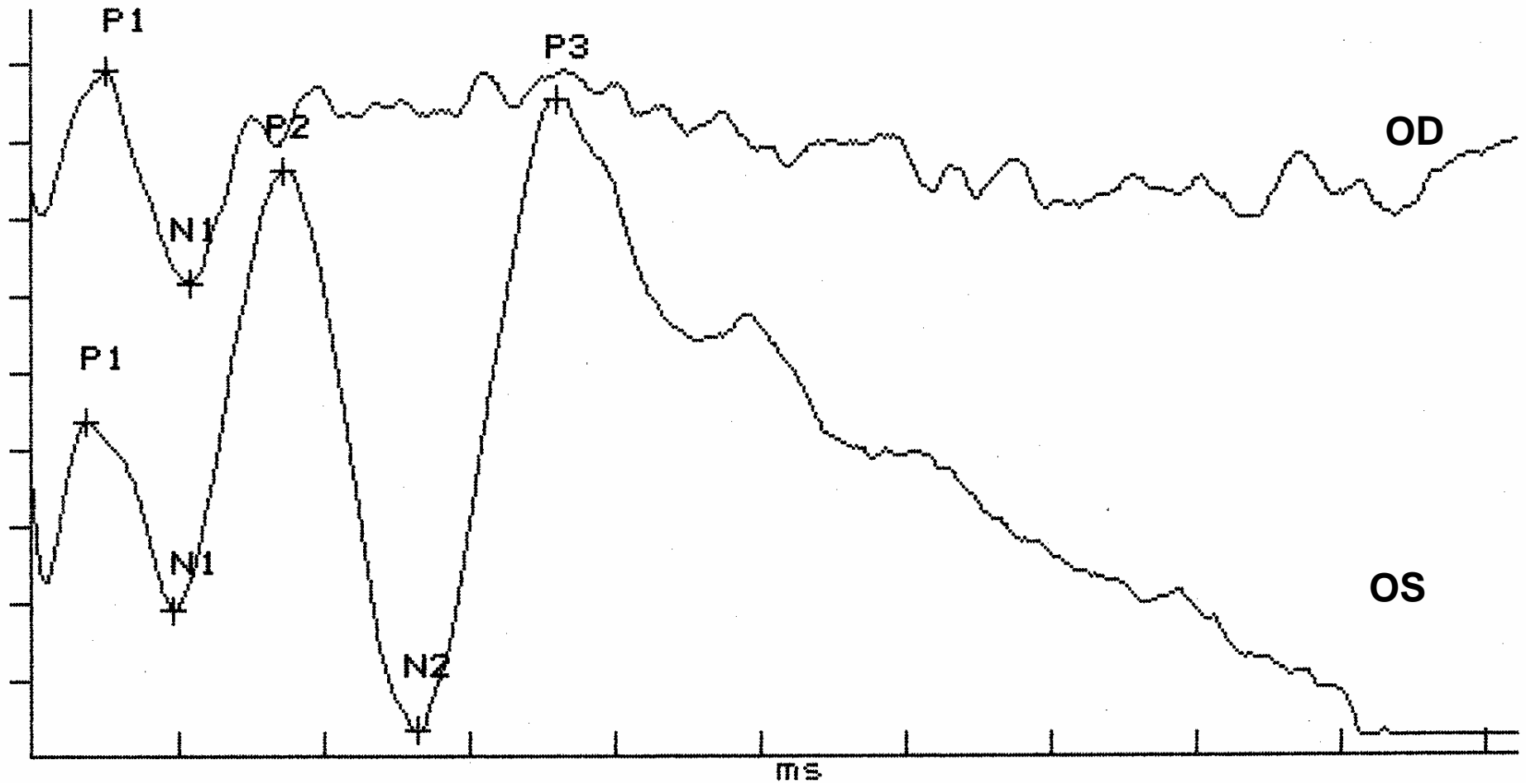


# Canine Visual Evoked Potentials

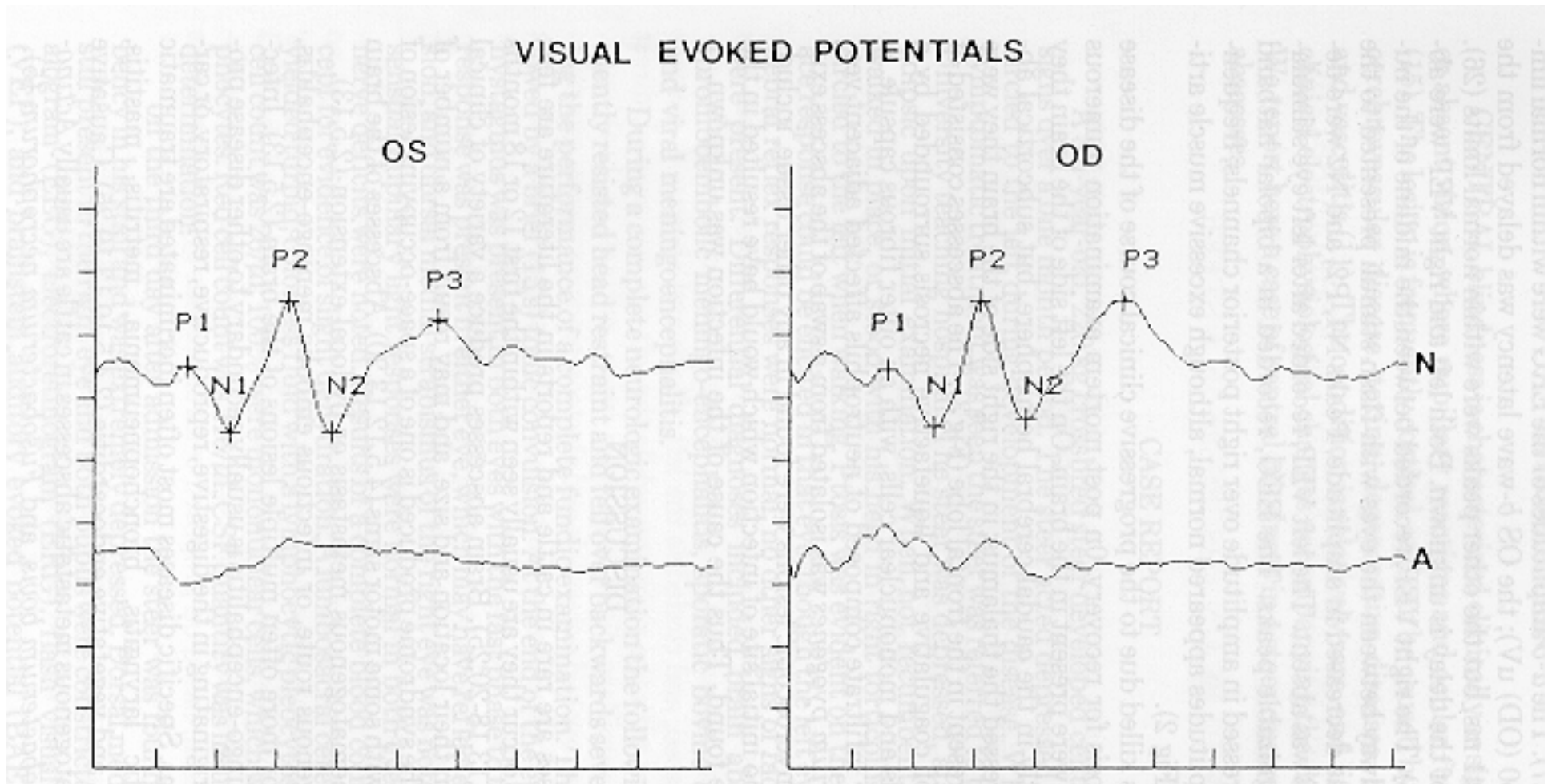




# Right Optic Neuritis - Yorkie



# Steer – Clinically Blind With Multiple Brain Abscesses



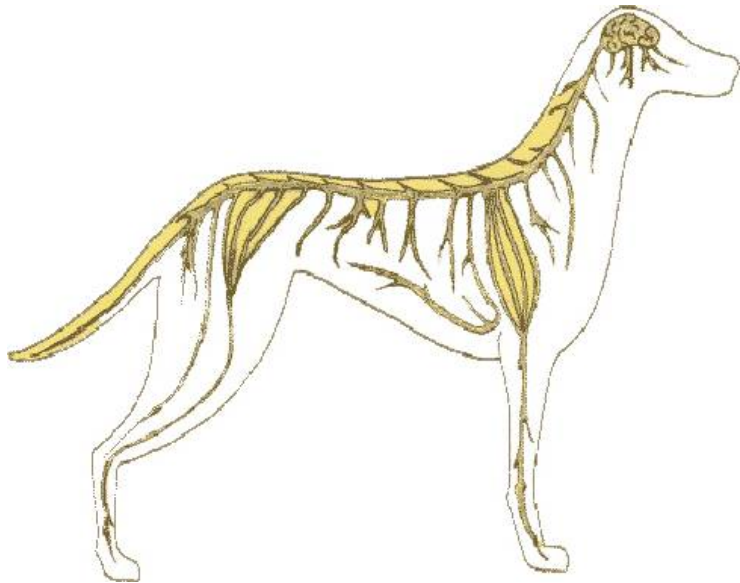
# VEP Uses in Veterinary Medicine

- Limited at present
- Assessment of cortical (central) blindness: polioencephalomalacia (thiamine deficiency in ruminants), abscesses, etc.
- Neurotoxicology research



# **Tests of Somatosensory – Motor System Function**

# Somatosensory Evoked Potential (VEP)

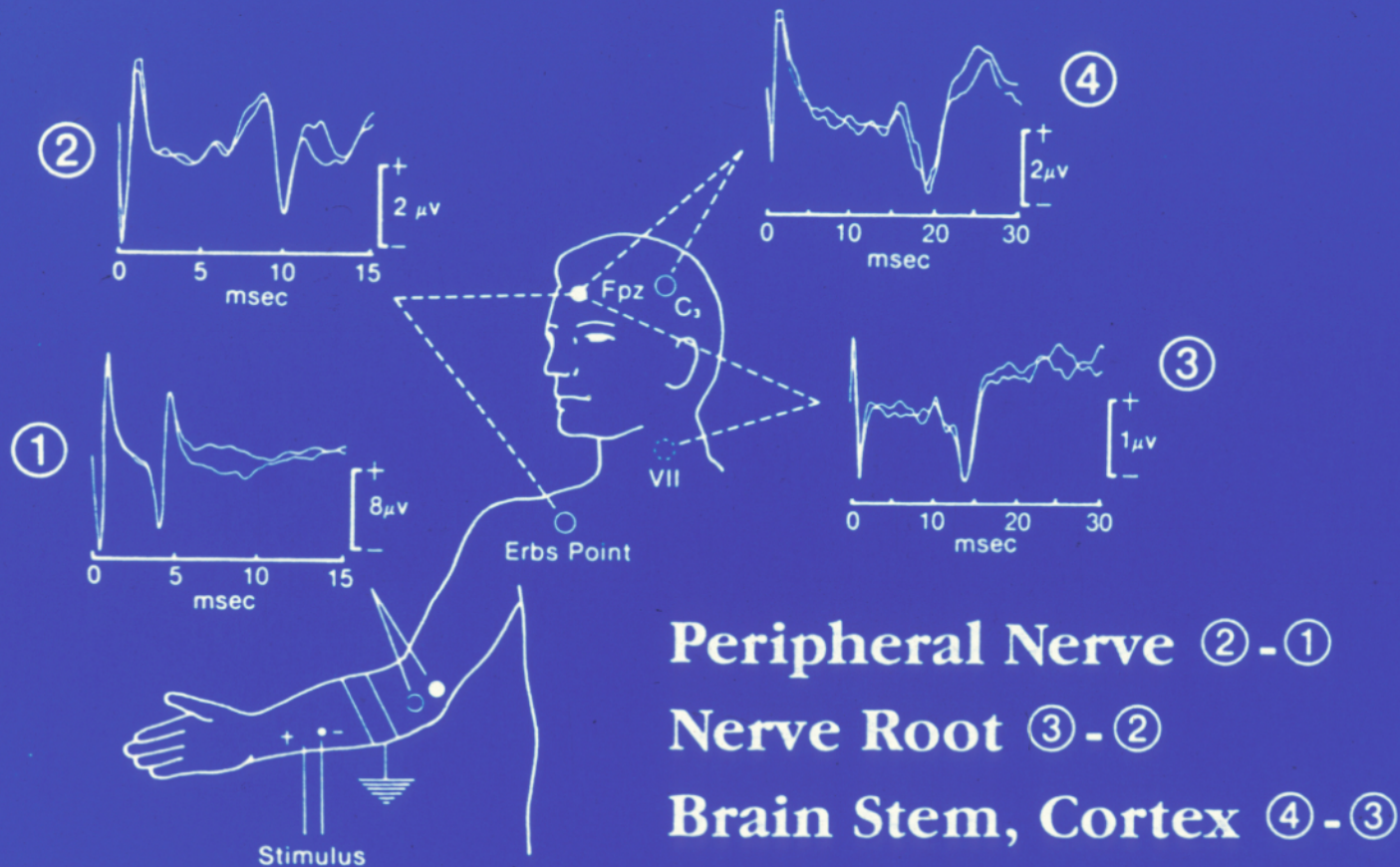


# Somatosensory Evoked Potential (SEP)

- Activity traveling from a peripheral sensory nerve, to the spinal cord, to the somatosensory cortex
- Stimulus: electrical shock to cutaneous sensory nerves
- Recording site: contralateral post-central gyrus vs. neutral point (ear or forehead); also over spinal cord
- Duration: approximately 100 msec
- Average ~ 100 responses

