33 The Organization of Movement

Kandel: Principles of Neural Science

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In this Chapter,

- Review the Principles govern Movement
- Motor Psychophysical studies

  ->Lawful Relationship
- Anatomical Organization of Motor System

  ~Spinal cord, Brain stem, & Cerebral cor.

3 Categories of Movement

- Reflexive (involuntary) -> Chap.35
- Rhythmic

~ pattern of muscle contraction & relaxation elicited by stimuli

- Voluntary

~ Goal-Directed Movement

Voluntary Movements

~Improvement with Practice

How to control posture & movement ?

The Nervous System Learns to Correct for External Perturbations in 2 ways;

(i) Feedback control,

(ii) Feed-forward control.

.

Feedback

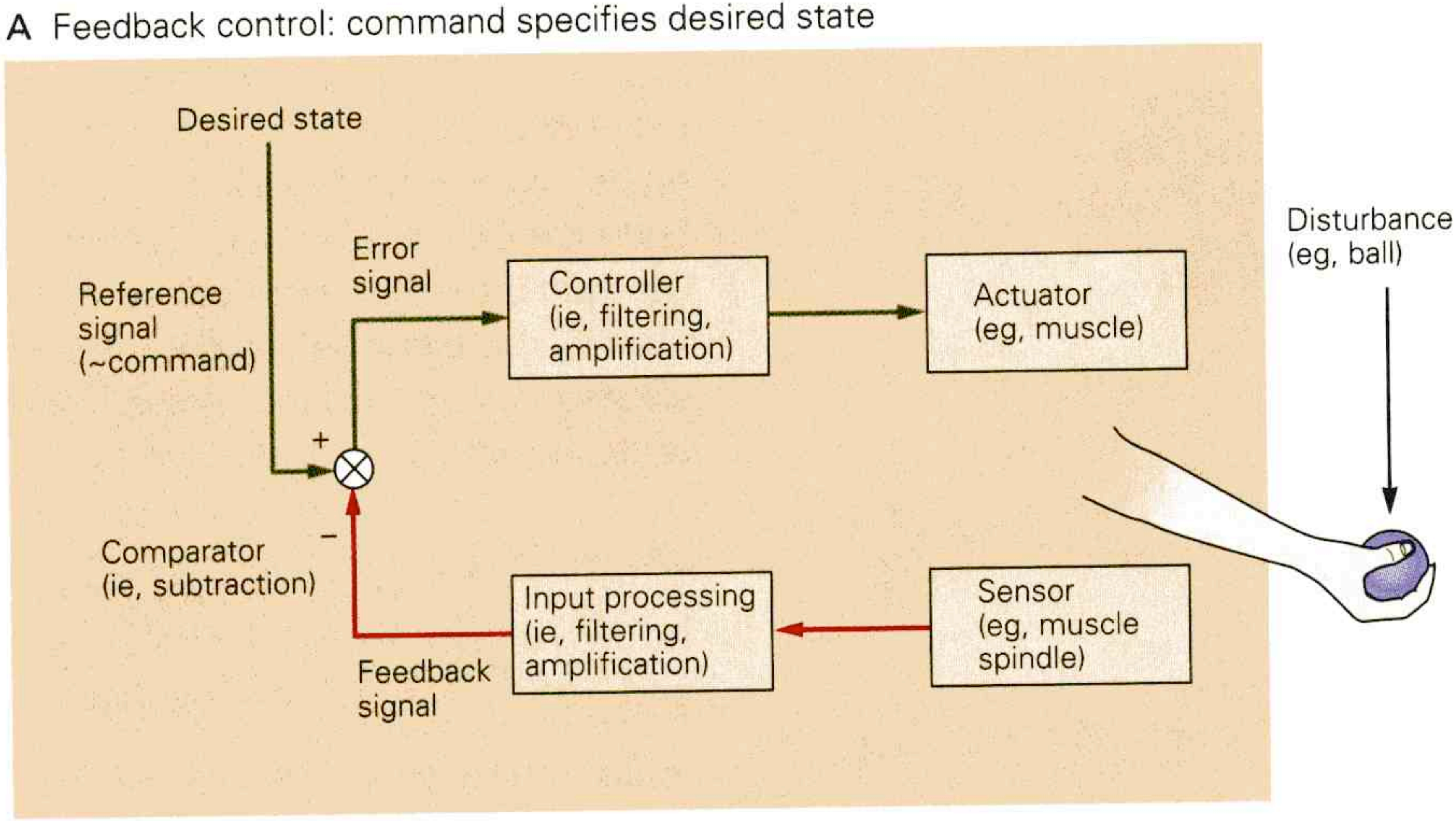


Fig. 33-1 A

Feed-forward