# Median Nerve SEP

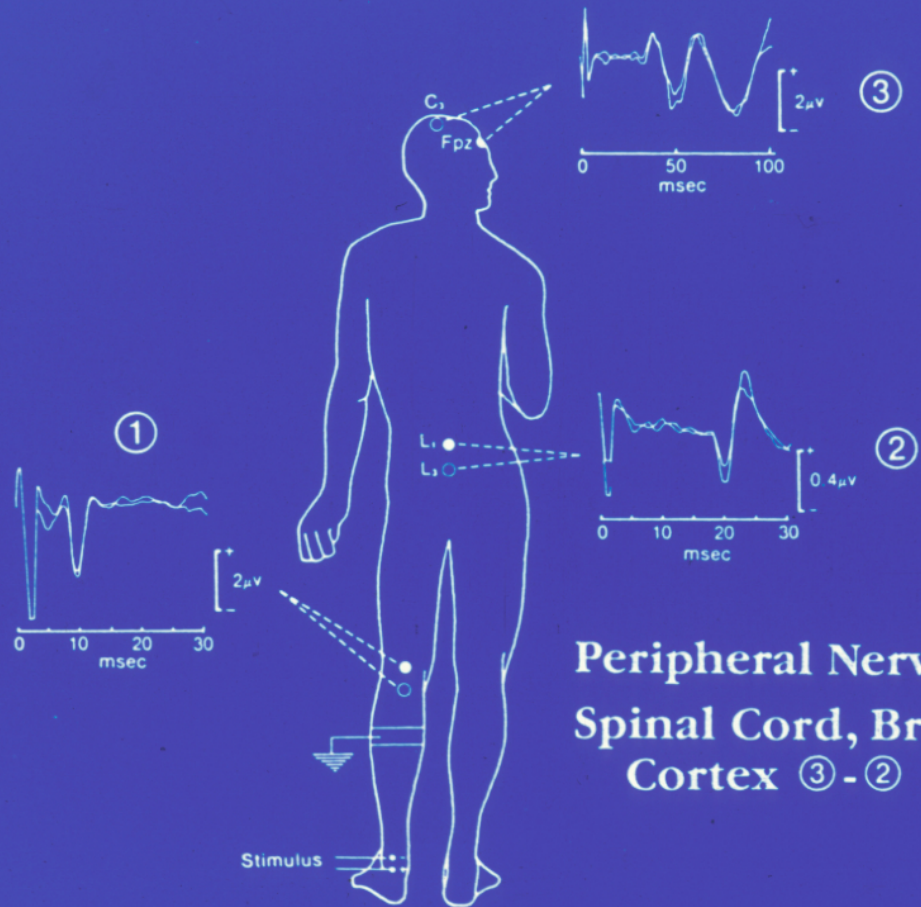
## Median Nerve Stimulation





# Tibial Nerve SEP

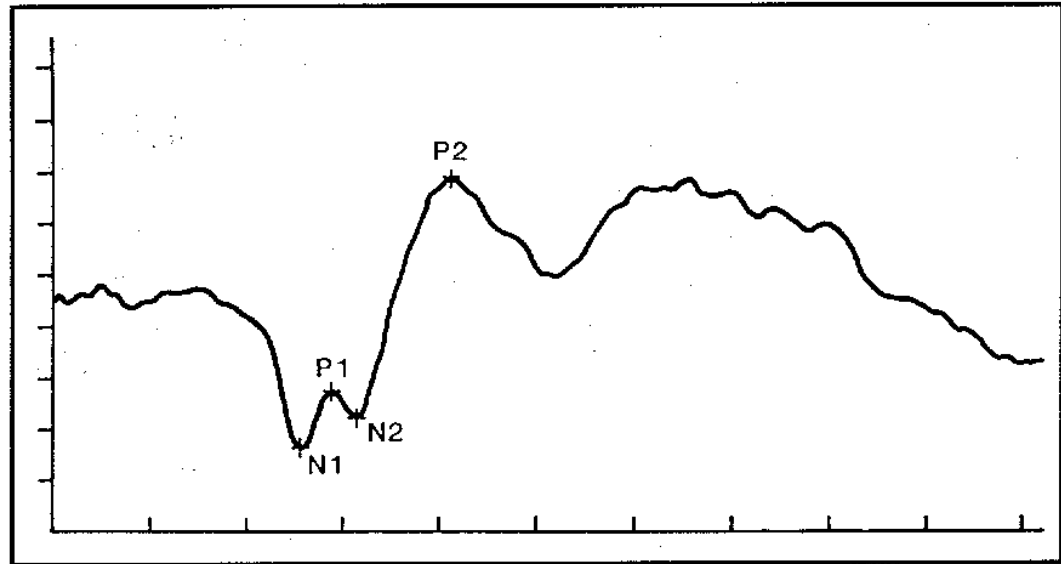
## Posterior Tibial Nerve Stimulation



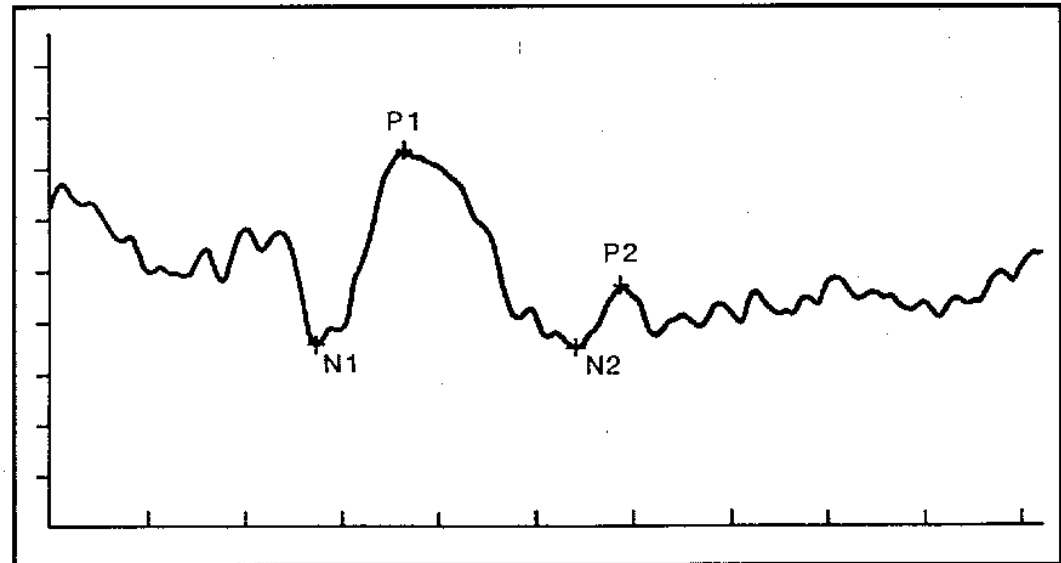
Peripheral Nerve ②-①  
Spinal Cord, Brainstem,  
Cortex ③-②



## Equine ulnar SEP



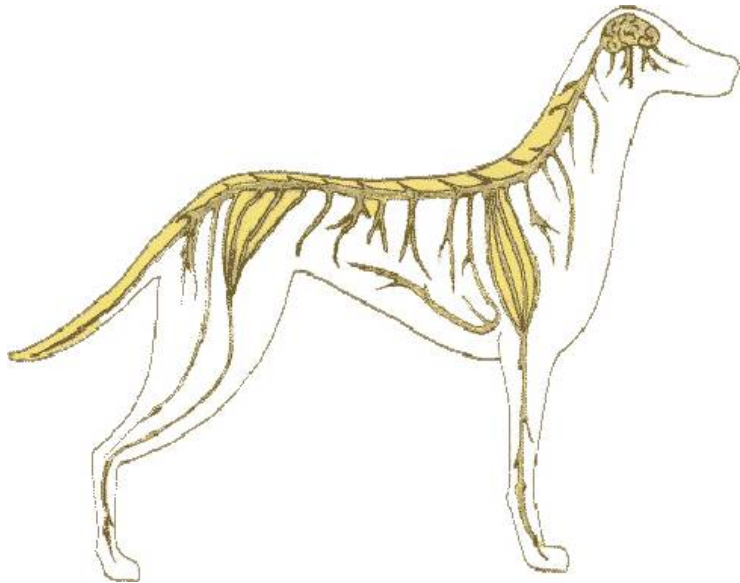
## Equine tibial SEP



# SEP Uses in Veterinary Medicine

- Limited at present
- Afferent sensory pathway assessment  
(motor pathways are usually more of concern)

# Electromyogram (EMG)



# Electromyogram (EMG)

- The EMG is a recording of muscle activity (spontaneous or evoked) using a needle electrode inserted in the muscle belly
- Generally performed under anesthesia, but not required
- Electrodes: positive, reference, ground
- Responses fed through an audio amplifier
- Components of needle EMG exam:
  - Insertional activity
  - Resting activity
  - Motor unit action potentials

# Electromyogram (EMG)

- Routine examination sequence:
  - Major muscles of hind limb
  - Paravertebral muscles (L7-C1)
  - Major muscles of forelimb
  - Muscles of head – if indicated
- Anatomic knowledge of nerve roots and nerves important

## EMG electrodes

- Active: muscle belly
- Reference: SQ
- Ground: SQ

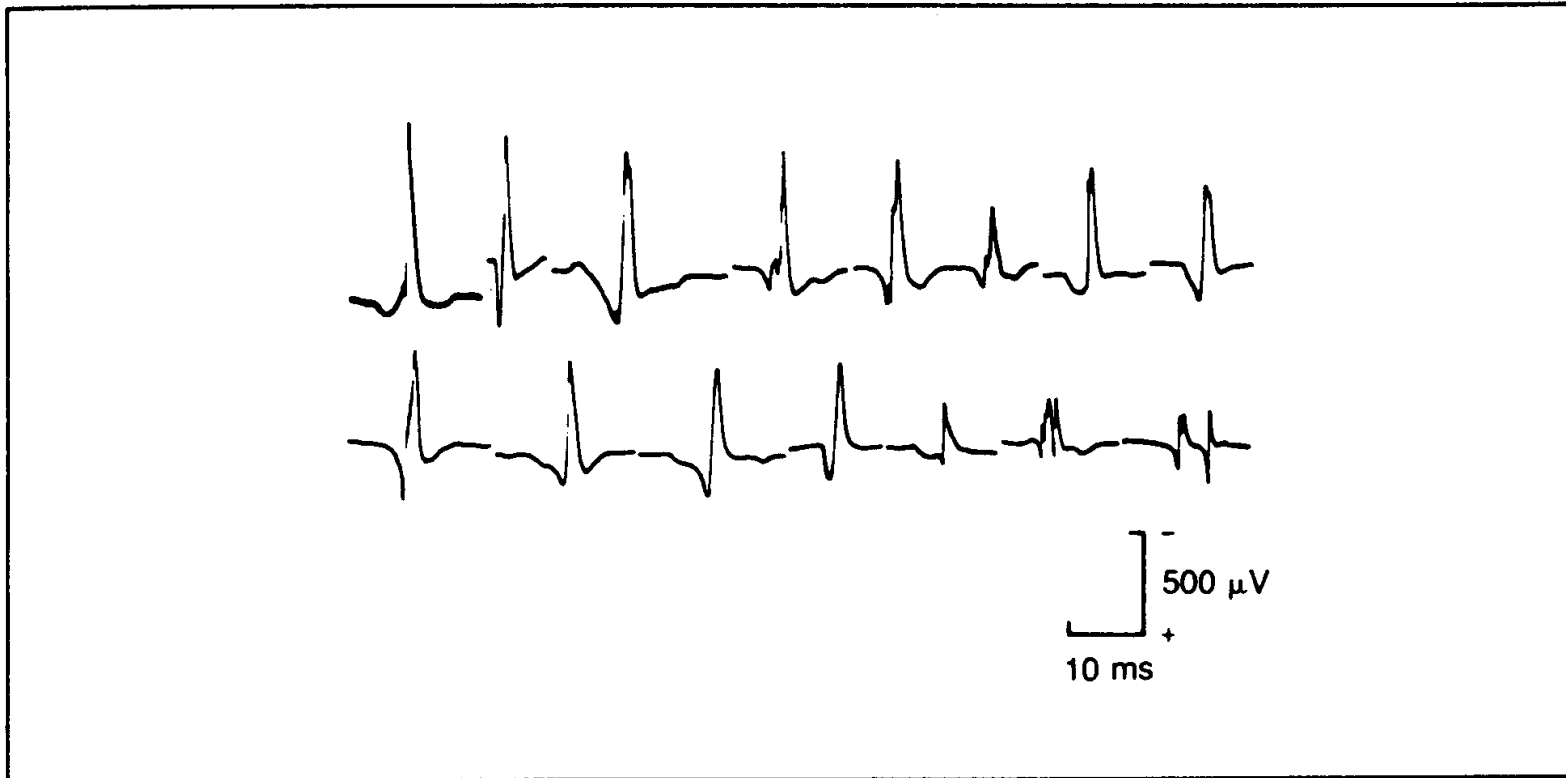


# Normal Muscle Responses

- Insertion activity: mechanically induced injury potentials, ~10-20 msec, ends when movement stops, crackle
- Motor unit action potentials (MUAP): electrical activity of a single motor unit; crisp popping sound, motor boat
- End plate potentials: spontaneous electrical activity when needle is near a neuromuscular junction; hissing sound

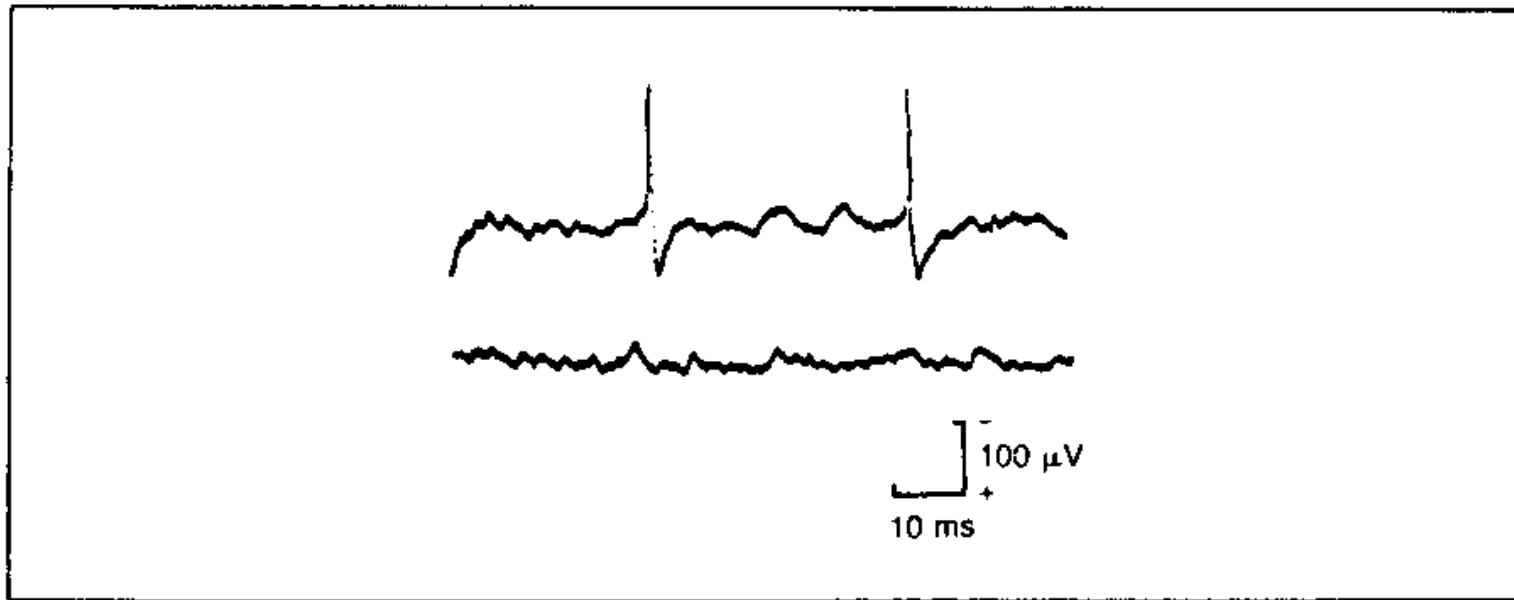


## MOTOR UNIT ACTION POTENTIALS



**Appendix Figure 4-28.** A motor unit action potential (MUAP) is the action potential reflecting the electric activity of a single anatomic motor unit. It is the compound action potential of those muscle fibers within the recording range of an electrode. With voluntary muscle contraction, the action potential is characterized by its consistent appearance with, and relationship to, the force of contraction. The following parameters should be specified, quantitatively if possible, after the recording electrode is placed so as to minimize the *rise time* (which by convention should be less than 0.5 ms).

## END-PLATE ACTIVITY



**Appendix Figure 4-19.** Spontaneous electric activity recorded with a needle electrode close to muscle end-plates. May be either of two forms: 1. *Monophasic* (upper and lower traces): Low-amplitude ( $10\text{--}20\ \mu\text{V}$ ), short-duration ( $0.5\text{--}1\ \text{ms}$ ), monophasic (negative) potentials that occur in a dense, steady pattern and are restricted to a localized area of the muscle. Because of the multitude of different potentials occurring, the exact frequency, although appearing to be high, cannot be defined. These nonpropagated potentials are probably *miniature end-plate potentials* recorded extracellularly. This form of end-plate activity has been referred to as *end-plate noise* or *sea shell sound* (*sea shell noise* or *roar*). 2. *Biphasic* (upper trace): Moderate-amplitude ( $100\text{--}300\ \mu\text{V}$ ), short-duration ( $2\text{--}4\ \text{ms}$ ), biphasic (negative-positive) spike potentials that occur irregularly in short bursts with a high frequency ( $50\text{--}100\ \text{Hz}$ ), restricted to a localized area within the muscle. These propagated potentials are generated by muscle fibers excited by activity in nerve terminals. These potentials have been referred to as *biphasic spike potentials*, *end-plate spikes*, and, incorrectly, *nerve potentials*.

# Responses in Disease

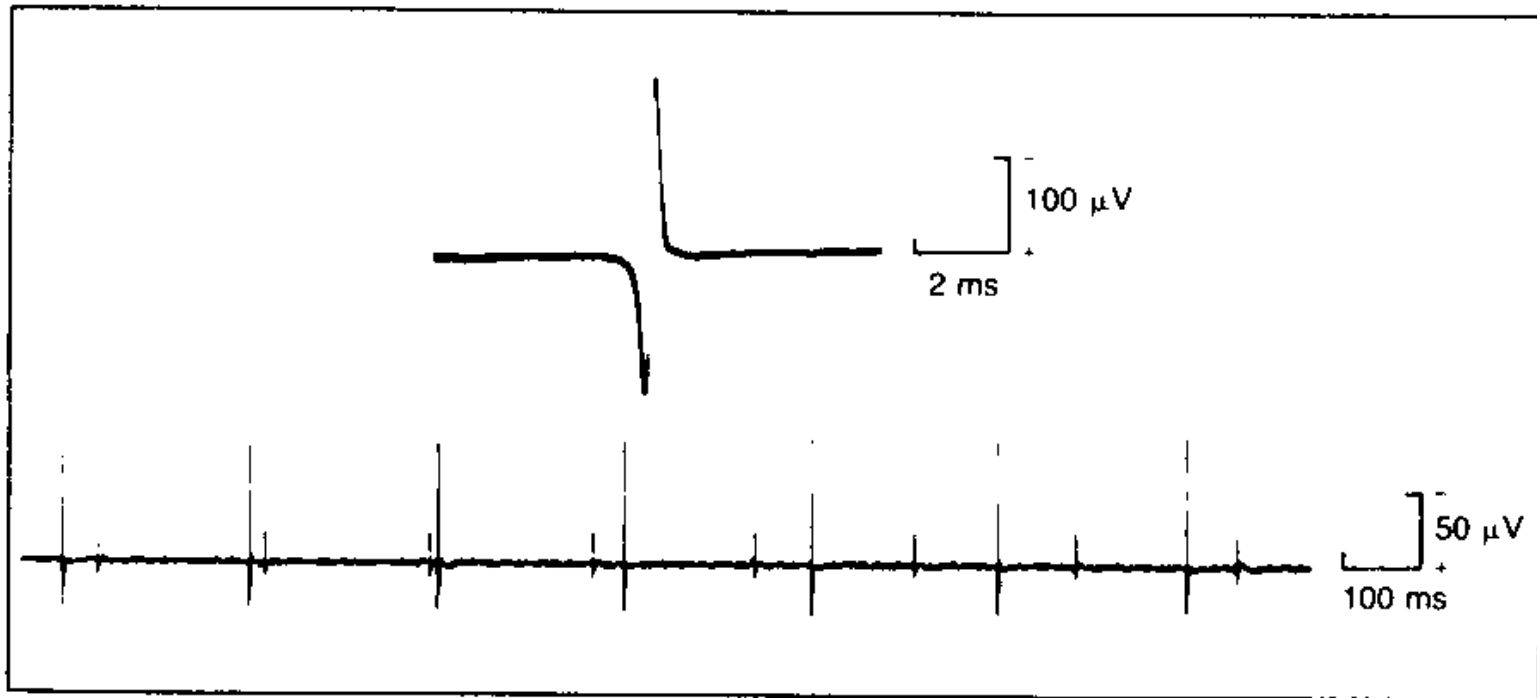
**Usually not diagnostic of a specific disease**

- Prolonged insertion activity – outlasts needle movement by as much as several minutes
- Indicates irritability of the muscle or instability of the muscle membrane
- Seen with denervation, myotonic disorders, or myositis

# Responses in Disease

- Fibrillation potentials – electrical activity from contraction (spontaneous or needle induced) of a spontaneously contracting (fibrillating) single muscle fiber – “fibs”
  - Enhanced by heat, passive stretching, neostigmine
  - Biphasic, smaller than MUAPs
  - May still be present in fibrosed muscle
  - Sound: rain on a tin roof; eggs frying
- Denervation or lower motor neuron disease
- Present after 5 days in small animals or 12-16 days in large animals

## FIBRILLATION POTENTIAL

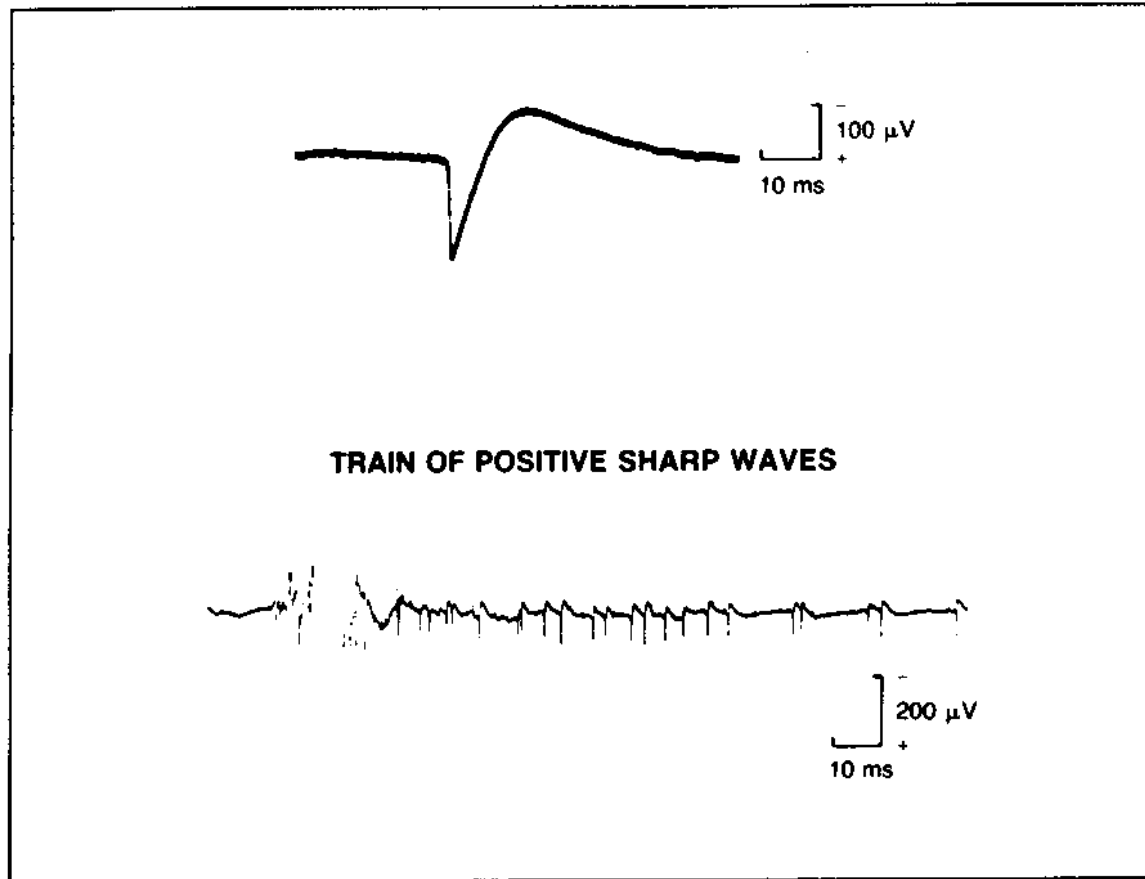


**Appendix Figure 4-20.** The top trace shows a single *fibrillation potential* waveform. The bottom trace shows the pattern of discharge of two other *fibrillation potentials* which differ with respect to amplitude and discharge frequency. A *fibrillation potential* is the electric activity associated with a spontaneously contracting (fibrillating) muscle fiber. It is the action potential of a single muscle fiber. The action potentials may occur spontaneously or after movement of the needle electrode. The potentials usually fire at a constant rate, although a small proportion fire irregularly. Classically, the potentials are biphasic spikes of short duration (usually less than 5 ms) with an initial positive phase and a peak-to-peak amplitude of less than 1 mV. When recorded with concentric or monopolar needle electrode, the firing rate has a wide range (1-50 Hz) and often decreases just before cessation of an individual discharge. A high-pitched regular sound is associated with the discharge of fibrillation potentials and has been described in the old literature as "rain on a tin roof." In addition to this classic form of fibrillation potentials, *positive sharp waves* may also be recorded from fibrillating muscle fibers when the potential arises from an area immediately adjacent to the needle electrode.

# Responses in Disease

- Positive sharp waves – fast positive wave followed by a slow negative wave; may be spontaneous or needle-induced, near a fibrillating fiber
  - Frequently occur in trains
  - Smaller than MUAPs
  - May persist as long as muscle fibers are present
  - Musical tone, idling motor, diving airplane
- Denervation or lower motor neuron disease
- Present after 5 days in small animals or 12-16 days in large animals

## POSITIVE SHARP WAVE



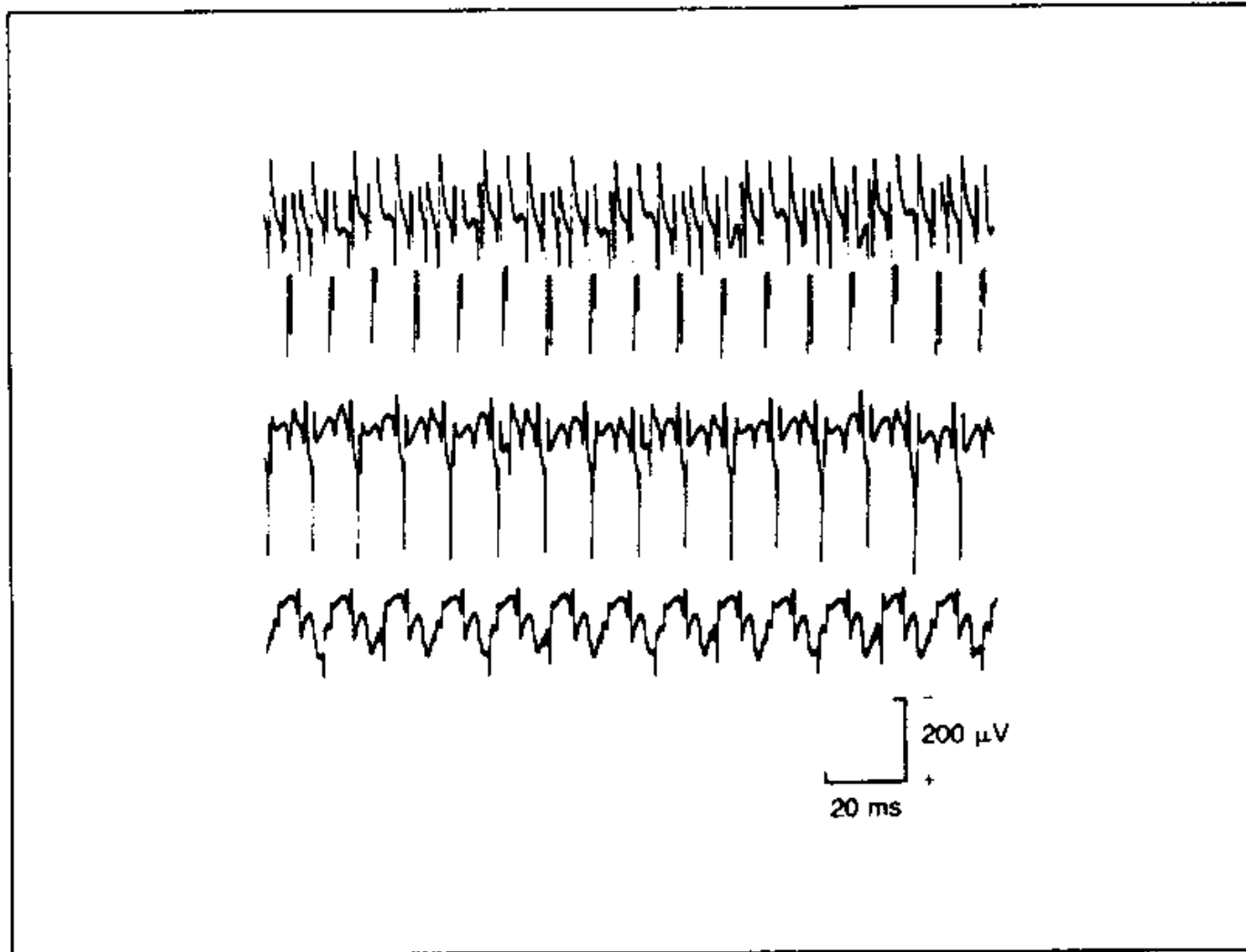
**Appendix Figure 4-21.** The top trace shows a single *positive sharp wave*. The bottom trace shows the pattern of initial discharge of a number of different *positive sharp waves* after movement of the recording needle electrode in denervated muscle. A *positive sharp wave* is a biphasic, positive-negative *action potential* initiated by needle movement and recurring in a uniform, regular pattern at a rate of 1 to 50 Hz; the discharge frequency may decrease slightly just before cessation of discharge. The initial positive deflection is rapid (<1 ms), its duration is usually less than 5 ms, and the amplitude is up to 1 mV. The negative phase is of low amplitude, with a duration of 10 to 100 ms. A sequence of positive sharp waves is commonly referred to as a *train of positive sharp waves*. Positive sharp waves can be recorded from the damaged area of fibrillating muscle fibers. Its configuration may result from the position of the needle electrode which is felt to be adjacent to the depolarized segment of a muscle fiber injured by the electrode. Note that the positive sharp waveform is not specific for muscle fiber damage. *Motor unit action potentials* and potentials in *myotonic discharges* may have the configuration of positive sharp waves.

# Responses in Disease

- Complex repetitive discharge – series of uniform polyphasic action potentials
  - Spontaneous or needle-induced
  - Possibly due to bared muscle spindles
  - Sound: banjo-like twang
  - Also known as bizarre high frequency discharge



## COMPLEX REPETITIVE DISCHARGE

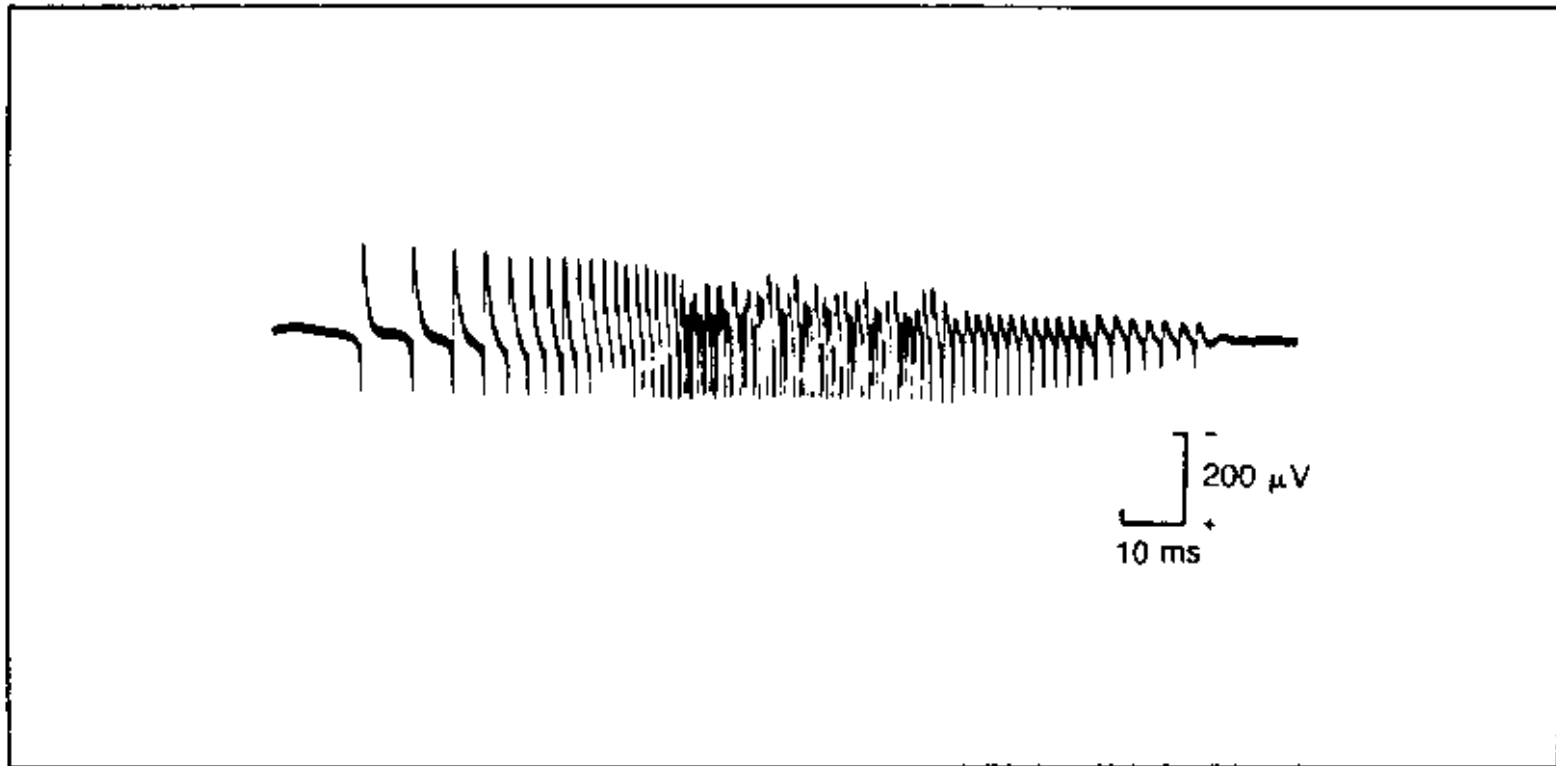


**Appendix Figure 4-23.** A *complex repetitive discharge* is a polyphasic or serrated action potential that may begin spontaneously or after a needle movement. They have a uniform frequency, shape, and amplitude, with abrupt onset, cessation, or change in configuration. Amplitude ranges from 100  $\mu\text{V}$  to 1 mV and frequency of discharge from 5 to 100 Hz. This term is preferred to *bizarre high frequency discharge*, *bizarre repetitive discharge*, *bizarre repetitive potential*, *near constant frequency trains*, *pseudomyotonic discharge* and *synchronized fibrillation*.