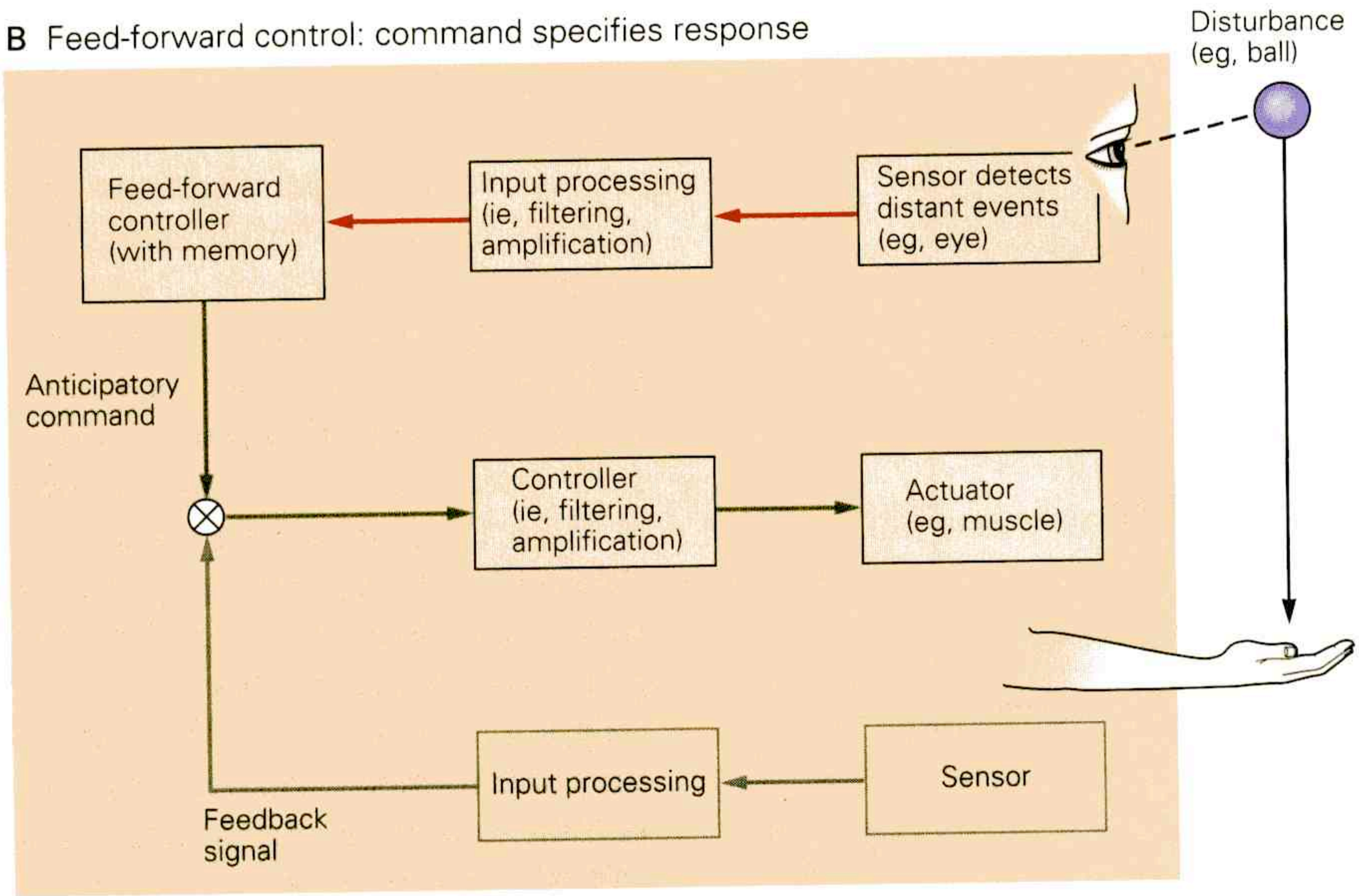


Fig. 33-1 B

Catching a ball

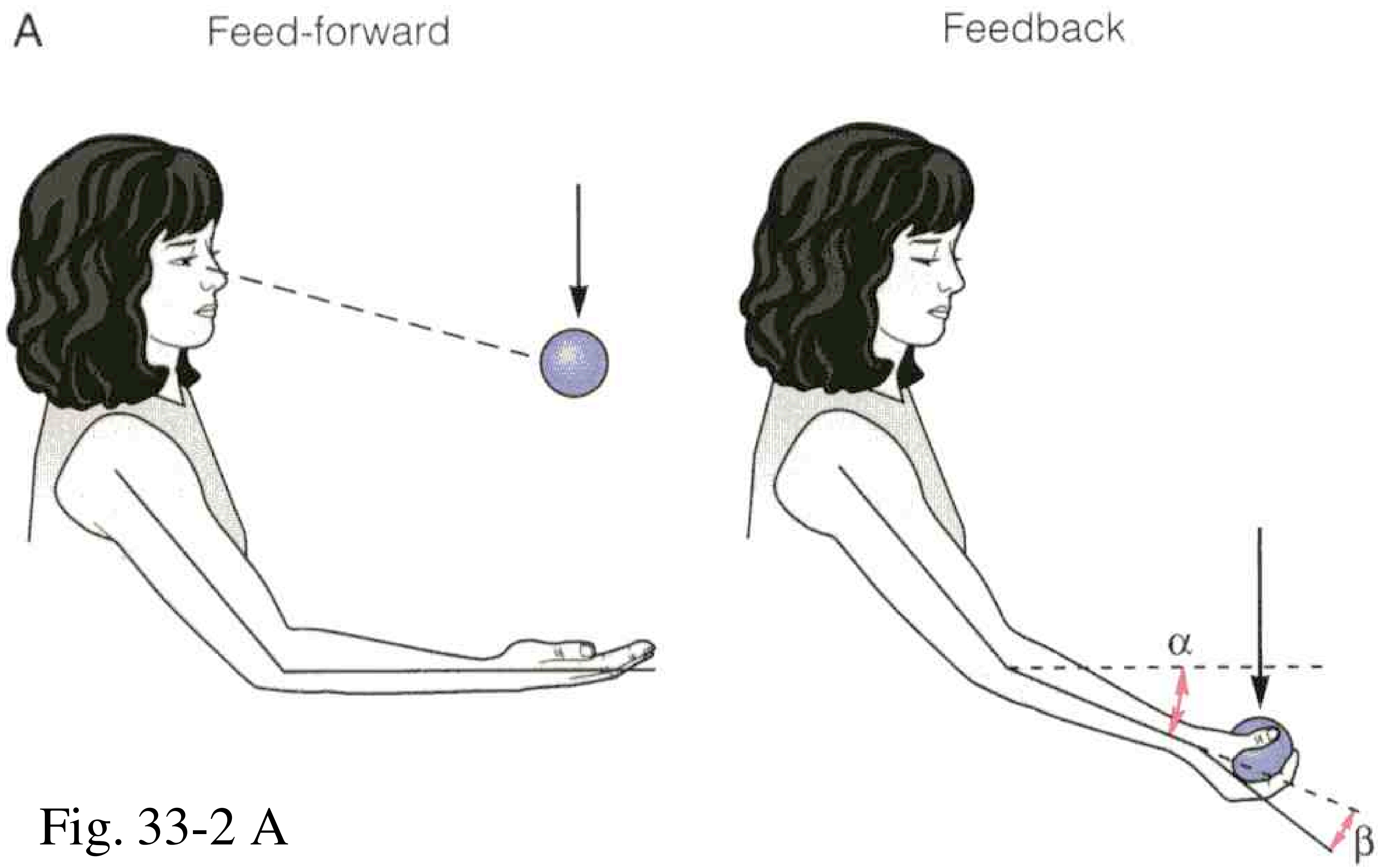


Fig. 33-2 A

Both Feed-forward & Feedback control are needed.

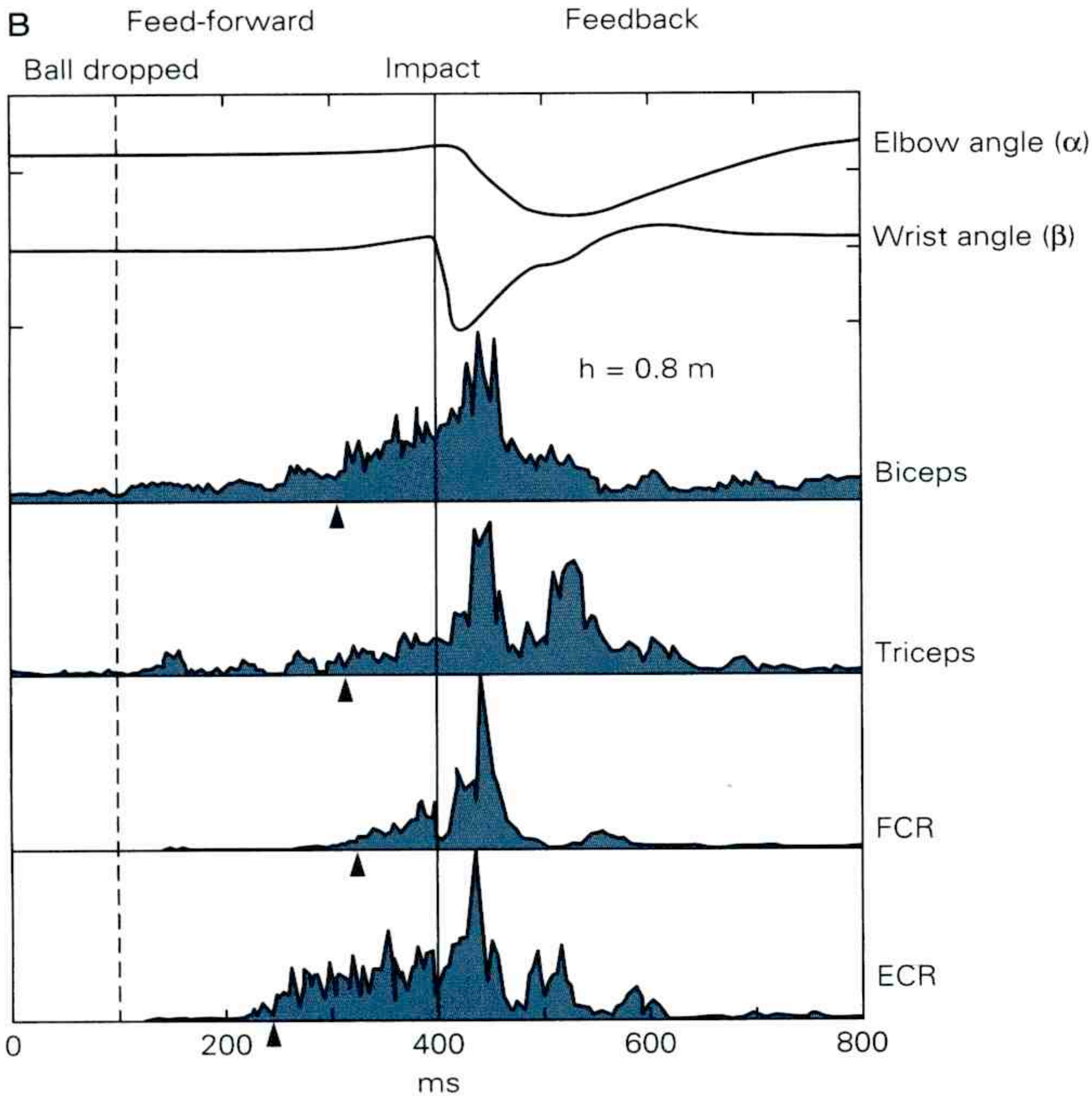

B
Feed-forward
Feedback
Ball dropped
Impact
Elbow angle (α)
Wrist angle (β)
h = 0.8 m
Biceps
Triceps
FCR
ECR
0
200
400
600
800
ms

Fig. 33-2 B

3 key principles in Feed-forward control

- Essential for Rapid action
- Prediction of sensory events
- Modifing feedback mechanism

Voluntary Movement obey Psychophysical Principles

Motor system = reverse of Sensory system

3 laws of Voluntary Movements

1. Brain represents the result of Motor action independently of the spesific effector or the way.
2. RT depends on the amount of information.
3. Trade-off @ Speed & Acuracy of Movement