# Responses in Disease

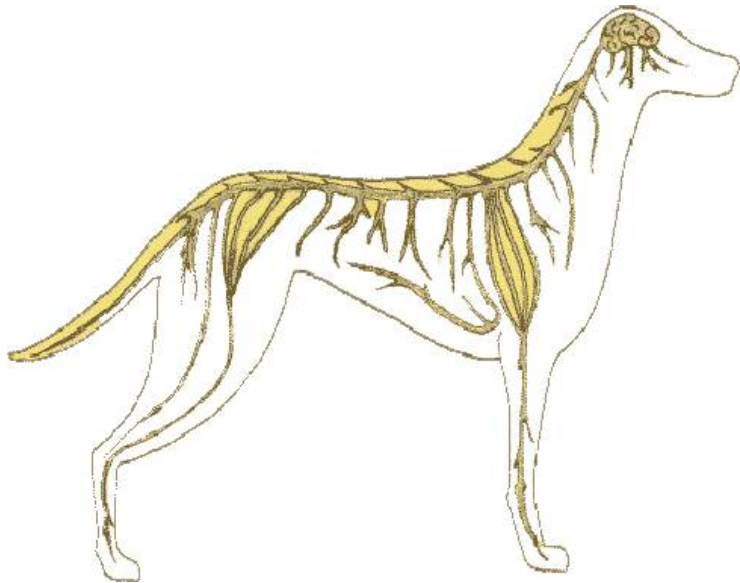
- Myotonic discharge – repetitive discharges that wax and wane in amplitude and frequency
  - Spontaneous or needle-induced
  - Sound: diving airplane, dive bomber
- Accompany myotonic muscle contractions

## MYOTONIC DISCHARGE



**Appendix Figure 4-22.** Repetitive discharge at rates of 20 to 80 Hz are of two types: (1) biphasic (positive-negative) spike potentials less than 5 ms in duration resembling *fibrillation potentials*, (2) positive waves of 5 to 20 ms in duration resembling *positive sharp waves*. Both potential forms are recorded after needle insertion, after voluntary muscle contraction or after muscle percussion, and are due to independent, repetitive discharges of single muscle fibers. The amplitude and frequency of the potentials must both wax and wane to be identified as myotonic discharges. This change produces a characteristic musical sound in the audio display of the electromyograph due to the corresponding change in pitch, which has been likened to the sound of a dive bomber. Contrast with *waning discharge*.

# Nerve Conduction Velocity (NCV)



# NCV

- Measurement of nerve conduction velocity can help differentiate between peripheral nerve disease and muscle disease
- Motor NCV (MNCV) measurements are used more commonly than sensory NCV (SNCV) measurements because motor function can be more important than sensory function, and SNCV are more difficult to measure
- Performed under anesthesia
- EMG recorded in response to electrical stimulation of the nerve that innervates it

# Electrodes

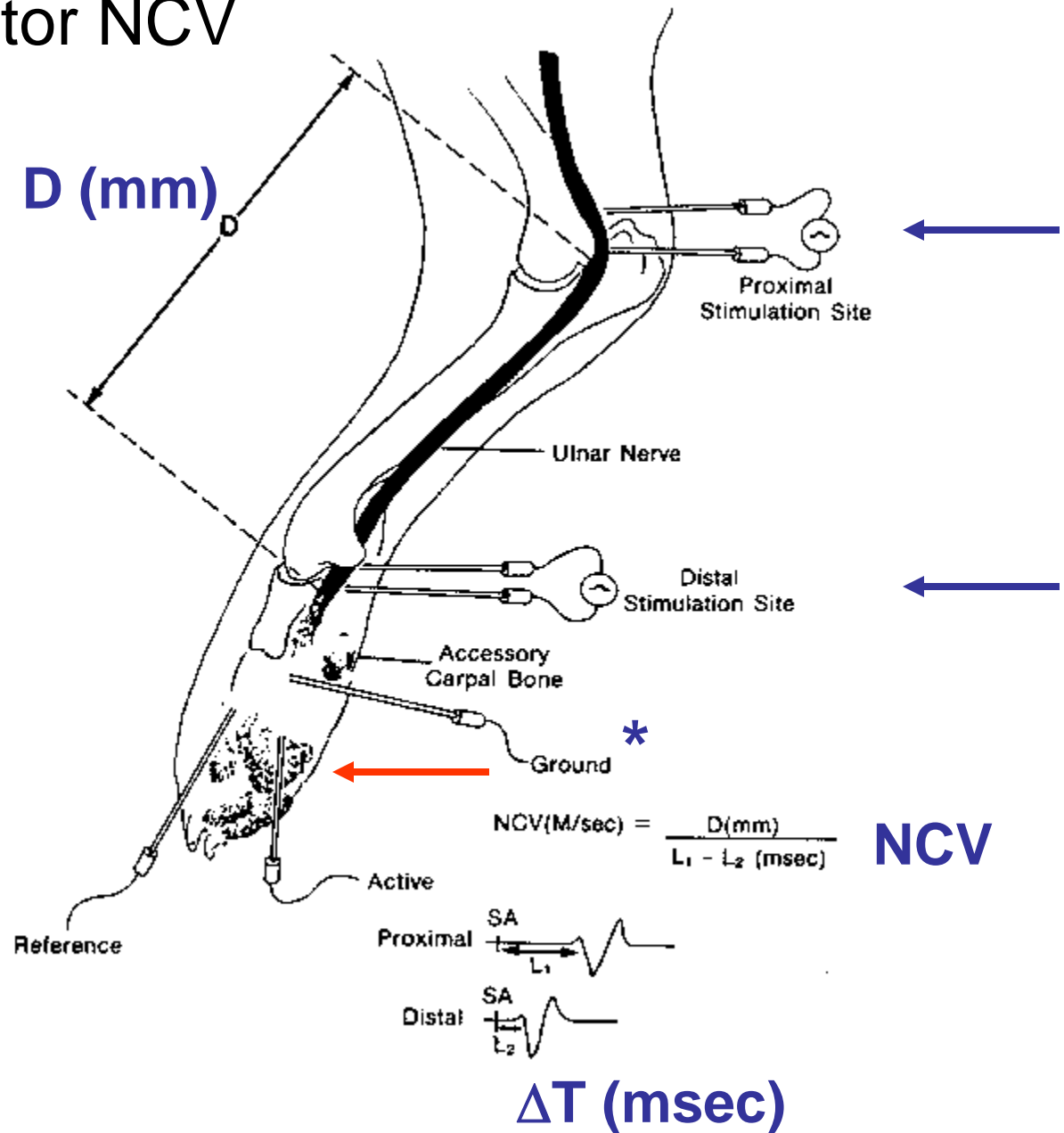
- Stimulating electrodes
  - Cathode (negative pole, attracts cations) – depolarizes the neuron
  - Anode (positive pole, attracts anions) – hyperpolarizes the neuron; rebound stimulation
  - Stimuli: supramaximal, 50  $\mu$ sec
- Electrode types
  - Stimulating (cathode): stripped tip; return (anode): subcutaneous
  - Recording: same as normal EMG; ground between stimulating and recording to decrease artifact

# Factors Altering NCVs

- Effect of temperature: NCV decreases as body temperature decreases (1.8 m/sec/°C)
- Abnormalities:
  - Reduced amplitude, possibly increased latency
  - Increased latency with normal amplitude
  - Absent response
- Axon damage or dysfunction  $\Rightarrow$  decreased amplitude
- Demyelination  $\Rightarrow$  increased conduction time
- NCVs < 50 m/sec generally abnormal
- SNCV amplitudes are smaller than MNCV, may show earlier signs of change in disease

# Ulnar Nerve Motor NCV

Figure 5-35. Schematic diagram of the latency technique for determination of ulnar motor nerve conduction velocity. Latency ( $L_2$ ) of the evoked potential induced by stimulation at the level of the accessory carpal bone is subtracted from the latency ( $L_1$ ) of the evoked potential induced by stimulation at the level of the olecranon. The difference represents the conduction time for impulses in the fastest conducting fibers of the nerve segment ( $D$ ) between the stimulating electrodes. Conduction velocity is calculated with the formula given in the diagram. The active electrode tip was in an interosseous muscle.





# Tibial MNCV

TIBIAL NERVE  
(medial aspect)

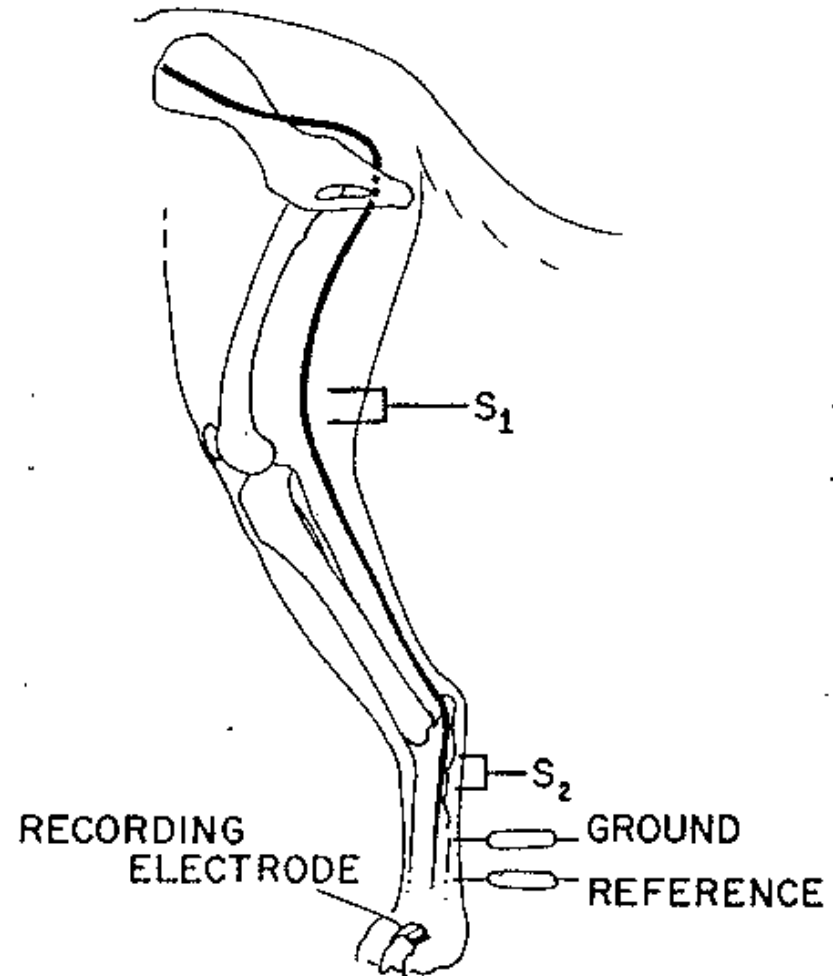


Fig. 98-16. The stimulating and recording sites for tibial MNCV. S<sub>1</sub>, One stimulation site; S<sub>2</sub>, second stimulation site.

# Sciatic-Tibial MNCV

## SCIATIC-TIBIAL NERVE (lateral aspect)

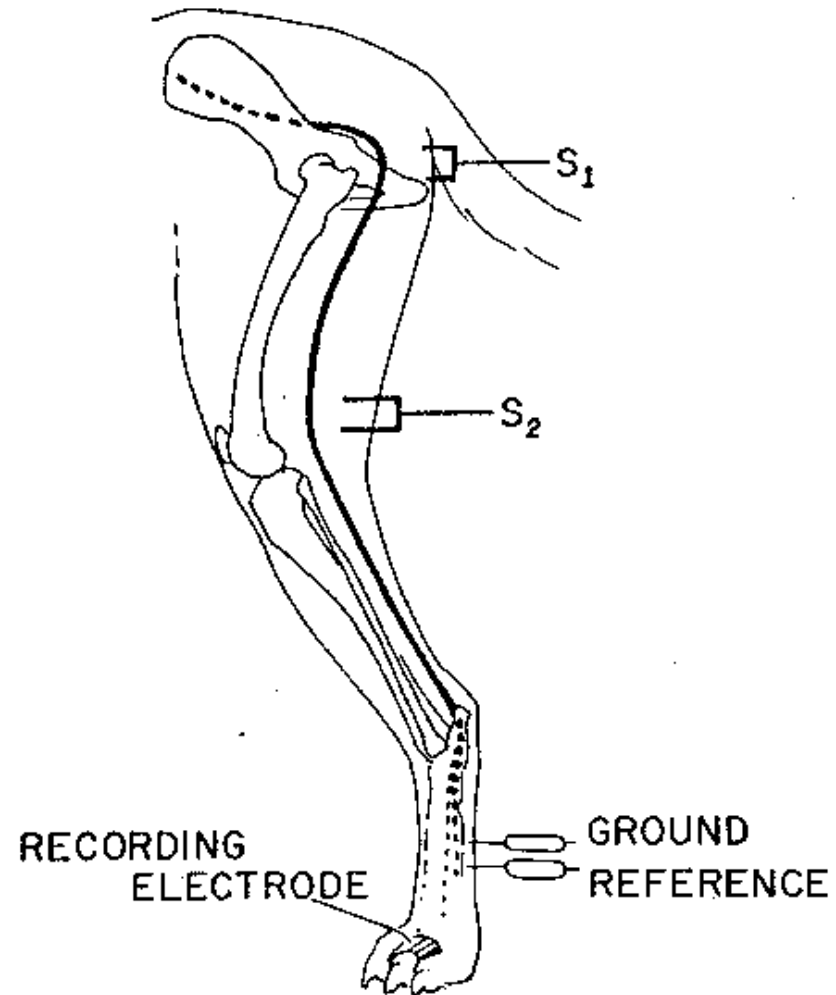


Fig. 98-15. The stimulating and recording sites for sciatic-tibial MNCV. S<sub>1</sub>, One stimulation site; S<sub>2</sub>, second stimulation site.

SUPERFICIAL RADIAL NERVE  
( lateral aspect )

Radial Sensory NCV

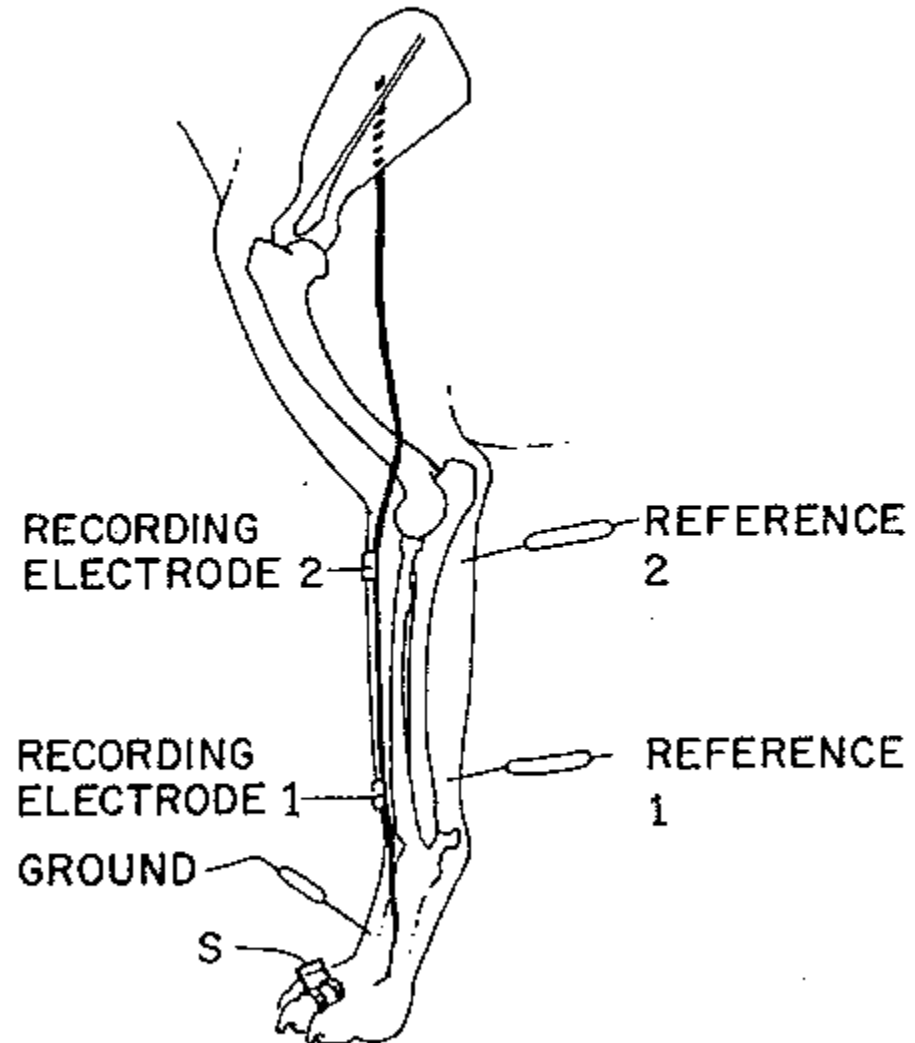


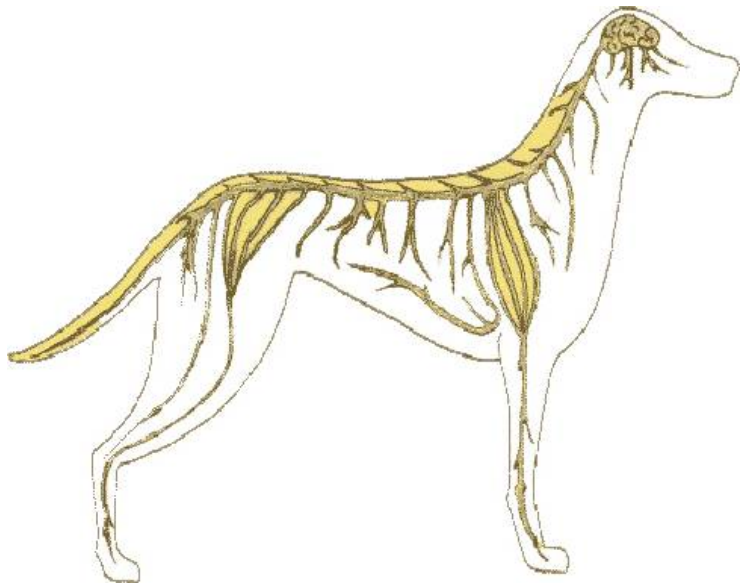
Fig. 98-19. The stimulating and recording sites for radial SNCV. S, stimulation site.