Invariant Feature in Voluntary

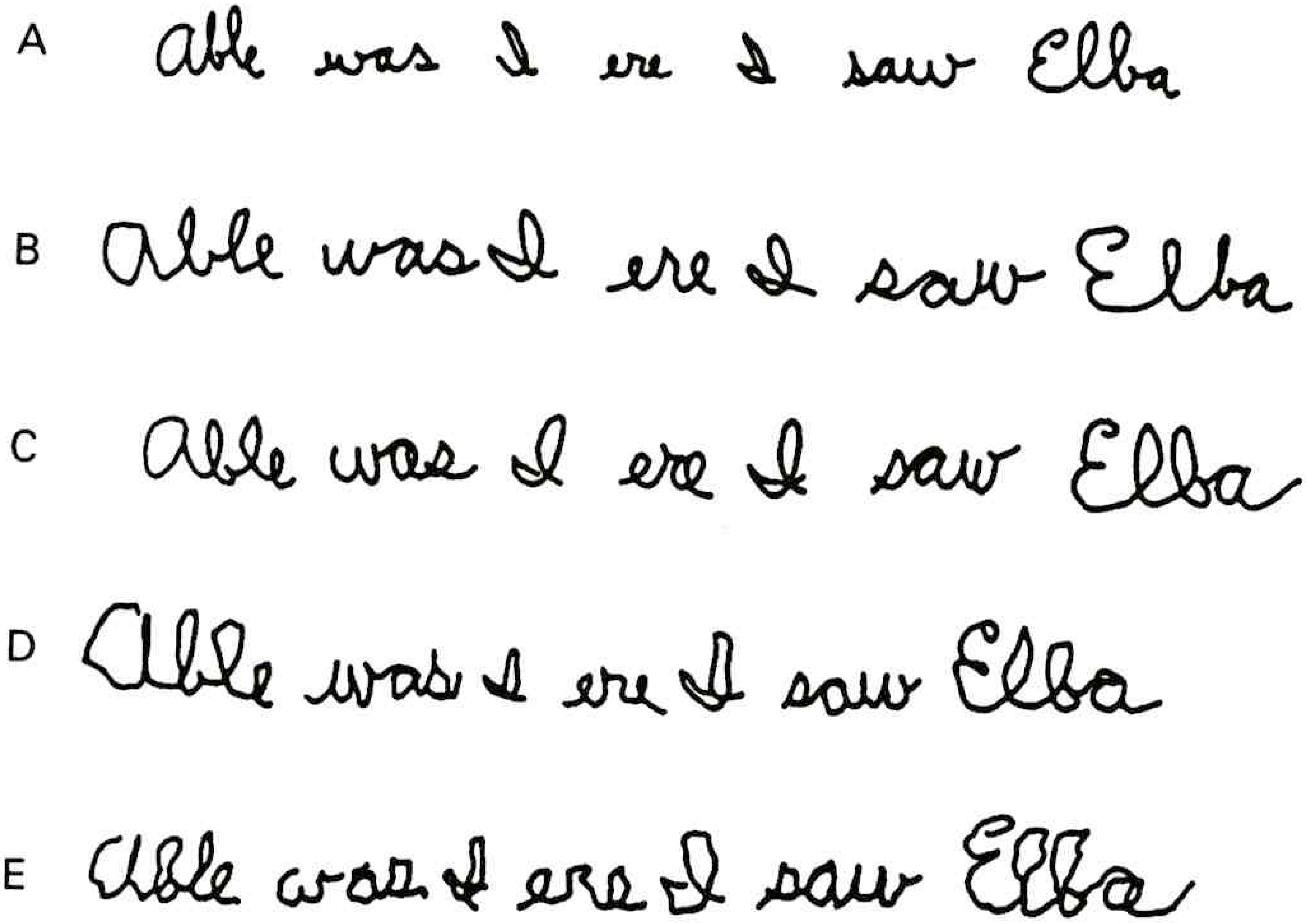


Fig. 33-3 Motor Equivalence

Complex Motion of the Joints

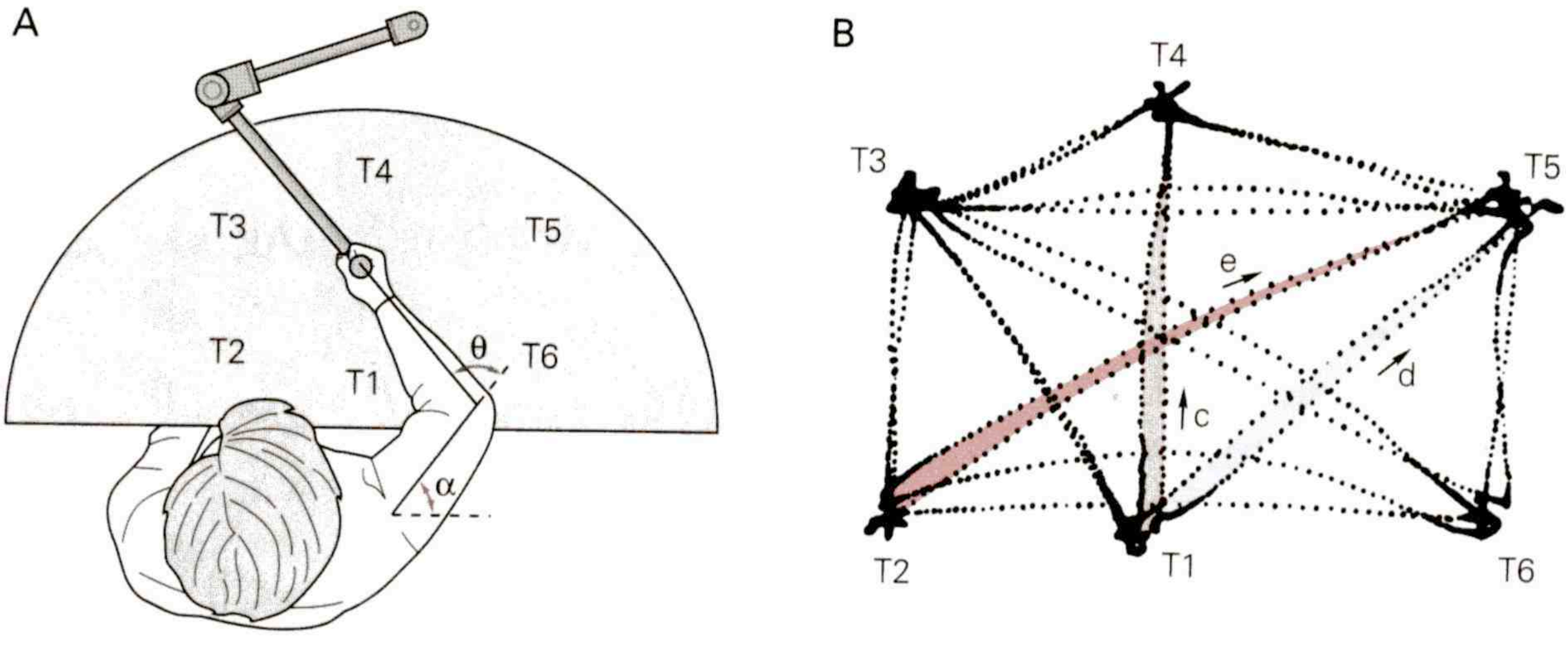


Fig. 33-4 A, B

Planning Reaching Movement

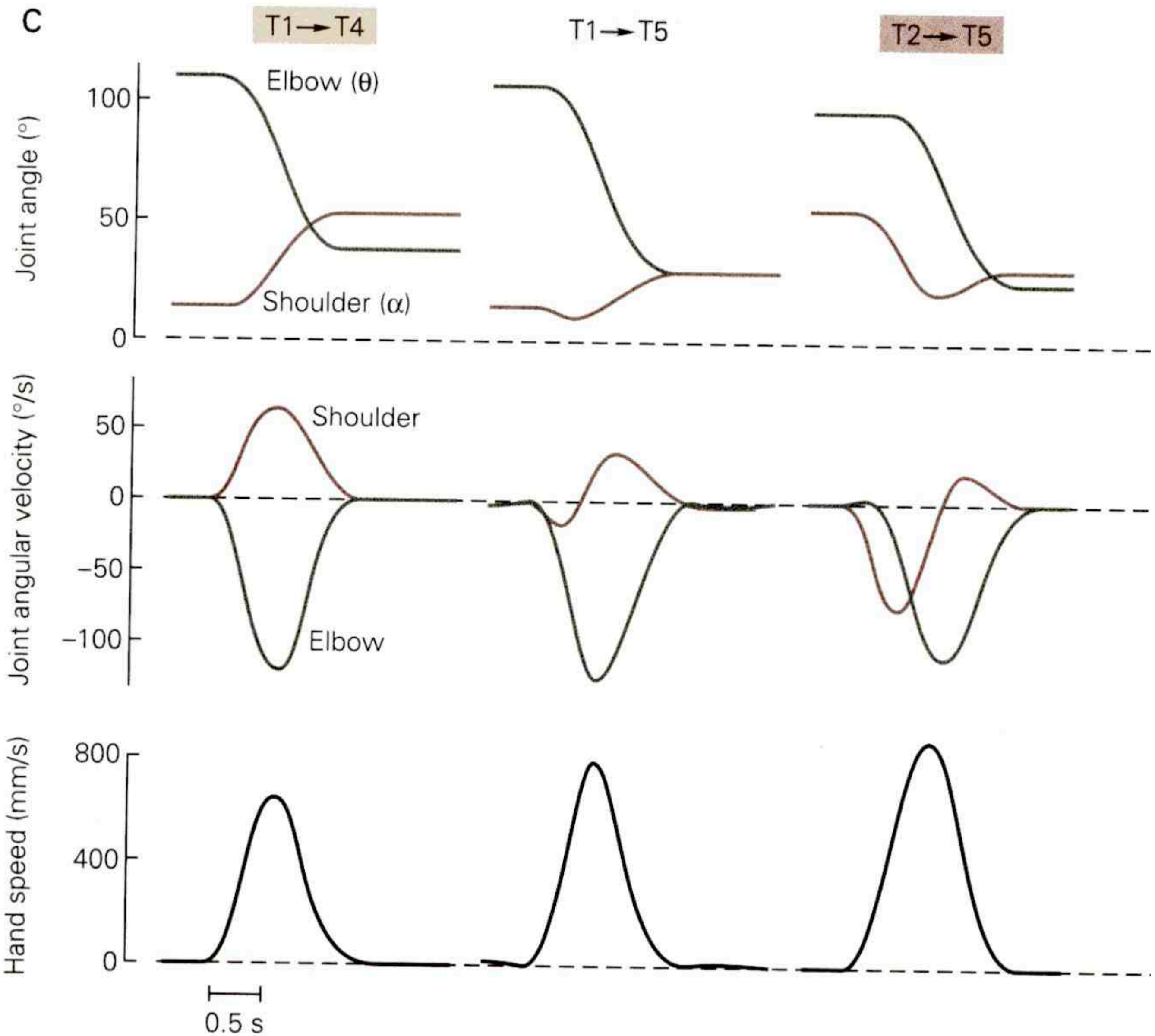


Fig. 33-4 C

Acceleration & Velocity of Reaching

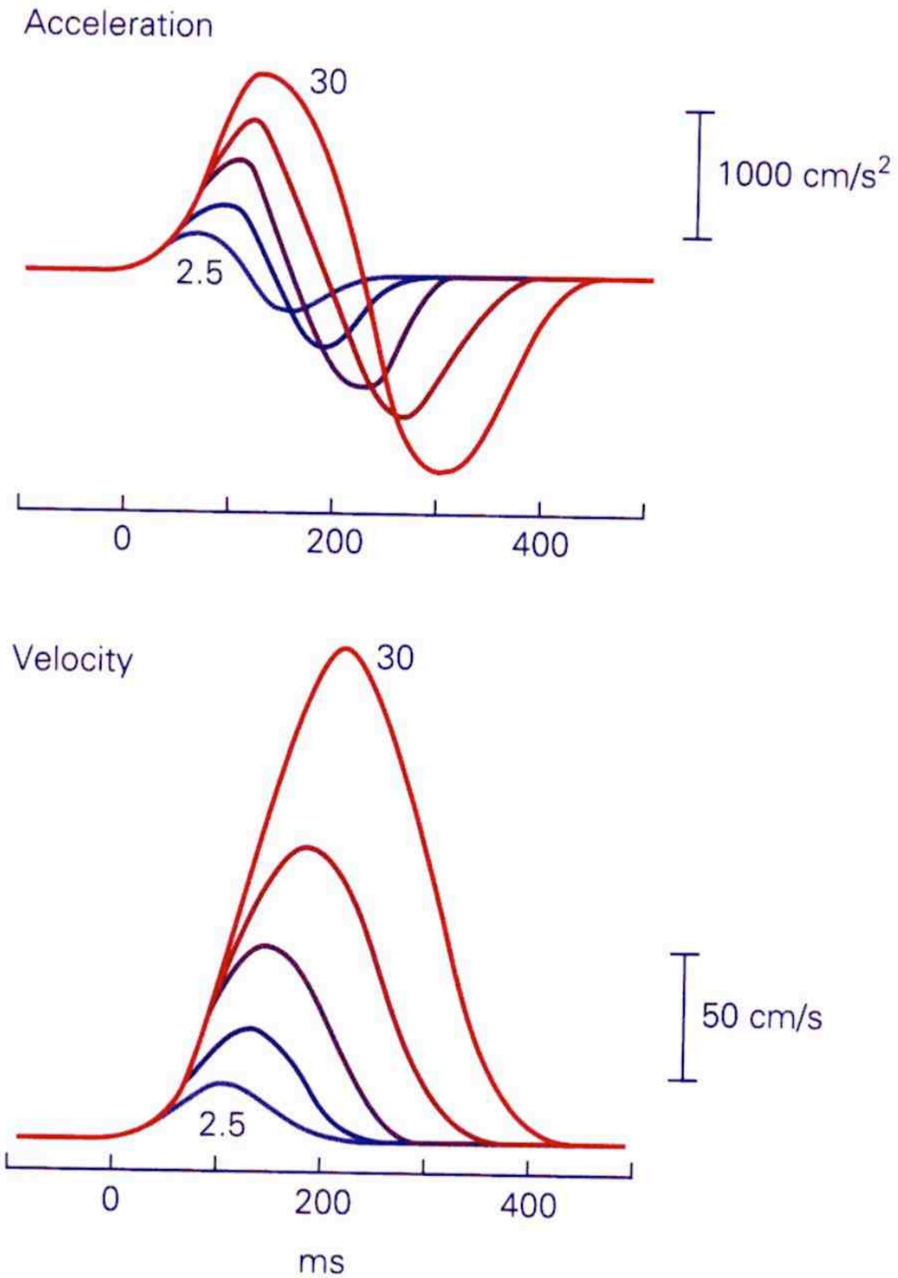


Fig. 33-5

Motor Planning

- Brain forms a representation of a Movement

before its exectuion. = Motor Planning

Ex) Movement Kinematics

Movement Dynamics

How to respond to Sensory Information

-> Experiment of Slippery object

Lifting Slippery Objects

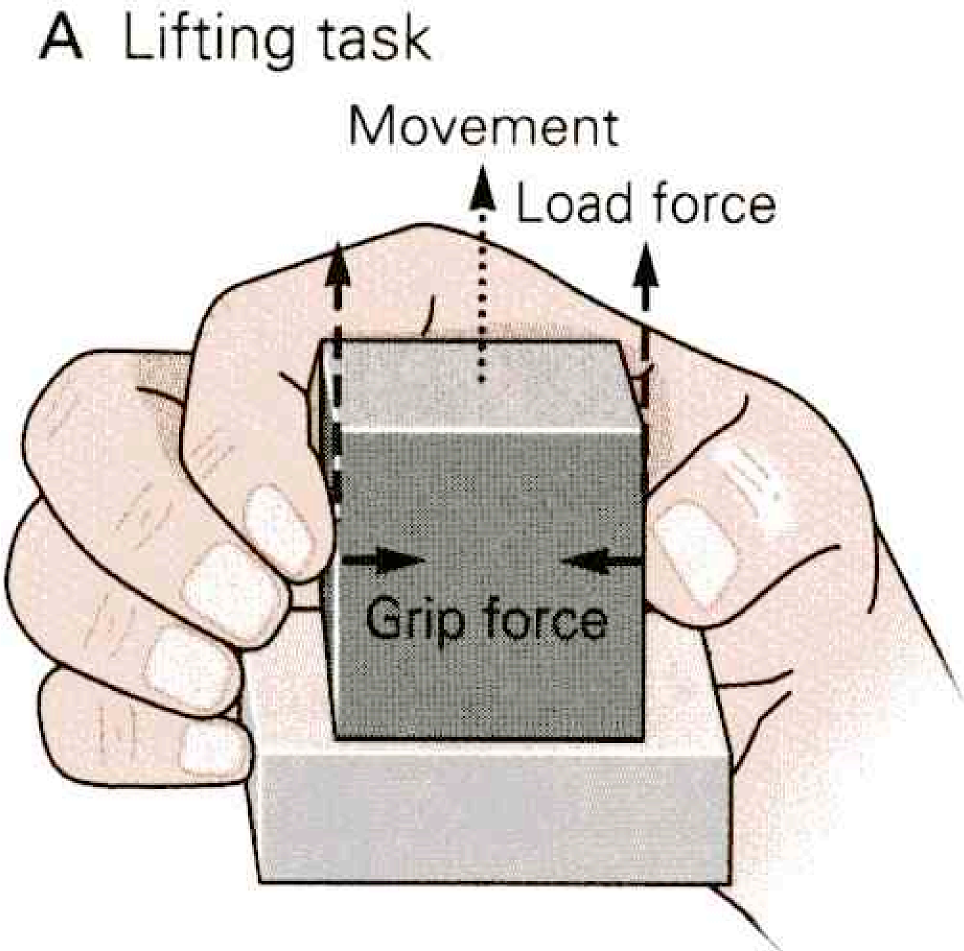


Fig. 33-6 A

B Correctly anticipated weights

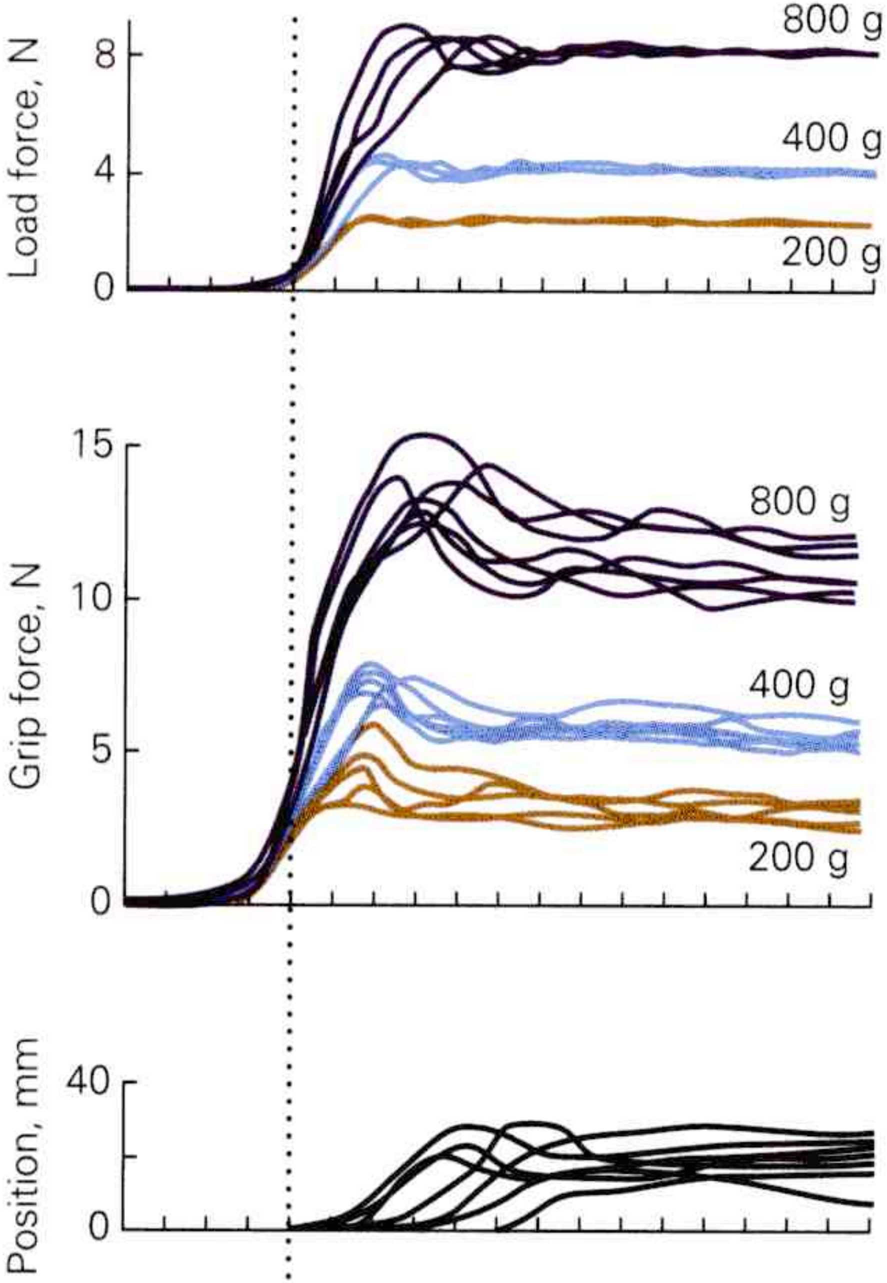


Fig. 33-6 B

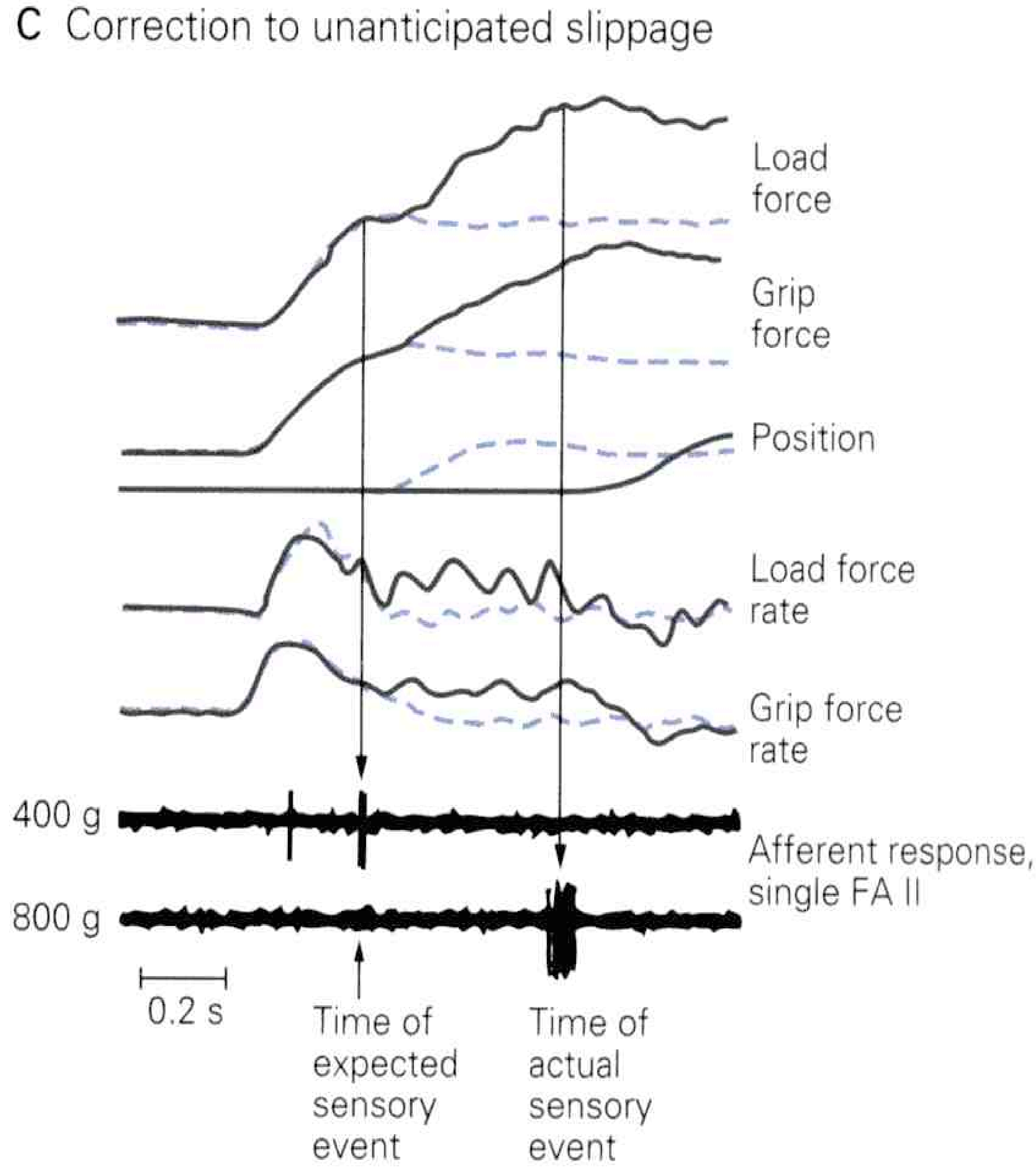

C Correction to unanticipated slippage
Load force
Grip force
Position
Load force rate
Grip force rate
400 g
800 g
Afferent response, single FA II
0.2 s
Time of expected sensory event
Time of actual sensory event