# Motor and Sensory Nerve Conduction Velocities

Species	Nerve Function	Nerve Conduction Velocity (m/sec)				
		Radial	Median	Ulnar	Tibial	Peroneal
Dog <sup>1</sup>	Motor	72	66	59	68	80
Dog <sup>2</sup>	Motor	–	–	60	60	75
Cat <sup>3</sup>	Motor	–	–	77	79	75
Chicken <sup>4</sup>	Motor	–	–	–	35	–
Horse <sup>5</sup>	Motor	79	73	71	90	90
Dog <sup>6</sup>	Sensory	62	–	68	–	–
Dog <sup>7</sup>	Sensory	65	–	69	63	64
Cat <sup>8</sup>	Sensory	84	–	89	80	85
Pony <sup>9</sup>	Sensory	–	79	71	–	–

1. Walker et al 1979. 2. Lee & Bowen 1970. 3. Bowen, unpublished data. 4. Kornegay et al 1983; 2-4 weeks of age. 5. Sprinkle 1977. 6. Holliday et al 1977. 7. Redding et al 1982. 8. Redding & Ingram 1984. 9. Blythe et al 1983.

# Repetitive Nerve Stimulation (RNS)



# RNS

- Diseases affecting the neuromuscular junction (NMJ) can cause fatigue of synaptic transmission
- Diminished responses can be from reduced transmitter release or reduced response at the post-synaptic membrane
- Myasthenia gravis, motor neuron disease, dying back neuropathies

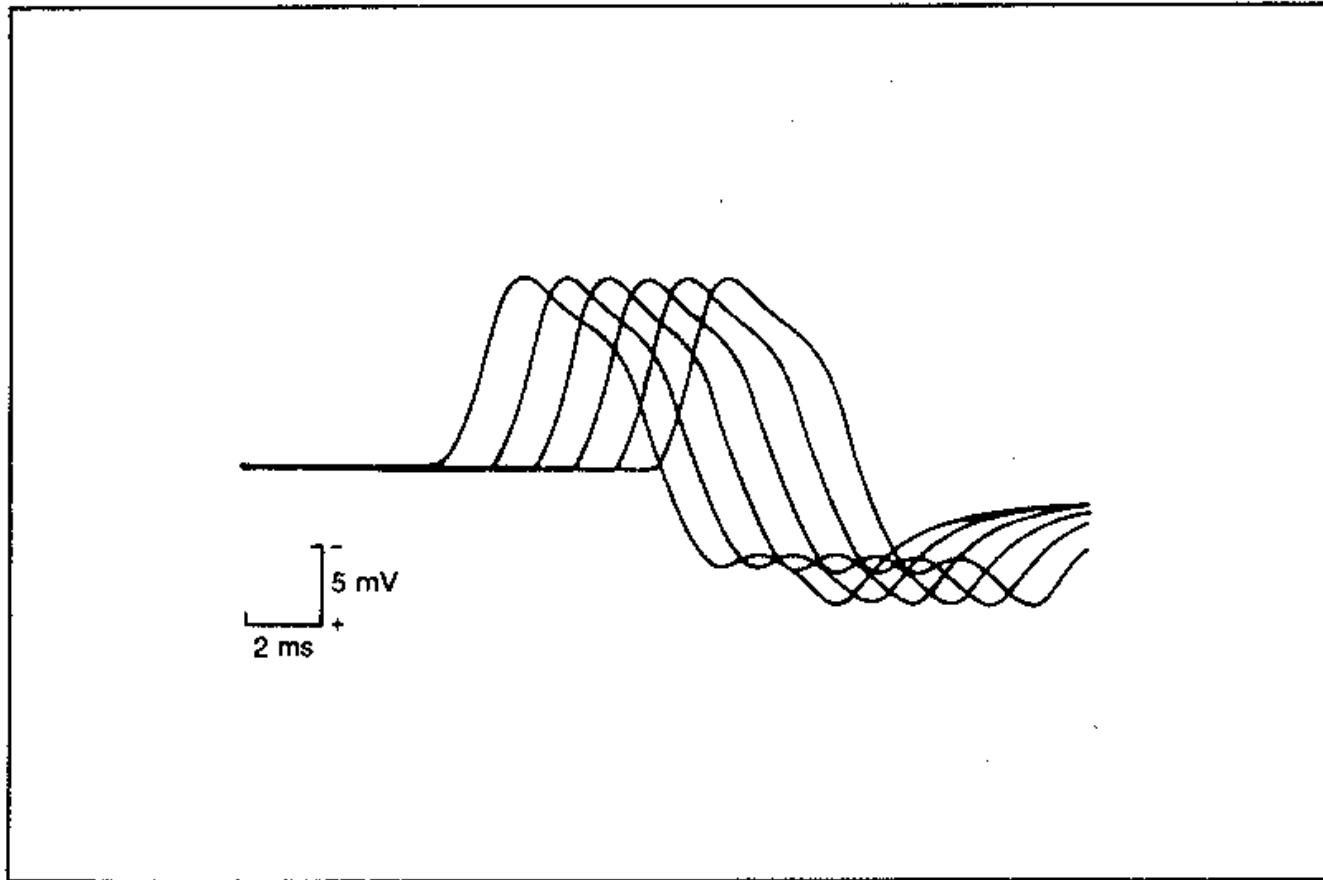
# Repetitive Nerve Stimulation

- Stimulate ~ 5/sec, record from distal muscle, analyze first 3-5 responses
- Decremental (decreasing) responses seen in:
  - Myasthenia gravis, myasthenic syndrome, motor neuron disease, dying back neuropathies, botulism, regenerating nerves

## REPETITIVE NERVE STIMULATION

### NORMAL RESPONSE

# Normal

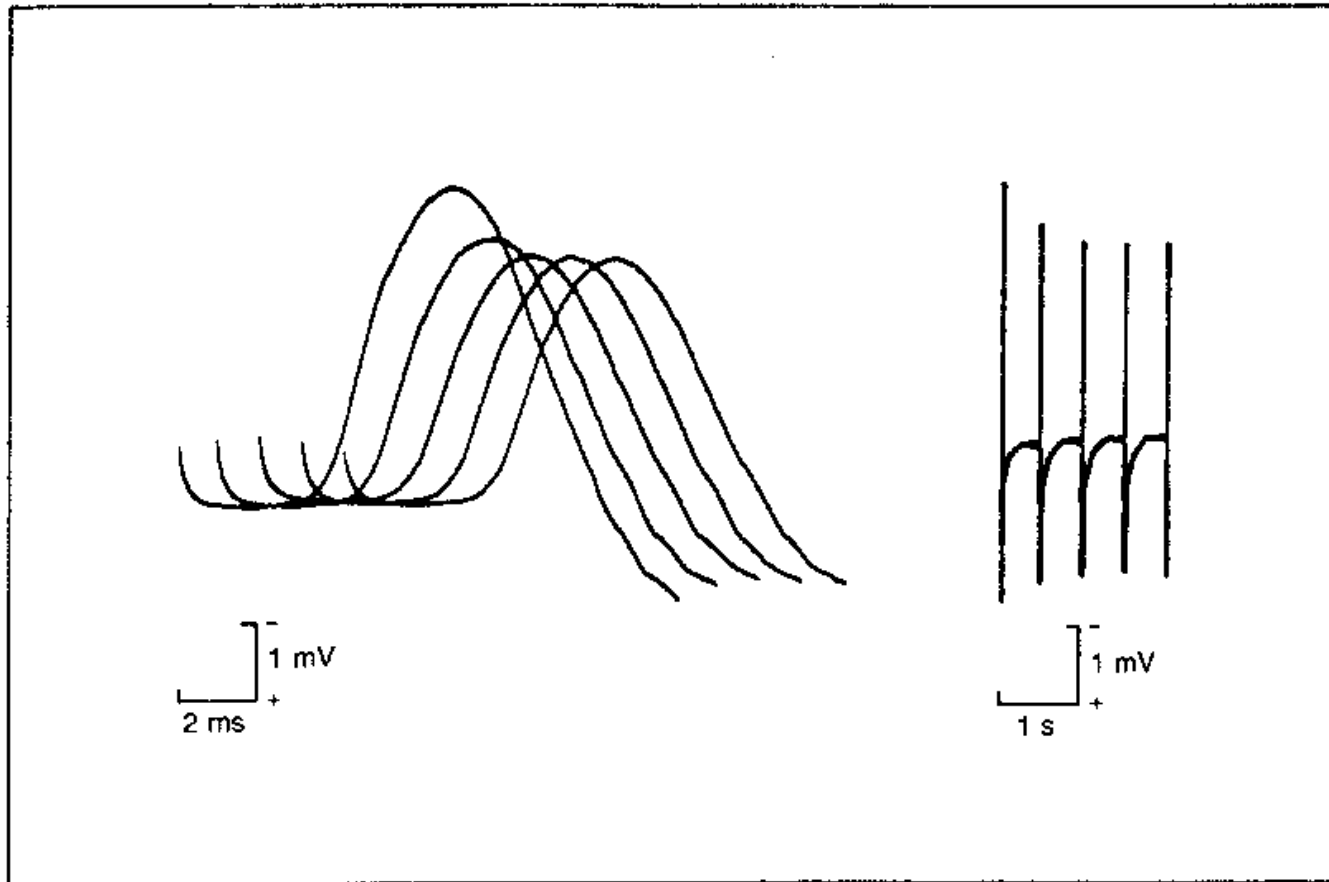


**Appendix Figure 4-13.** Study in a normal subject. The successive M waves are displayed to the right. The M waves were recorded with surface electrodes over the hypothenar eminence (abductor digiti quinti) during ulnar nerve stimulation at a rate of 3 Hz. Note the configuration of the successive M waves is unchanged. *Repetitive nerve stimulation* is a technique of repeated supramaximal stimulations of a nerve while recording M waves from muscles innervated by the nerve. The number of stimuli and the frequency of stimulation should be specified. Activation procedures performed prior to the test should be specified, e.g., sustained voluntary contraction or contraction induced by nerve stimulation. If the test was performed after an activation procedure, the time elapsed after the activation procedure was completed should also be specified. The technique is commonly used to assess the integrity of neuromuscular transmission. For a description of specific patterns of responses, see the terms *incrementing response*, *decrementing response*, *facilitation* and *postactivation depression*.



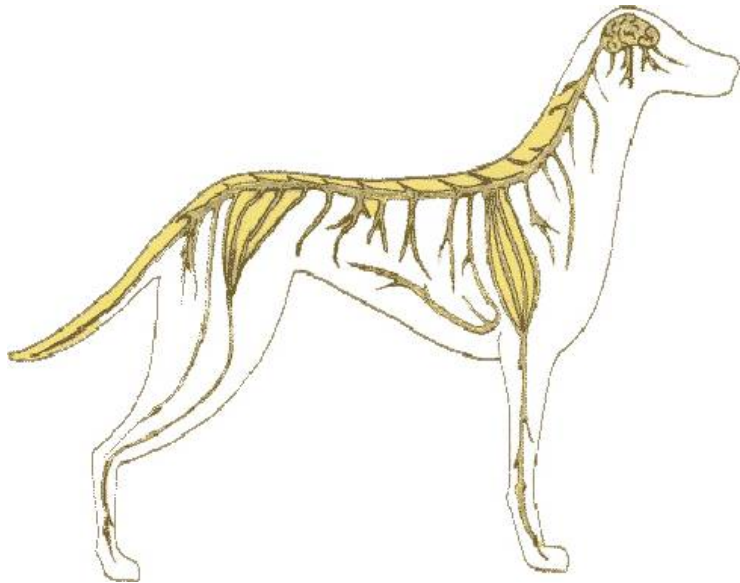
# Myasthenia

## REPETITIVE NERVE STIMULATION DECREMENTING RESPONSE



**Appendix Figure 4-14.** Repetitive nerve stimulation study in a patient with myasthenia gravis. Successive M waves were recorded with surface electrodes over the rested cheek (nasalis) muscle during repetitive facial nerve stimulation at a rate of 2 Hz, with a display to permit measurement of the amplitude and duration of the negative phase (left) or peak-to-peak amplitude (right). A *decrementing response* is a reproducible decline in the amplitude and/or area of the M wave of successive responses to *repetitive nerve stimulation*. The rate of stimulation and the total number of stimuli should be specified. Decrementing responses with disorders of neuromuscular transmission are most reliably seen with slow rates (2-5 Hz) of nerve stimulation. A decrementing response with repetitive nerve stimulation commonly occurs in disorders of neuromuscular transmission, but can also be seen in some neuropathies, myopathies, and motor neuron disease. An artifact resembling a decrementing response can result from movement of the stimulating or recording electrodes during repetitive nerve stimulation. Contrast with *incrementing response*.

# Magnetic Motor Evoked Potential (MEP)



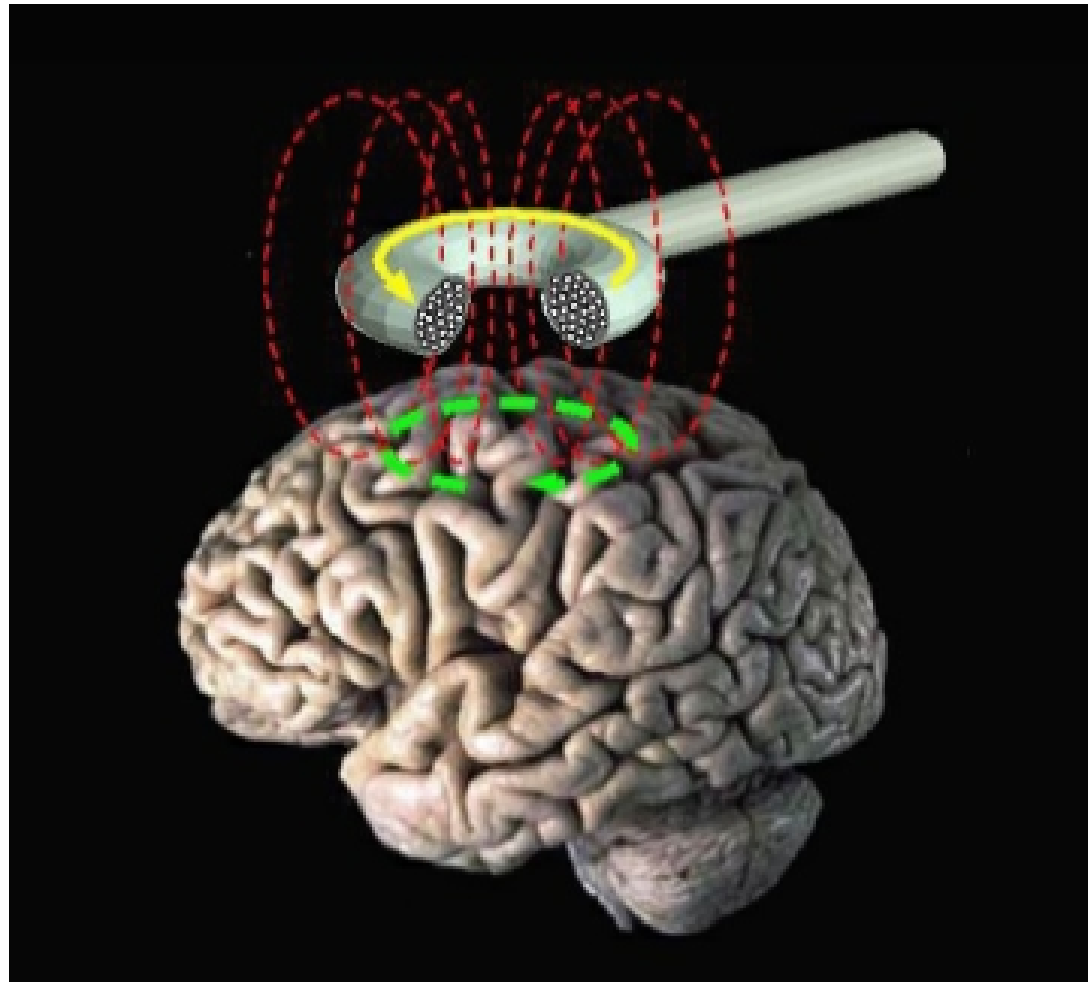
# Magnetic Motor Evoked Potential

- Potentials (EMG) recorded from skeletal muscles in response to magnetic activation of motor cortex or spinal cord regions
- Useful for determining the integrity of descending motor pathways with disc disease, neoplasia, trauma, etc.
- Evoked motor (not sensory) response