Fig. 33-6 C

Drawing of Figure 8

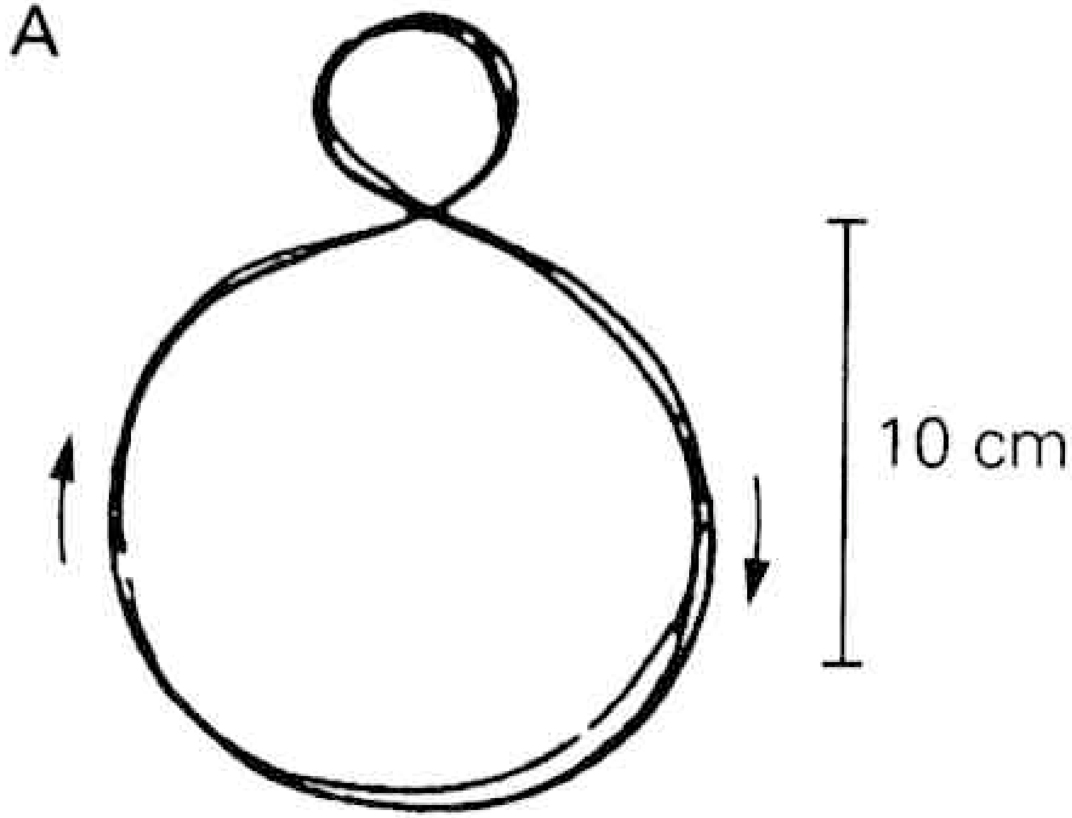


Fig. 33-7 A

Movement Primitives (Schemas)

B

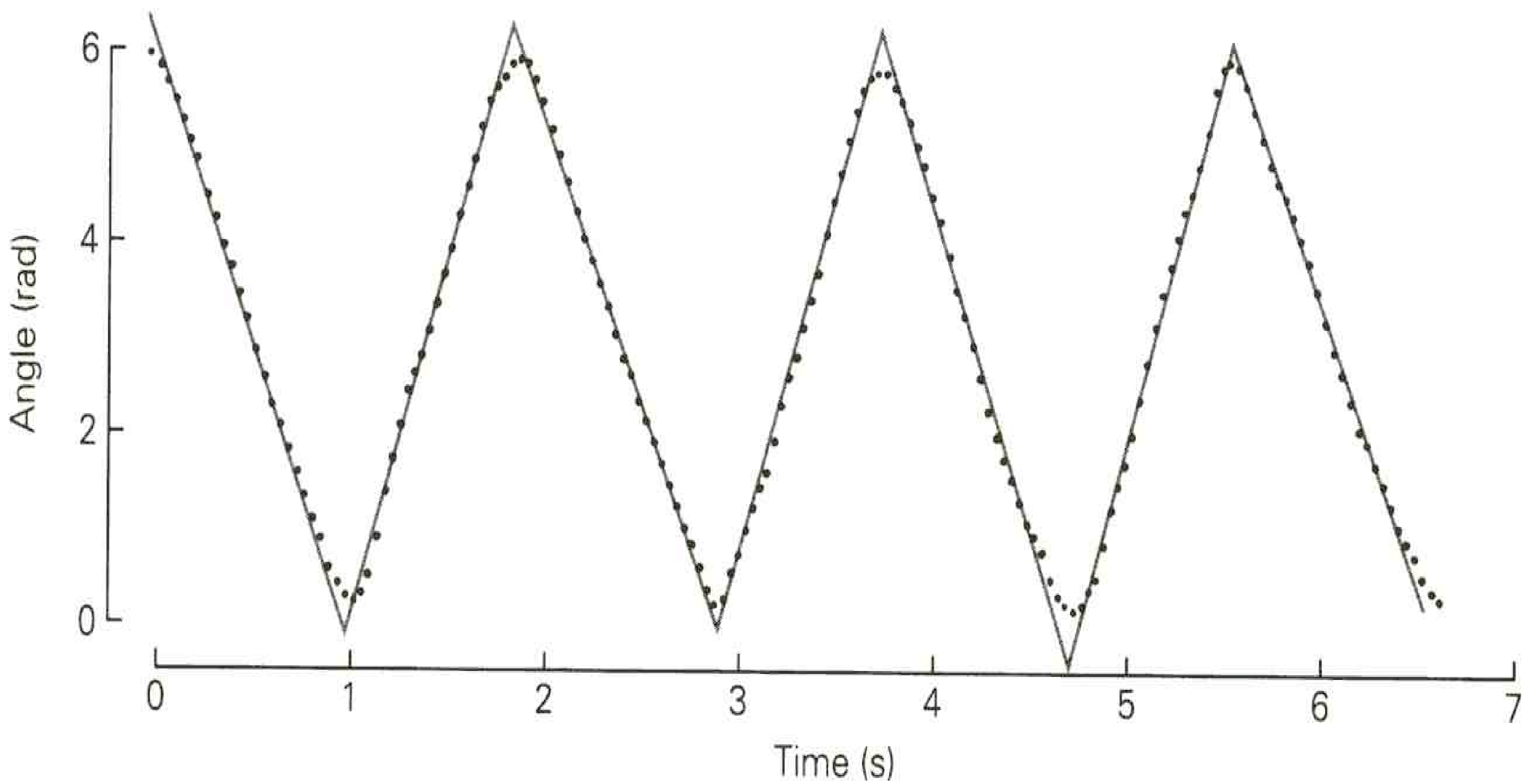


Fig. 33-7 B

RT Varies with the Amount of Info.

Reaction Time = Time betw. Stimuli & Response

Time scale of various response:

- Voluntary Response to proprioceptive stimuli ~ 80 – 120ms
- Shortest Monosynaptic Reflex response ~ 40ms
- Reaction to Visual Stimuli ~ 150-180ms

RT is shorter when subjects know which response to do, is prolonged when they must choose one of responses.

Choice Effect

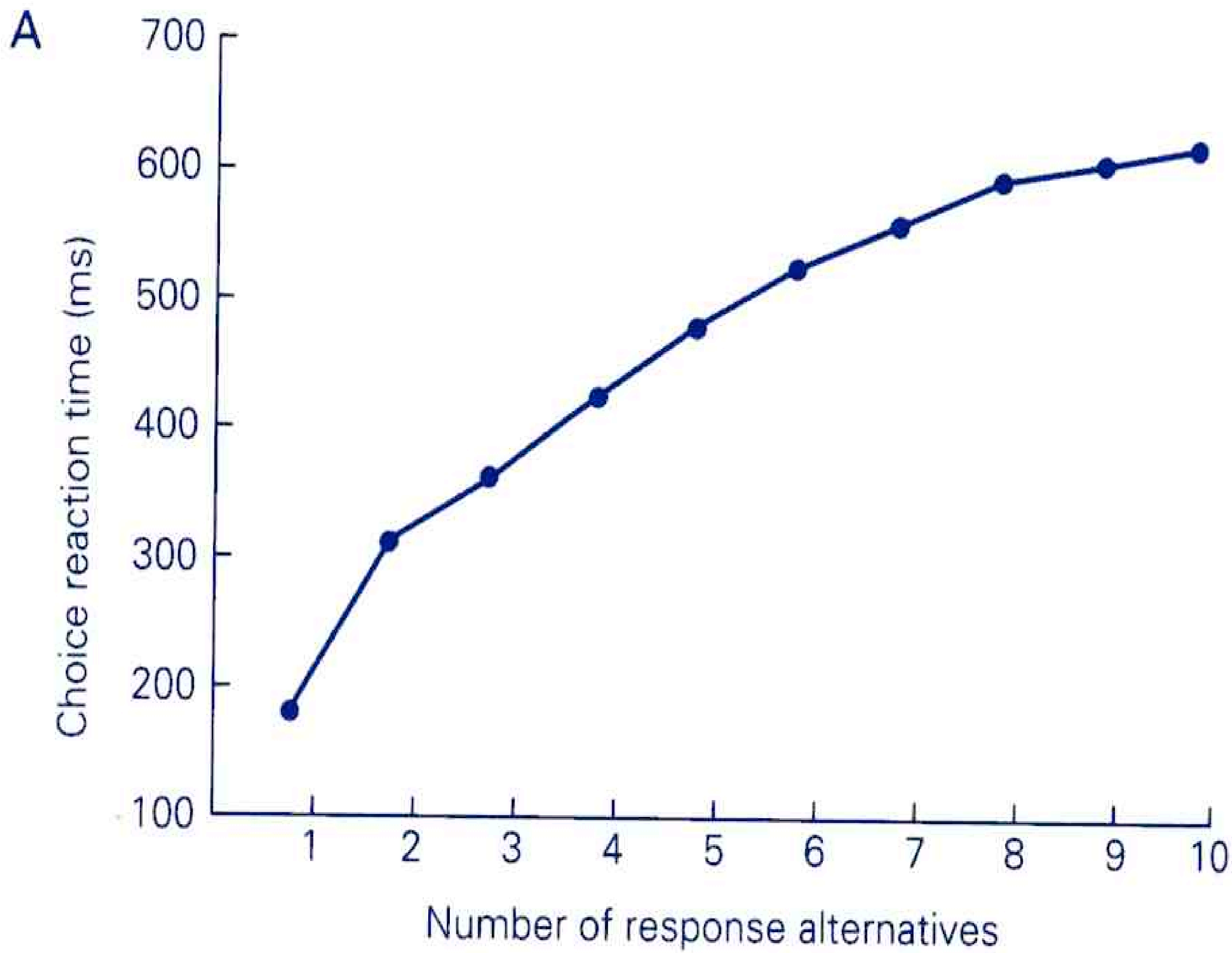


Fig. 33-8 A

Model of Info. Processing

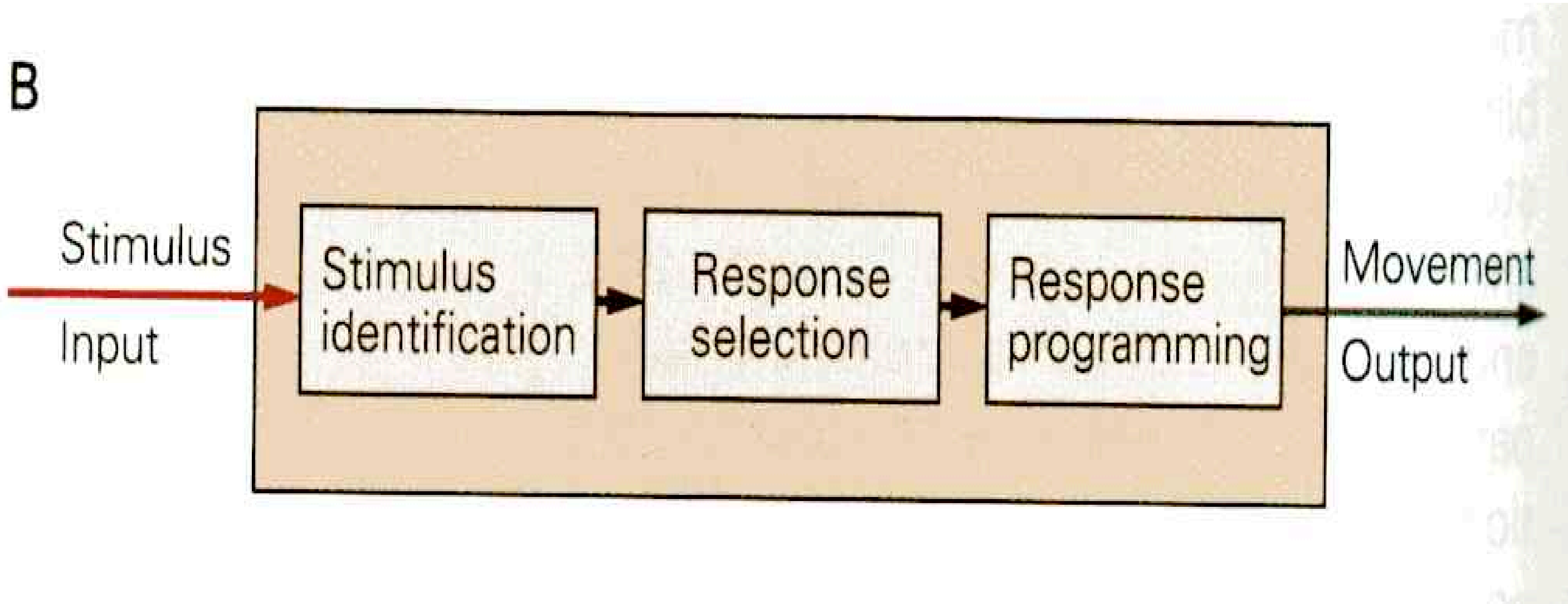


Fig. 33-8 B

RT decrease with Learning

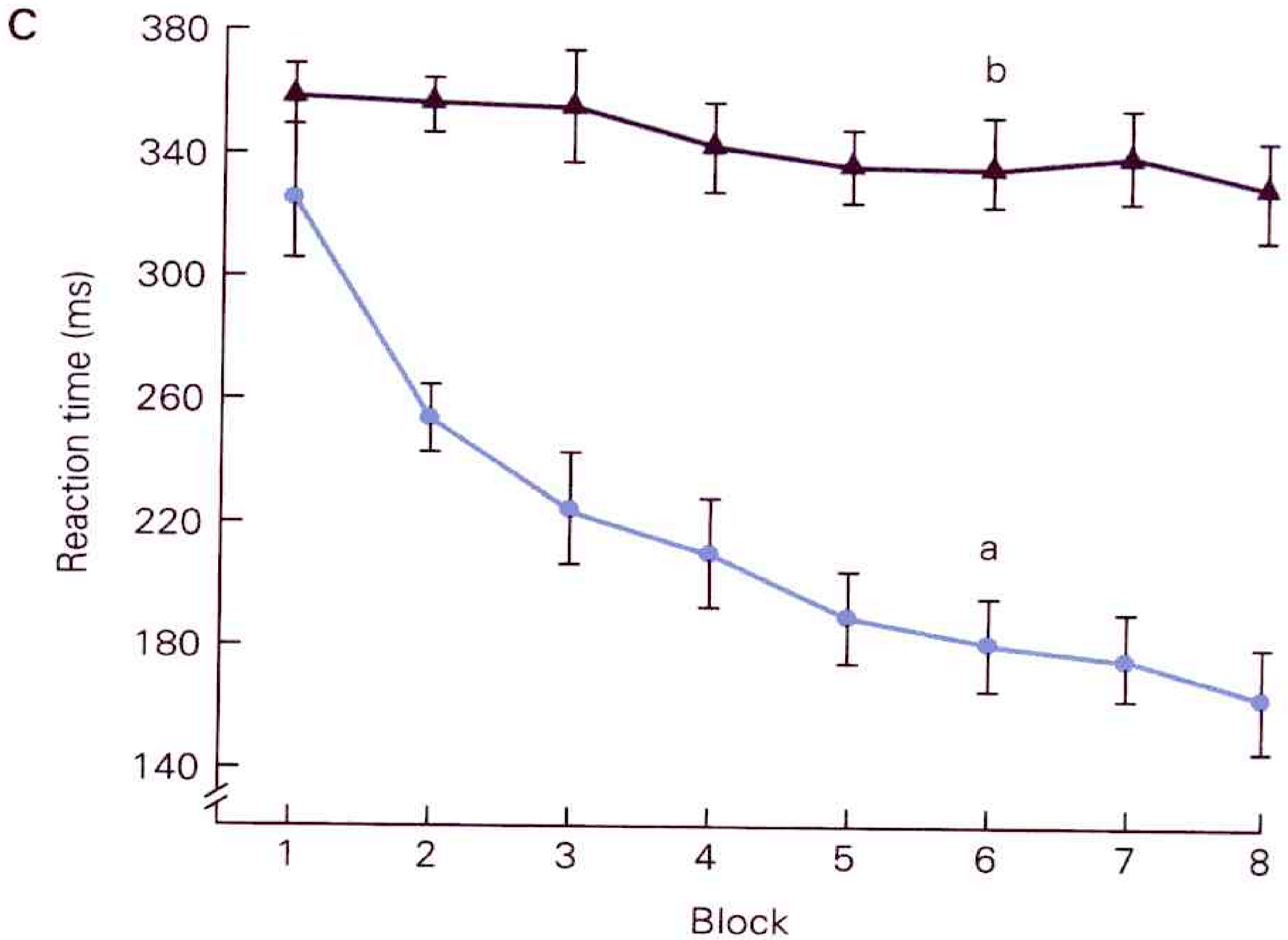


Fig. 33-8 C

Timed Response Paradigm

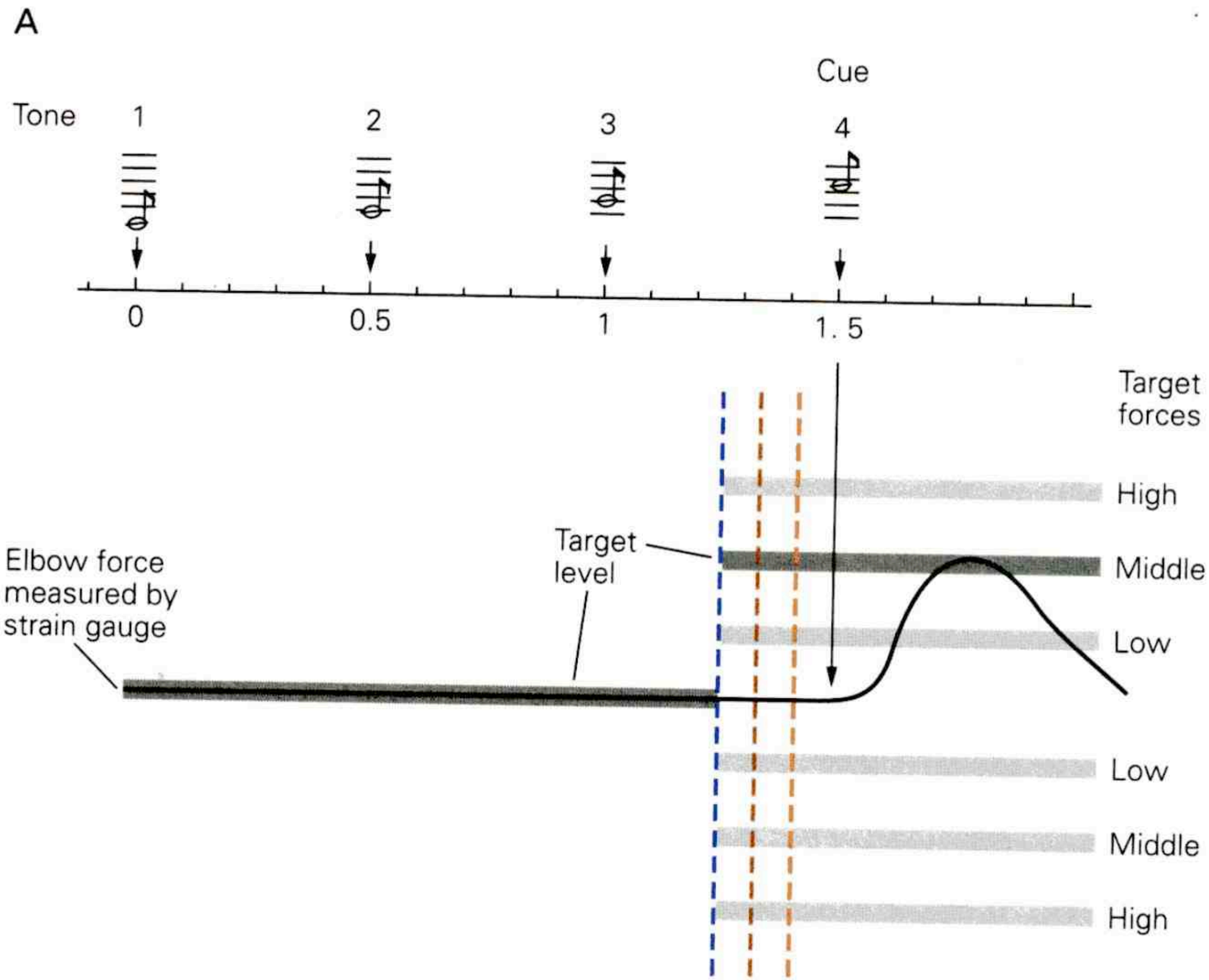


Fig. 33-9 A

Parallel Processing in Movement

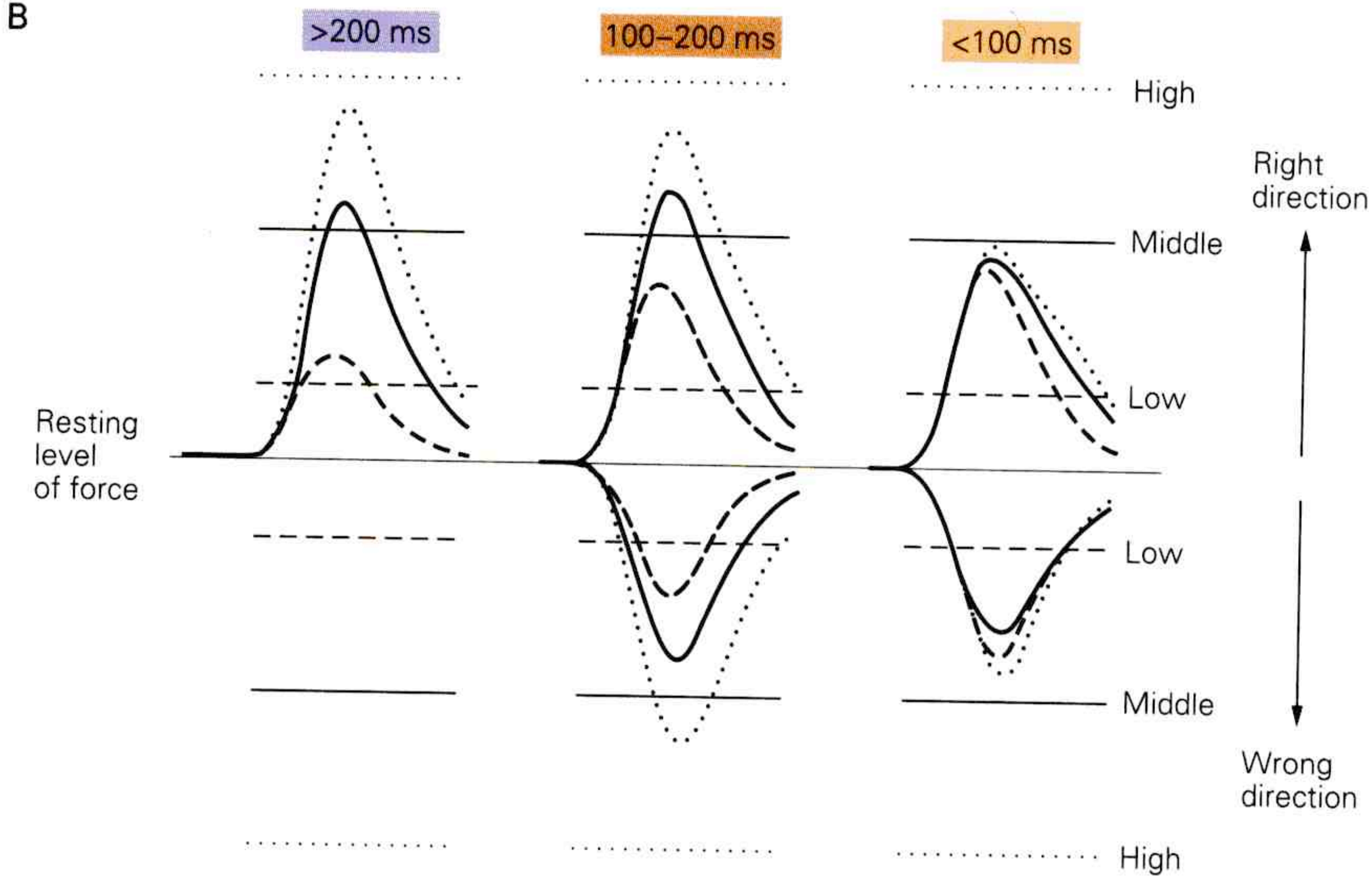


Fig. 33-9 B

Accuracy of Movement varies in proportion to Speed of Movement

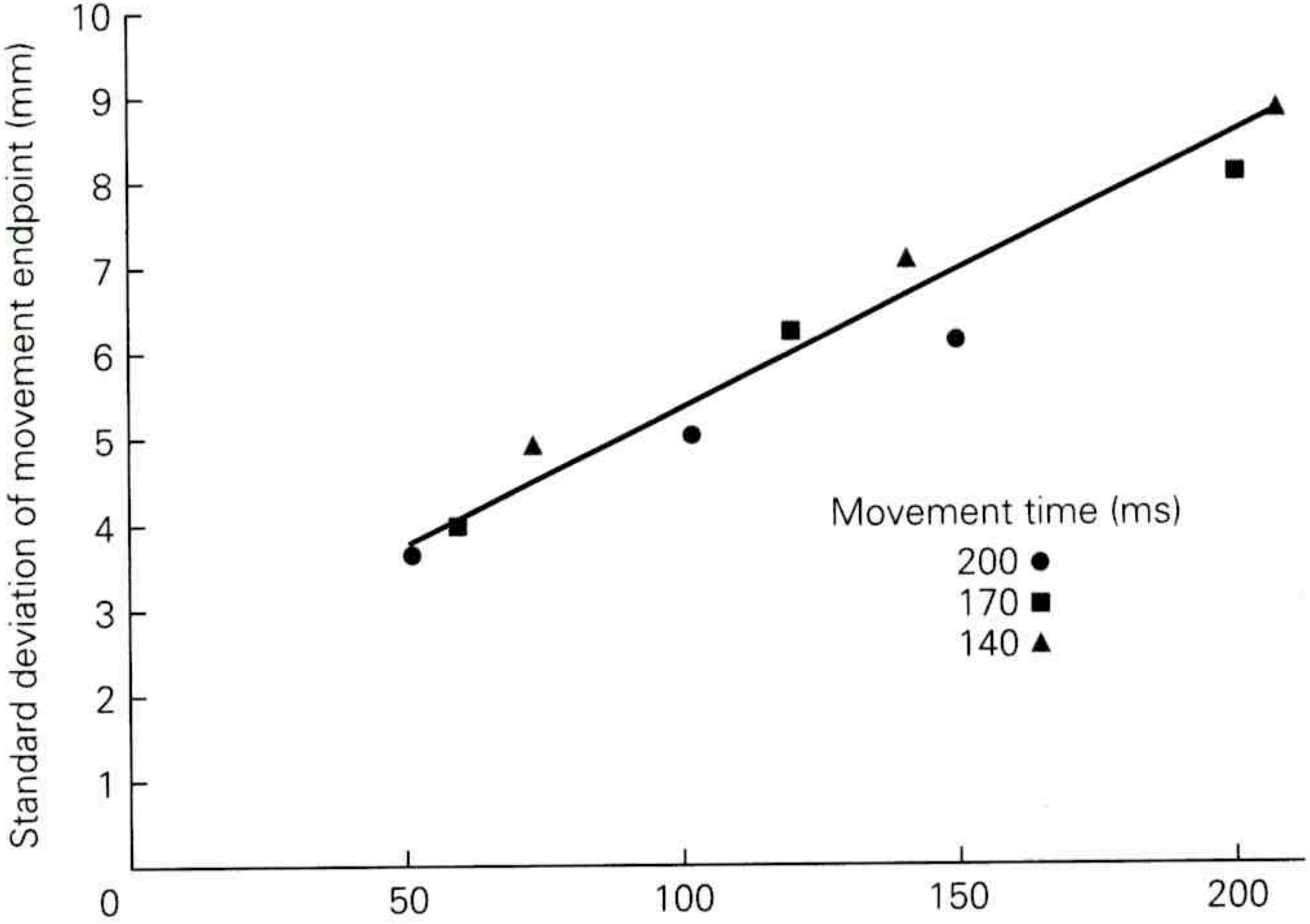


Fig. 33-10

Learning Improves the Accuracy

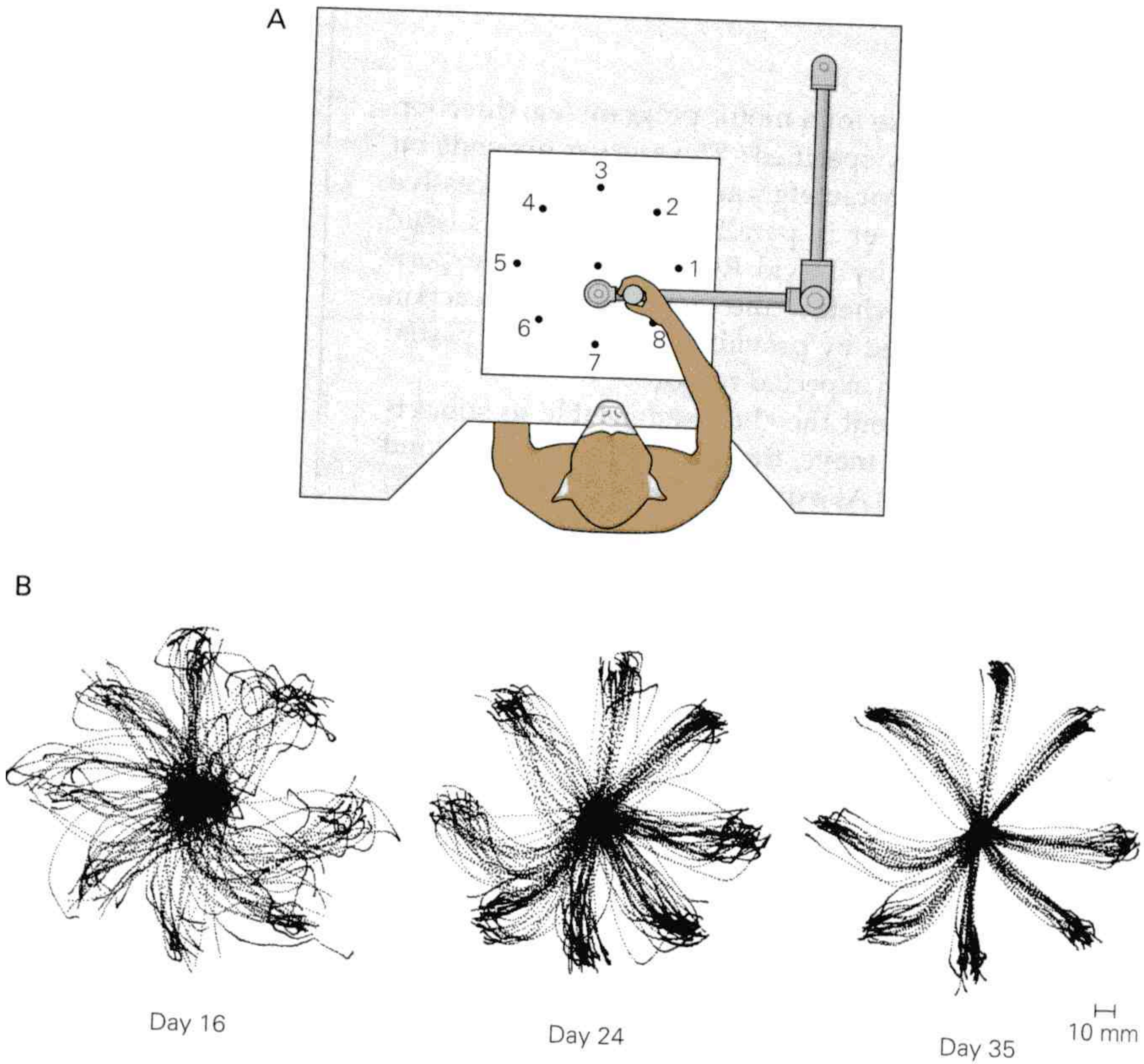


Fig. 33-11

Hierarchical Organization of the Motor System

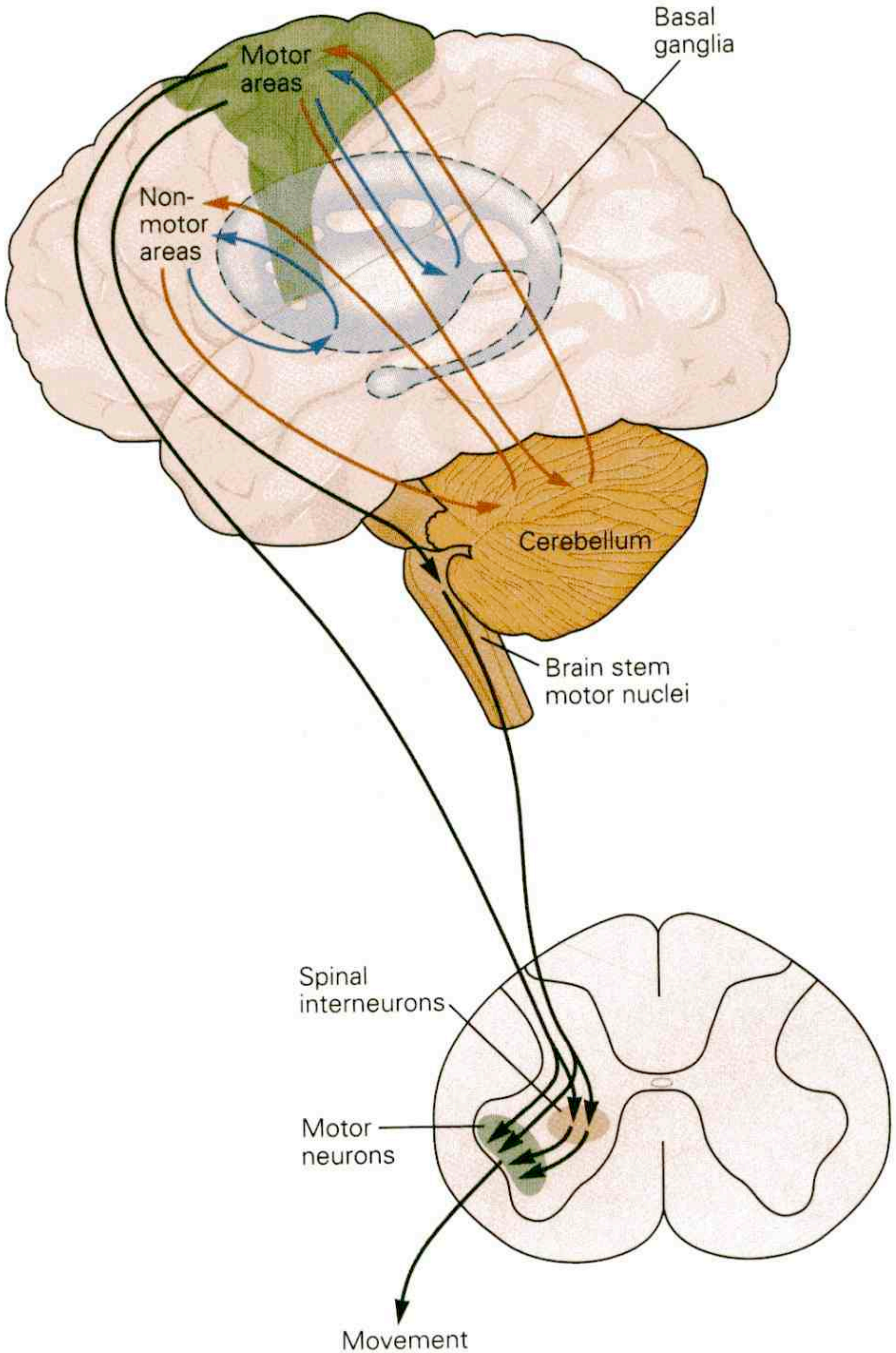


Fig. 33-12