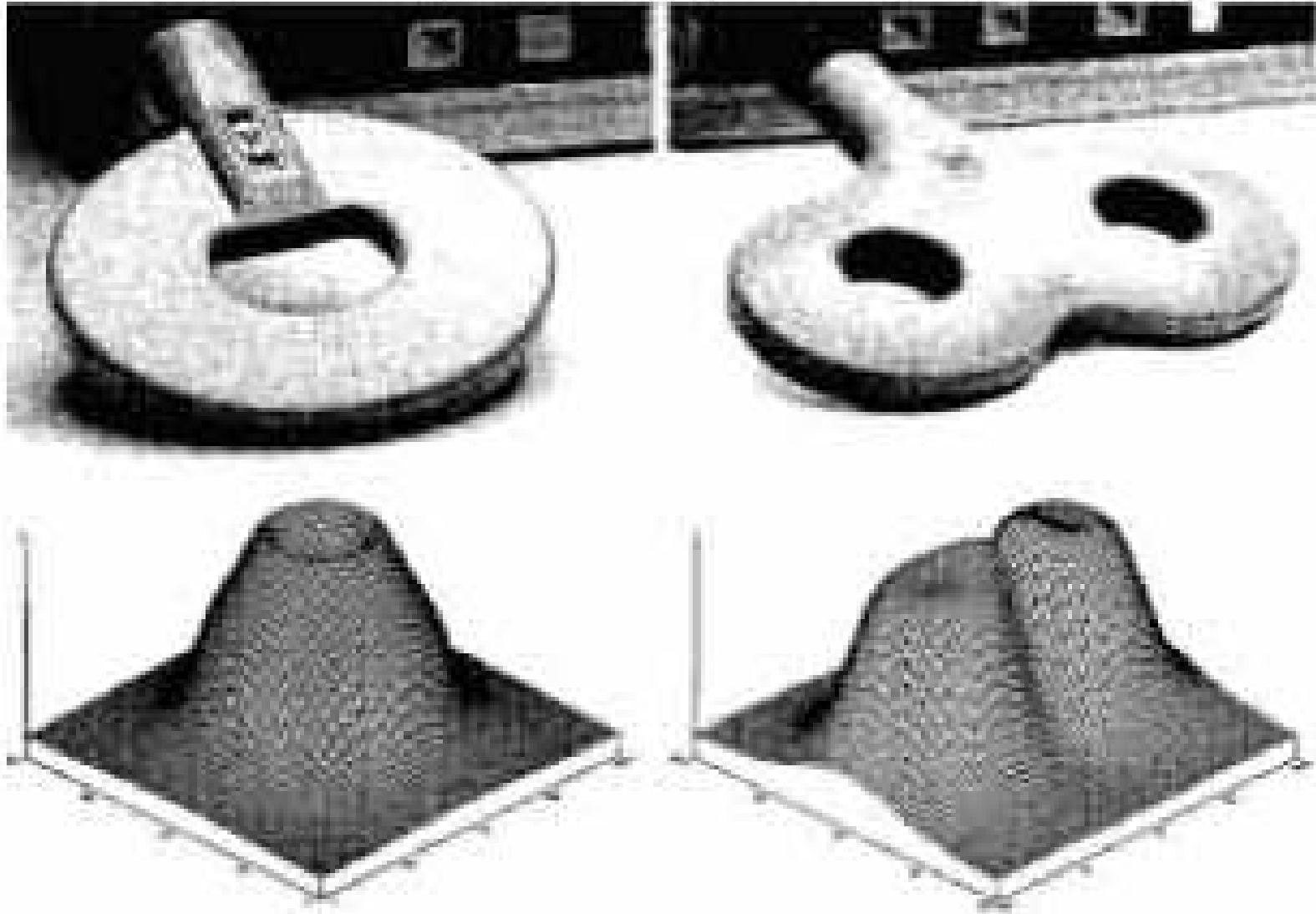
# Magnetic Motor Evoked Potential

- Stimulus: magnetic stimulation of motor cortex or spinal cord
- Recording site: contralateral skeletal muscle (EMG recording)
- Duration: < 50 msec, depending on stimulation and recording site, and animal size
- Use limited at this time

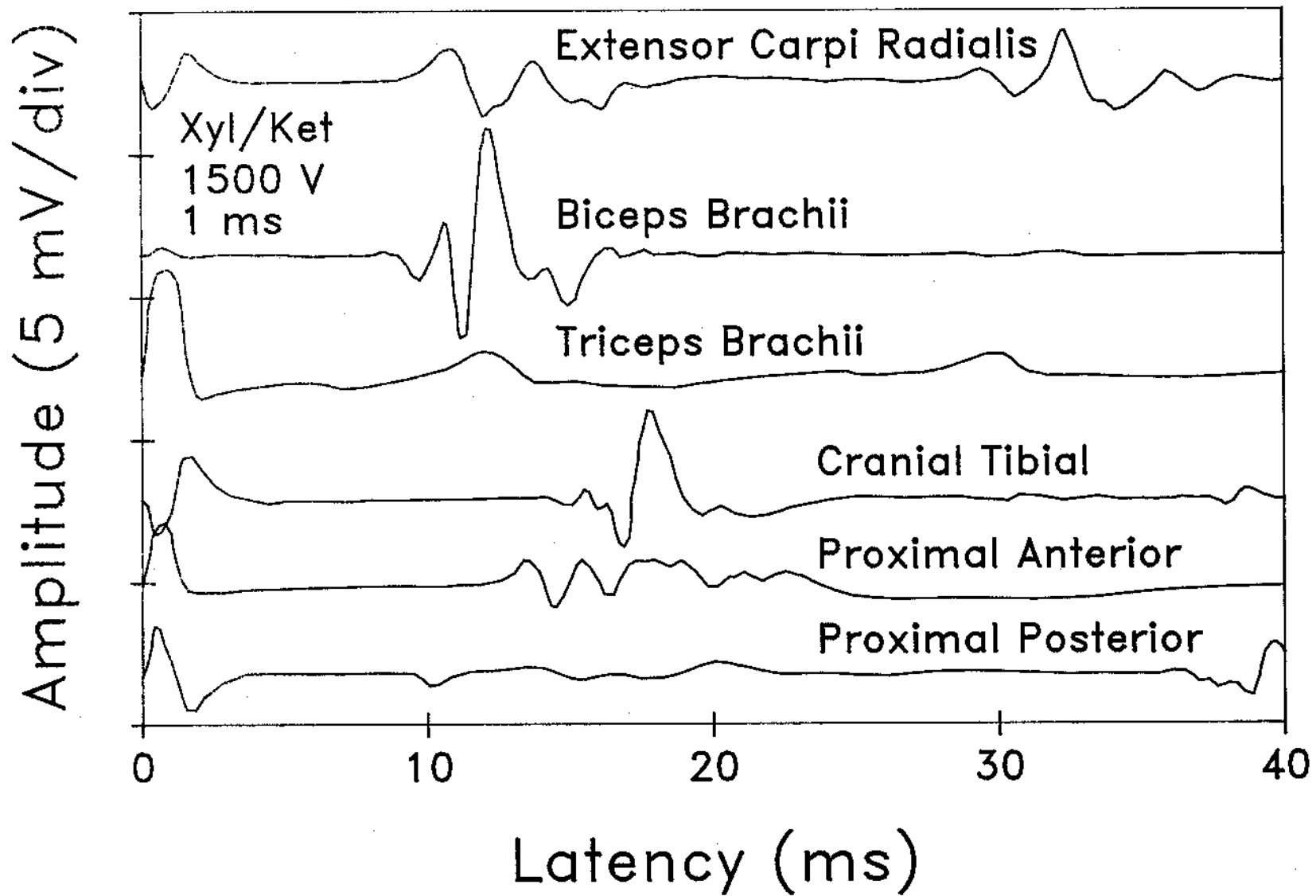
# Magnetic Fields Induce Currents In the Brain Which Activate Corticospinal Tract



# Available Electrode Configurations



# Canine TMEPs

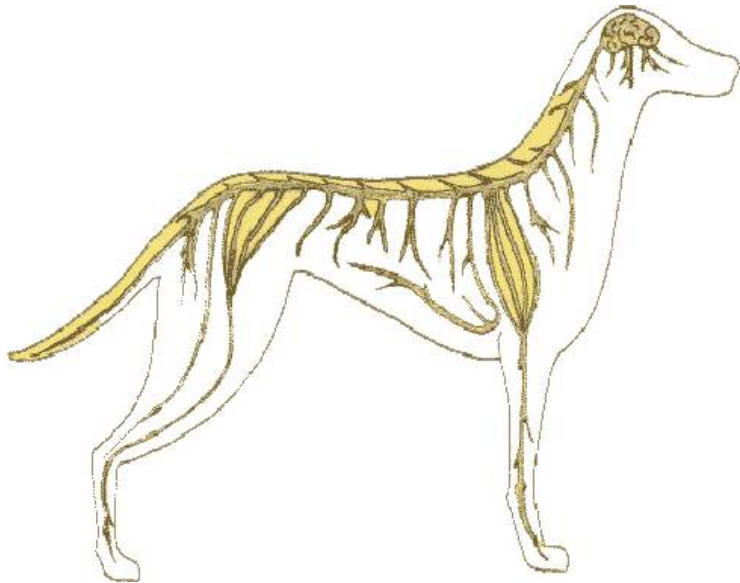




# Tests of Cortical Function



# Electroencephalogram (EEG)



# EEG

- The electroencephalogram (EEG) is spontaneous electrical activity of the brain recorded from the scalp with surface electrodes or subcutaneous needles
- Origin:
  - Post-synaptic potentials on apical dendrites of cortical pyramidal cells
  - Other cortical and subcortical components (minor contributions)

# Characterization of the EEG

- Amplitude: 2 - 400  $\mu\text{V}$
- Frequency: 0.5 - 50 Hz
  - delta ( $\Delta$ ): 0.5 - 3 Hz, 20 - 400  $\mu\text{V}$
  - theta ( $\theta$ ): 4 - 7 Hz, 5 - 100  $\mu\text{V}$
  - alpha ( $\alpha$ ): 8 - 13 Hz, 5 - 100  $\mu\text{V}$
  - beta ( $\beta$ ): 14 - 50 Hz, 2 - 20  $\mu\text{V}$
- Patterns are often superimposed –  $\theta$  with  $\alpha$  bursts

# Characterization of the EEG

- delta ( $\Delta$ ): deep sleep, coma, infancy
- theta ( $\theta$ ): sleep, childhood
- alpha ( $\alpha$ ): awake, relaxed, eyes closed, especially present over occipital cortex
- beta ( $\beta$ ): awake, alert, aroused, excitement (and REM sleep)

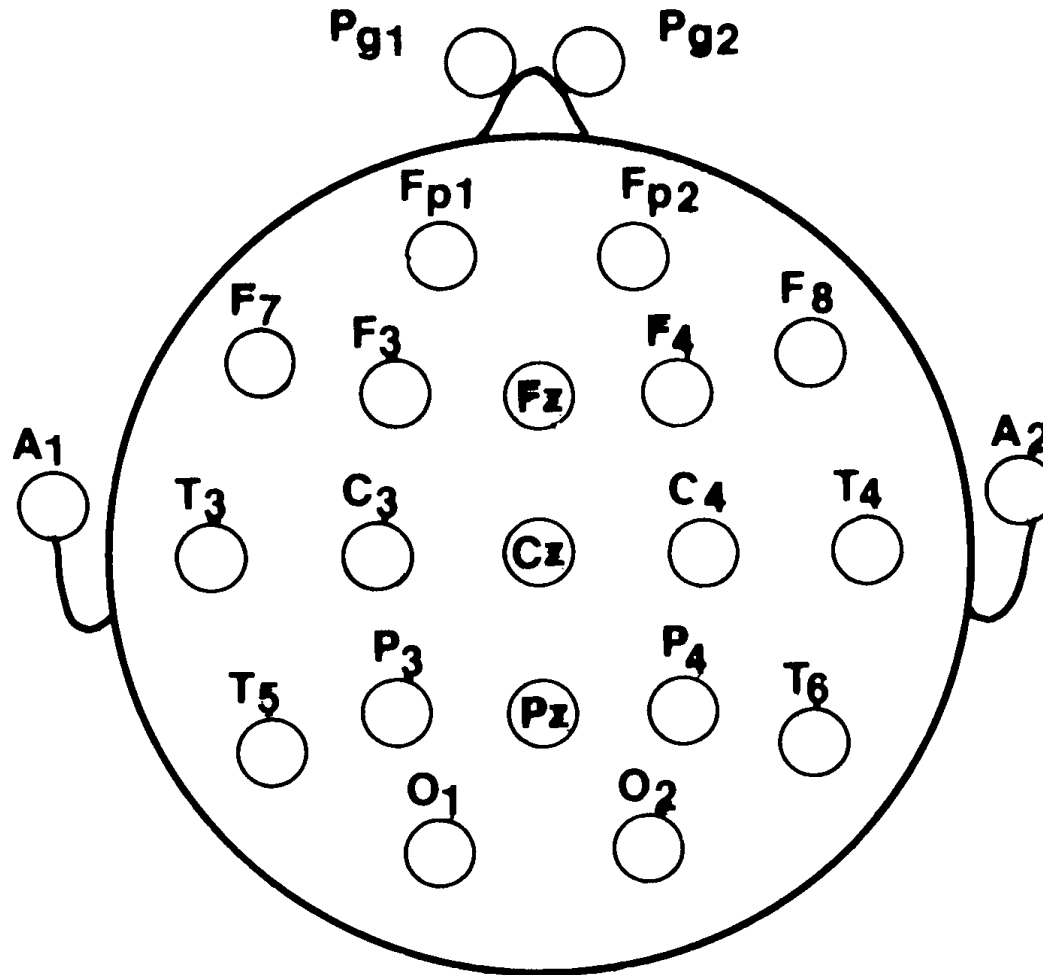
# EEG

- Normal patterns are low amplitude and high frequency (awake, alert) or high amplitude and low frequency (sleep)
- Abnormal EEGs can have:
  - High amplitude, high frequency – seizures
  - Low amplitude, low frequency – coma
  - Spikes, sharp waves, other wave complexes

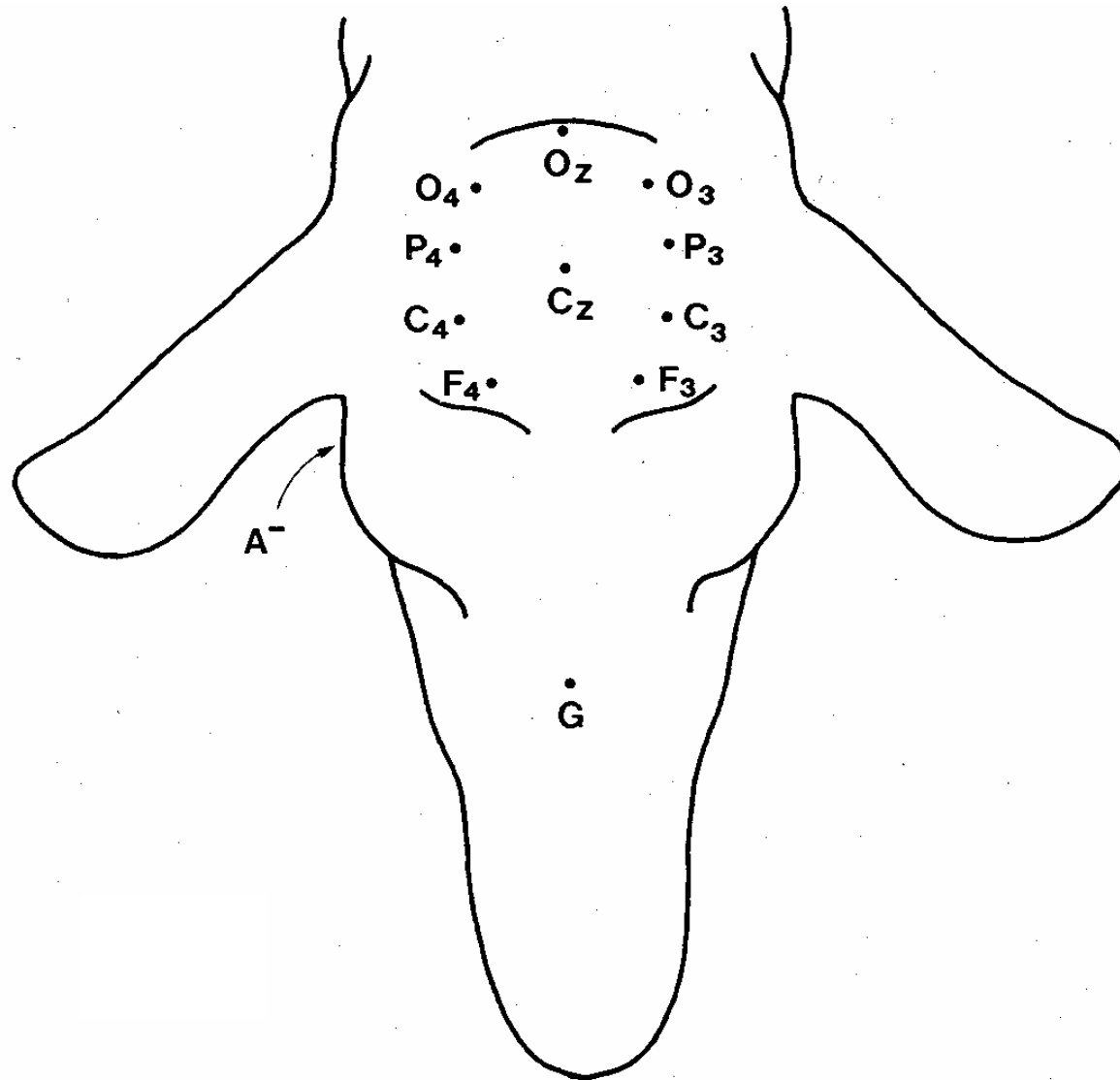
# International 10-20 Electrode System

- Naming convention for EEG electrode placements for consistency
- Z subscript – indicates midline
- Even subscript – indicates right scalp
- Odd subscript – indicates left scalp
- Letter indicates cortical region:
  - F – frontal
  - P – parietal
  - T – temporal
  - O – occipital
  - C – central

# International 10-20 Electrode System



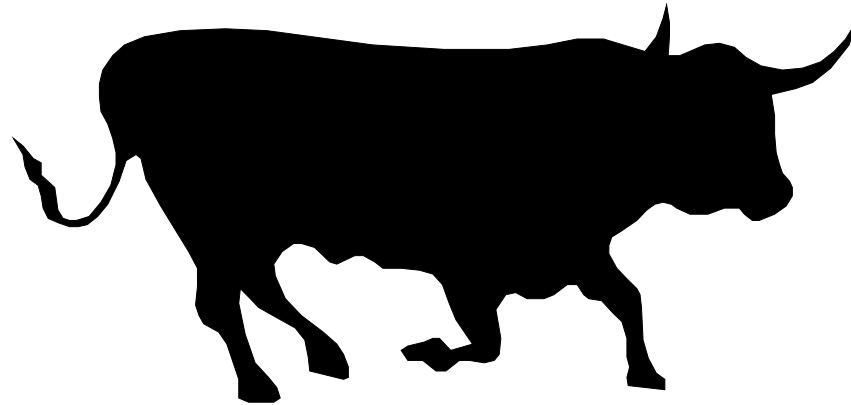
# Electrode Placements In Animals



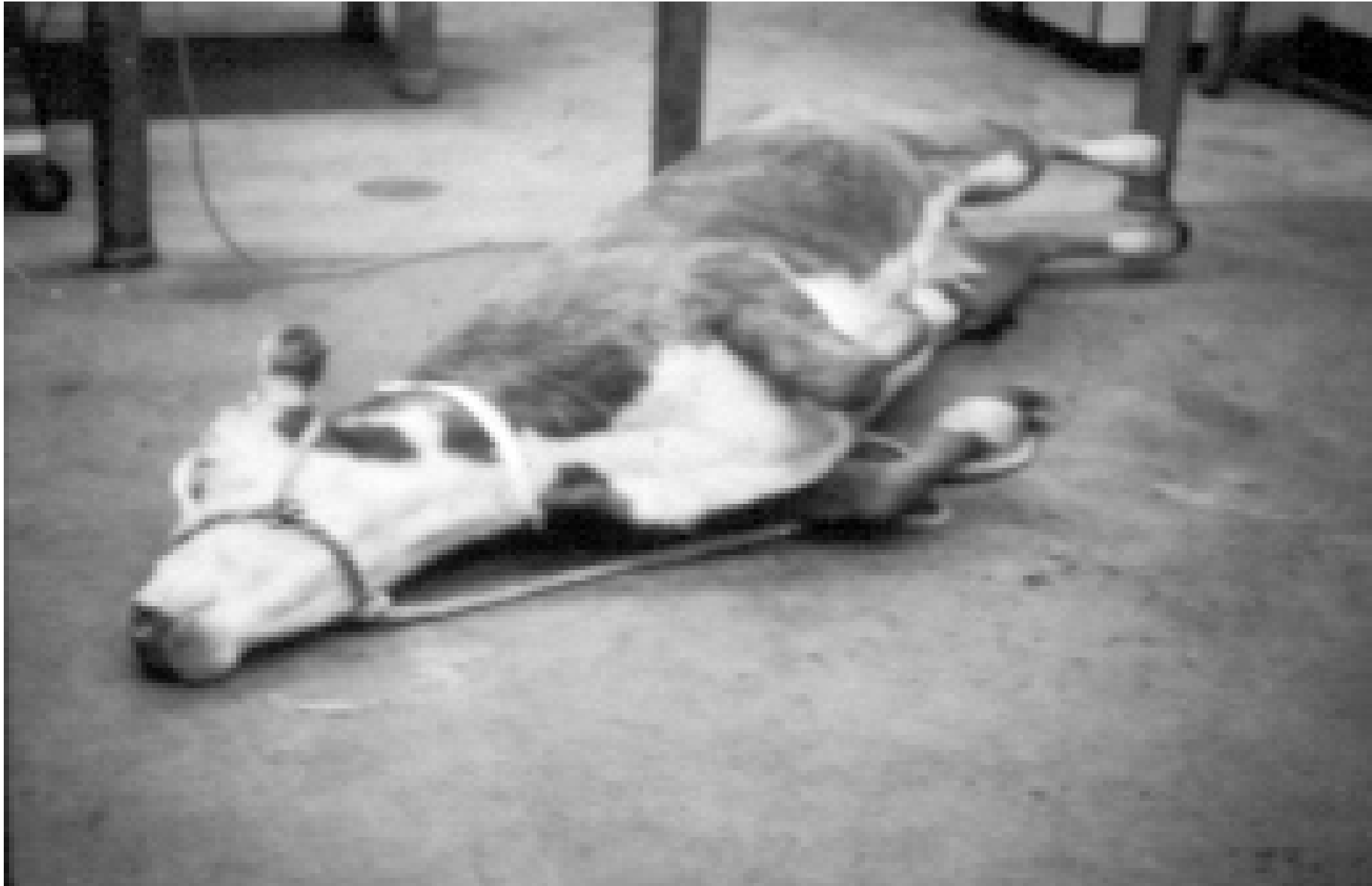


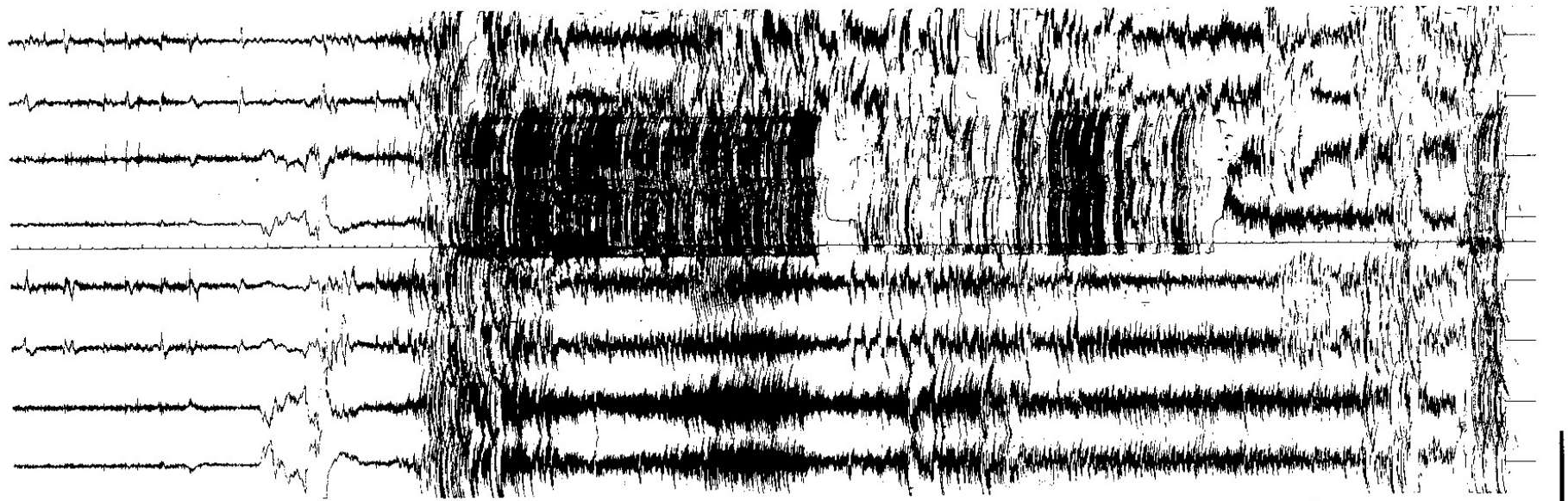
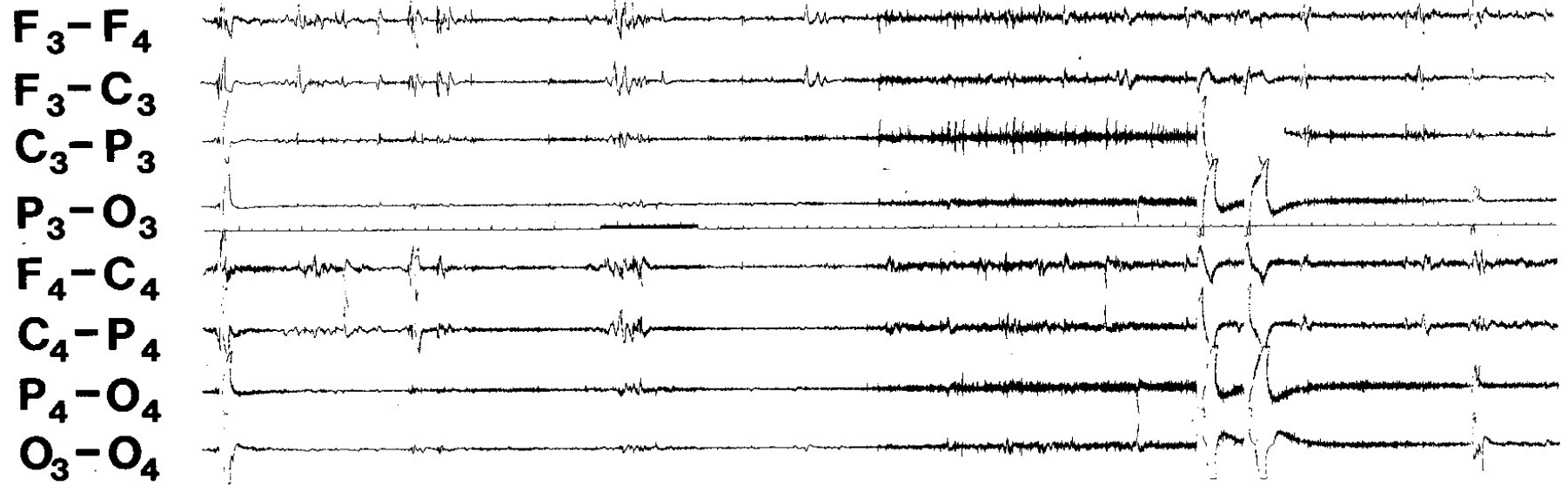
# Generalized Epilepsy In a Hereford Cow

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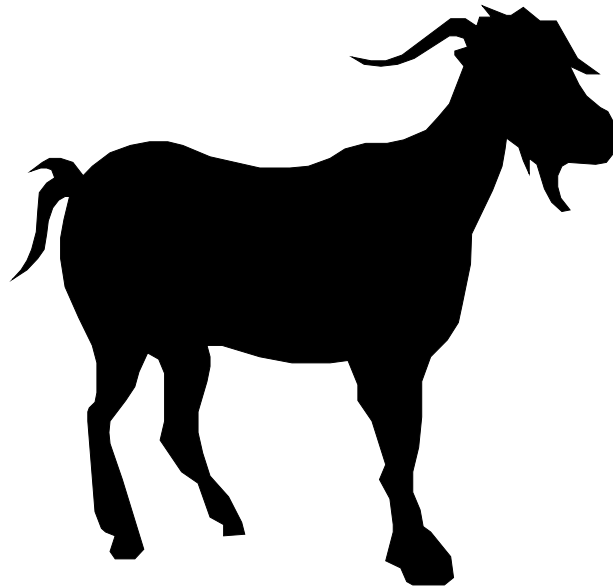
Strain, G.M., B.M. Olcott, and M.A.M. Turk. 1987. Diagnosis of primary generalized epilepsy in a cow. J. Am. Vet. Med. Assoc. 191:833-836.





# Focal Epilepsy in a Goat

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Olcott, B.M., G.M. Strain, and J.M. Kreeger. 1987. Diagnosis of partial epilepsy in a goat. *J. Am. Vet. Med. Assoc.* 191:837-840.

**F<sub>3</sub> - F<sub>4</sub>**

**F<sub>3</sub> - C<sub>3</sub>**

**C<sub>3</sub> - P<sub>3</sub>**

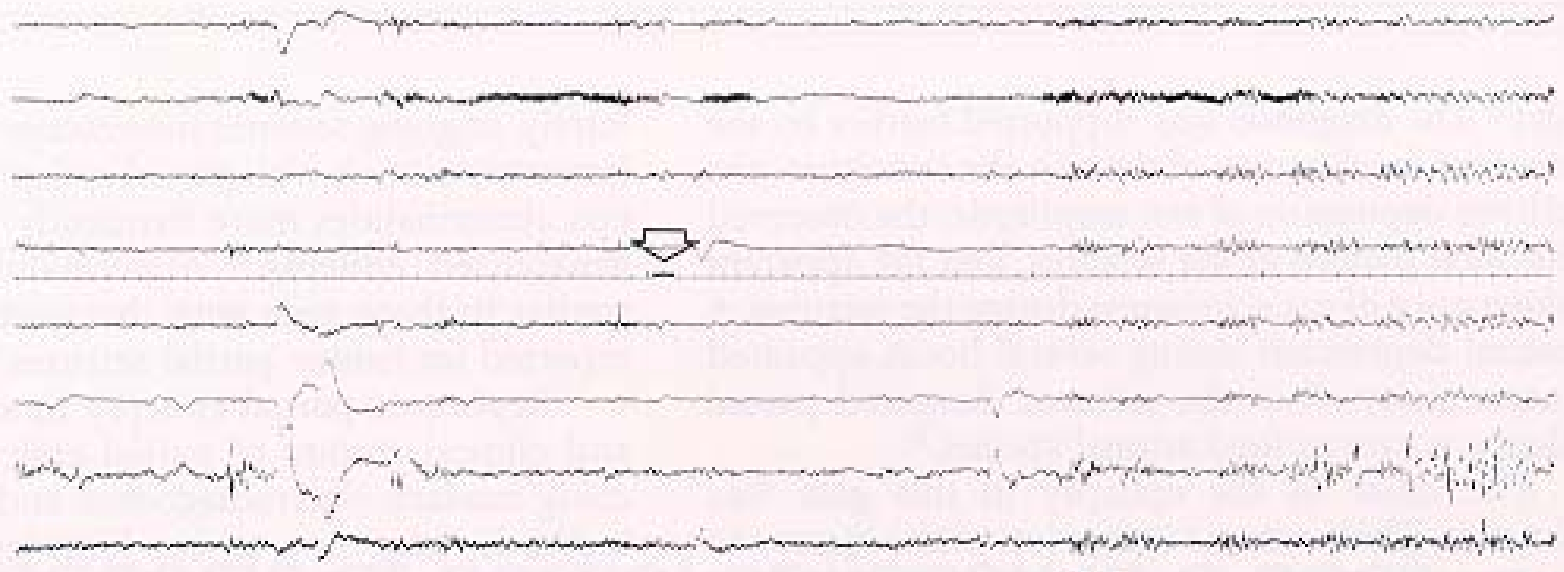
**P<sub>3</sub> - O<sub>3</sub>**

**F<sub>4</sub> - C<sub>4</sub>**

**C<sub>4</sub> - P<sub>4</sub>**

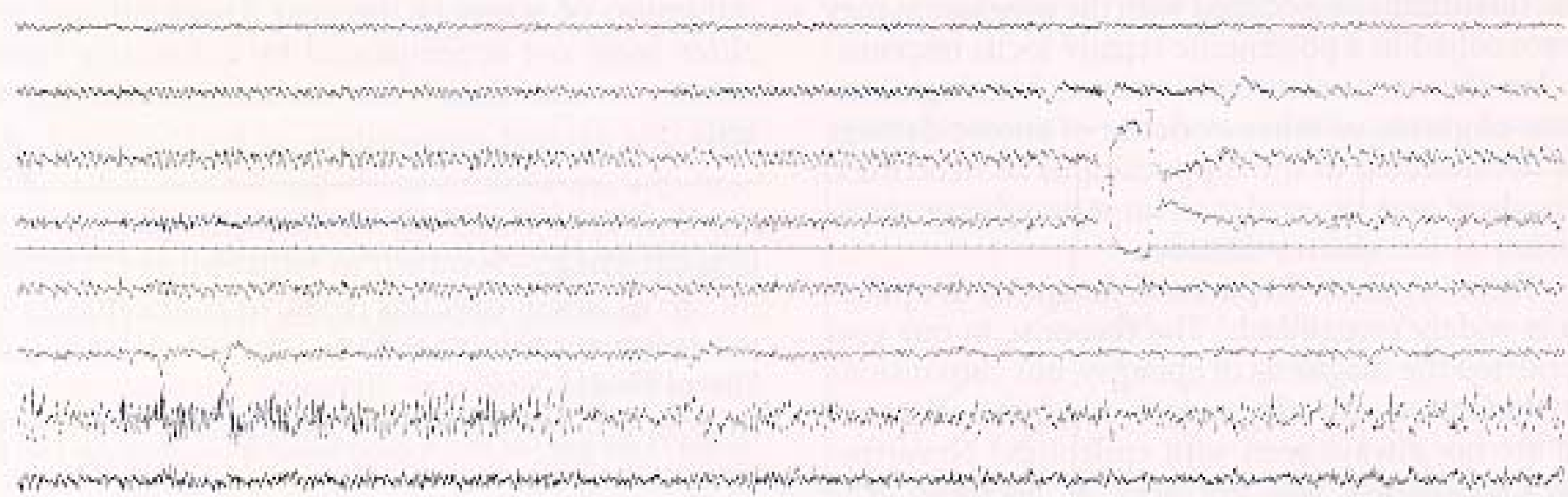
**P<sub>4</sub> - O<sub>4</sub>**

**O<sub>3</sub> - O<sub>4</sub>**



**HB**

**RM**



**SQ**

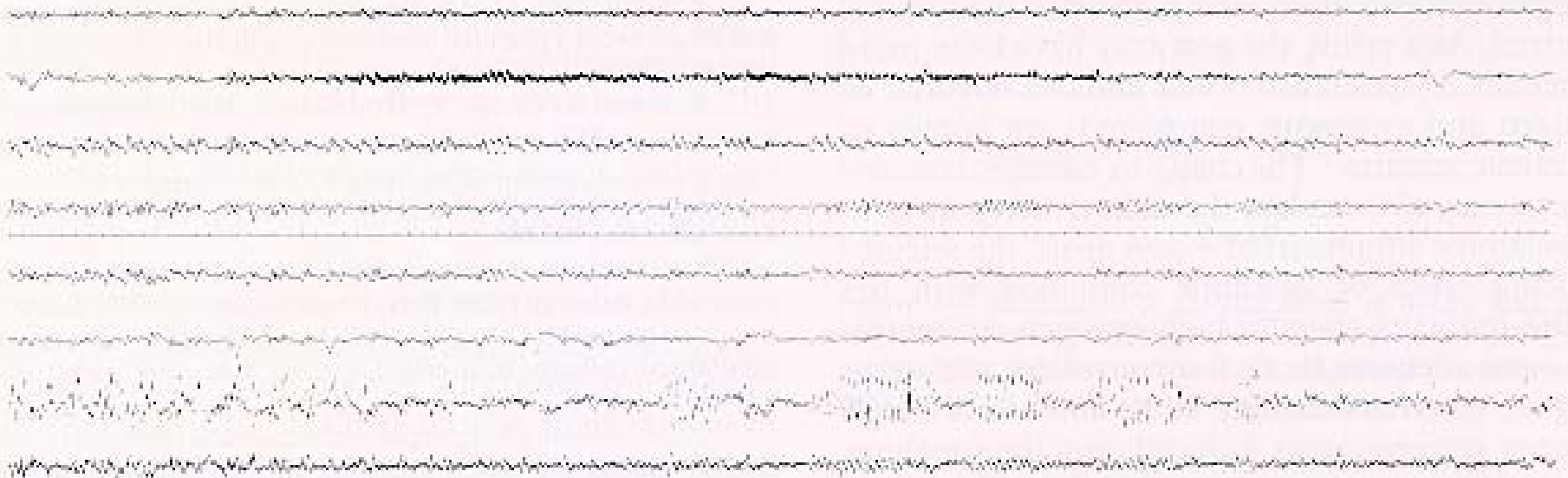
**PU**

**V**

**V**

**V**

**V**

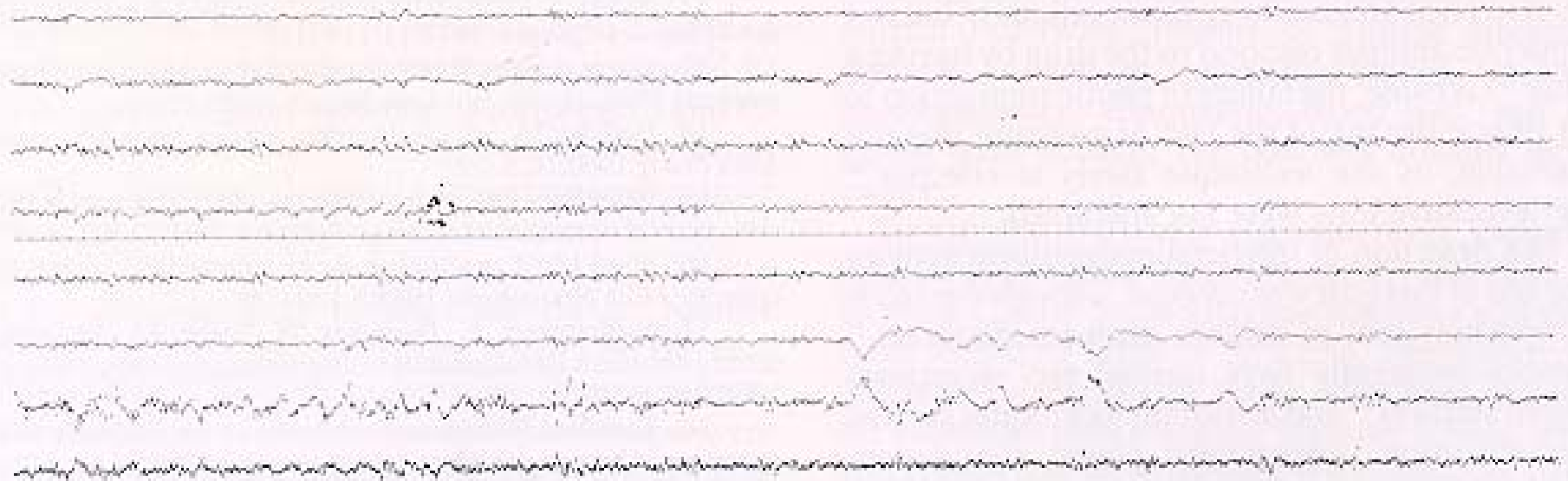


D

RM

U D

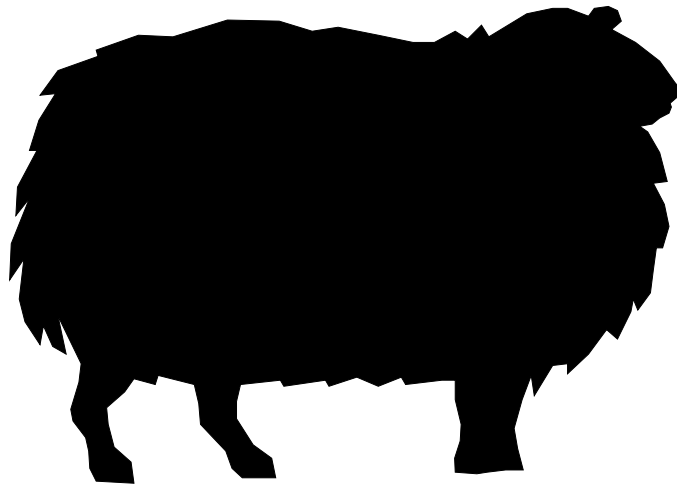
V V



V V V

# Scrapie In a Suffolk Sheep

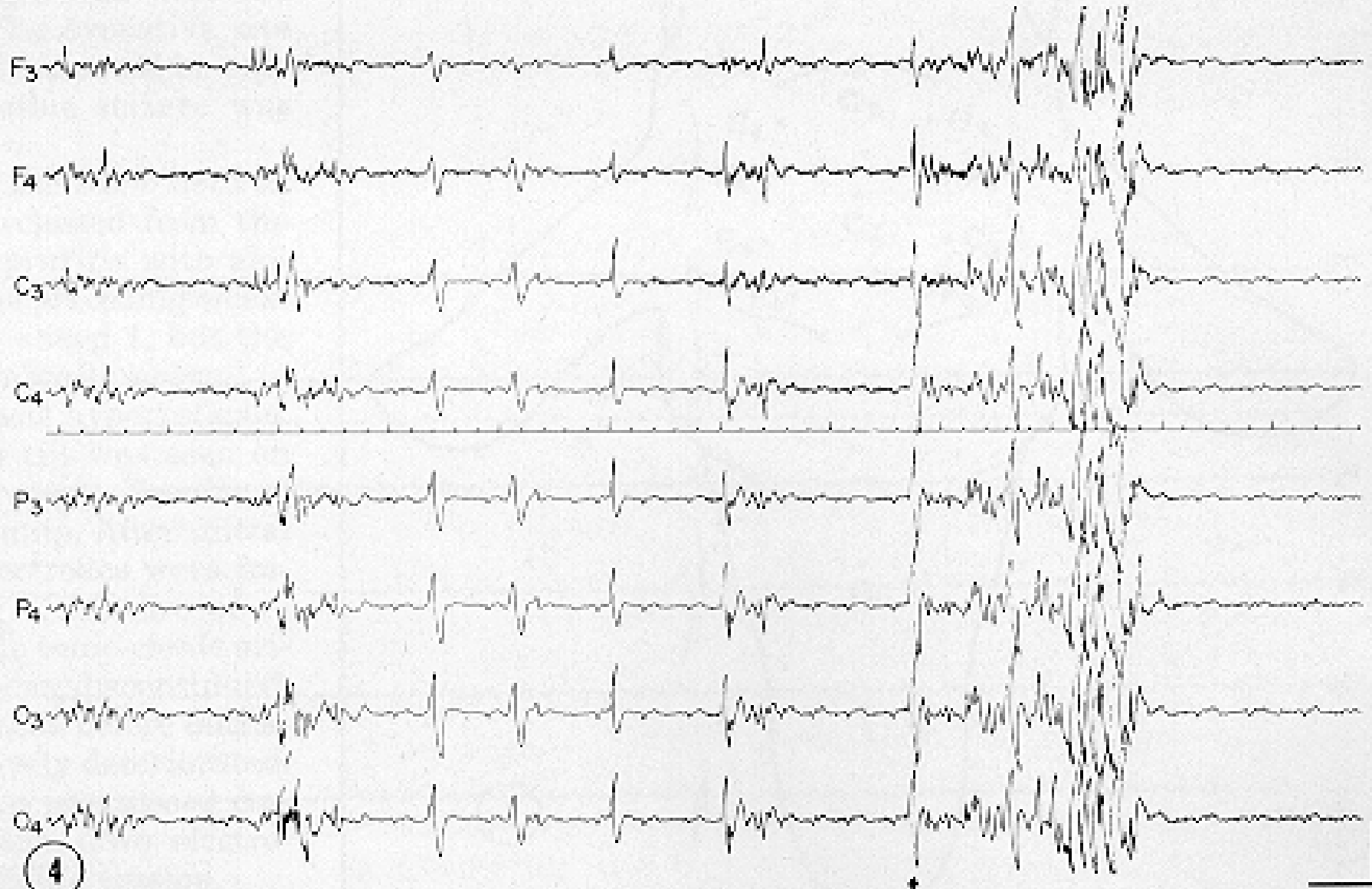
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Strain, G.M., B.M. Olcott, and W.F. Braun, Jr. 1986.  
Electroencephalogram and evoked potentials in naturally  
occurring scrapie in sheep. *Am. J. Vet. Res.* 47:828-836.

# Periodic synchronous sharp waves

SHEEP 1

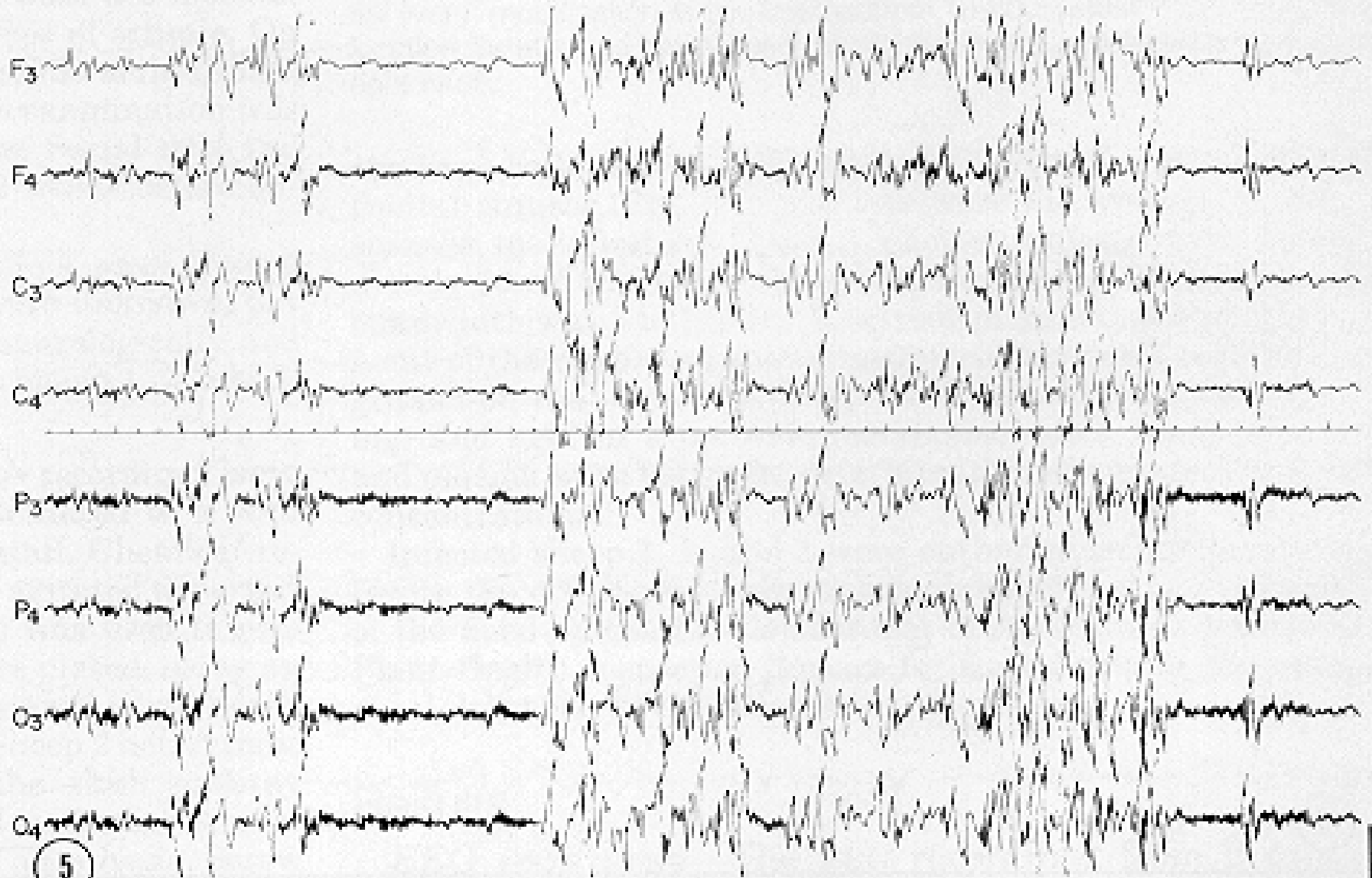


4



# Burst-suppression patterns

SHEEP 1



5