The Cerebellum & Basal Ganglia are Both Necessary for Motor Action

- Parkinson/Huntington disease @ Basal Ganglia

 -> involuntary movement, abnormal posture, etc…

 -> Motivation & Selection of Adaptive Behavioral Plan (Chap. 43)

- Vascular lesions & Familial Degenerative @ Cerebellum

 -> Loss of coordination & Accuracy of Limb Movement

 -> Timing & Coordination of Movements

& with Learning of Motor Skills (Chap. 42)

Lesions of the Motor Pathway -> Positive/Negative Signs

- Negative Signs = Loss of particular capacities controlled by the damaged system
- Positive Signs = Withdrawal of Tonic Inhibition from neural circuits mediating behavior

In human, Lesions of the pathway or Brain stem

-> Weakness of Voluntary Movements

& Increase of Muscle Tone

Diagnosis of Motor Impairment

3 important differences separate diseases of the descending pathway and motor neuron:

i) spasticity in the former

ii) denervation atrophy & reduce of muscle volume in the latter

iii) more diffusely in limb or face muscle/

a patchy way & limitation to singe muscle

4 Types of Neurons in the Spinal Gray Matter

1. Local Interneurons -> the same/adjacent segment
2. Propriospinal neurons -> distant spinal segment
3. Projection Neurons -> ascend to higher centers
4. Motor Neurons -> innervate muscles

(Right sites of arrows, “->” show axons terminal.)

The Motor Nuclei @ Spinal code

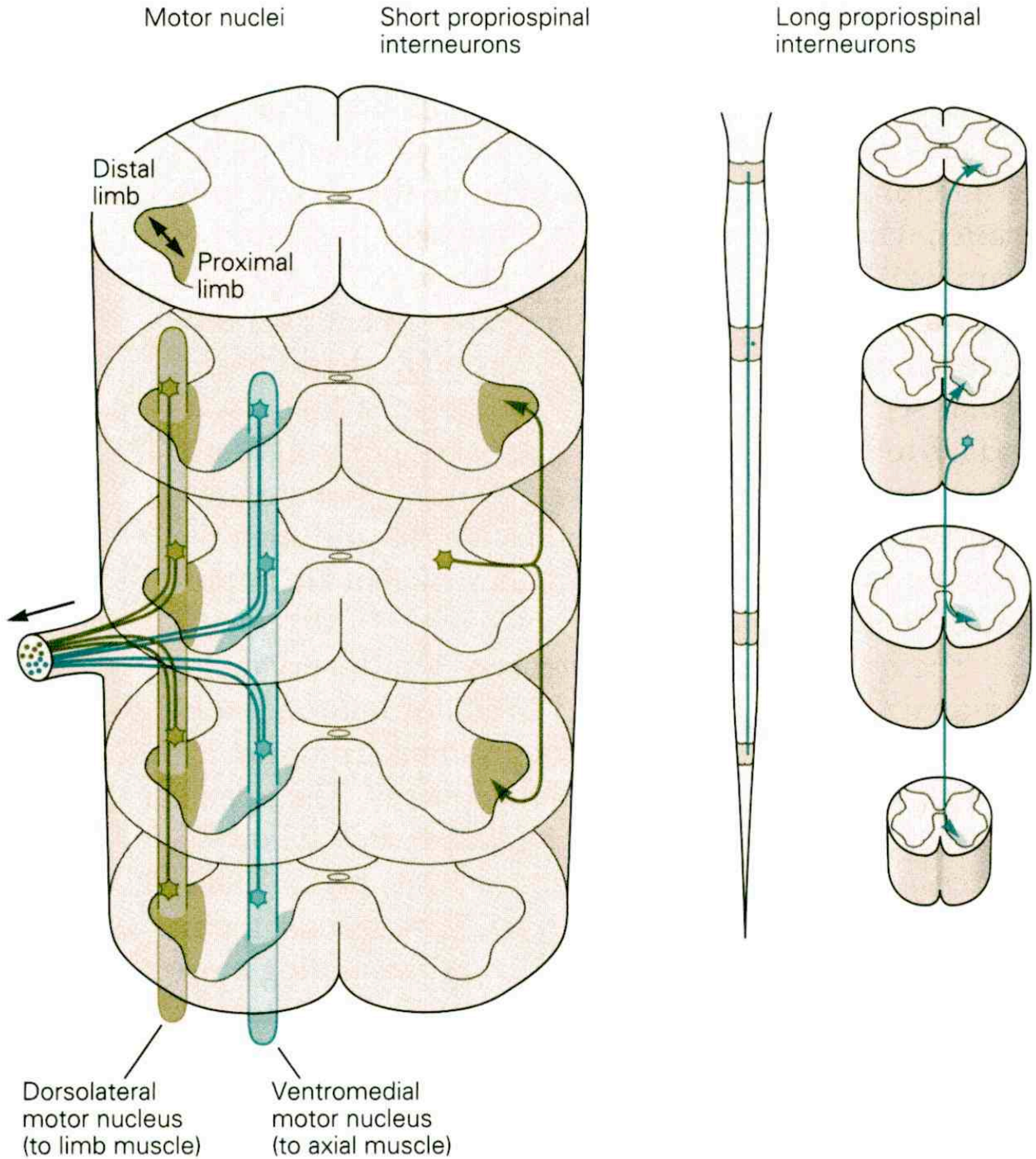


Fig. 33-13

Medial & Lateral Descending Pathways

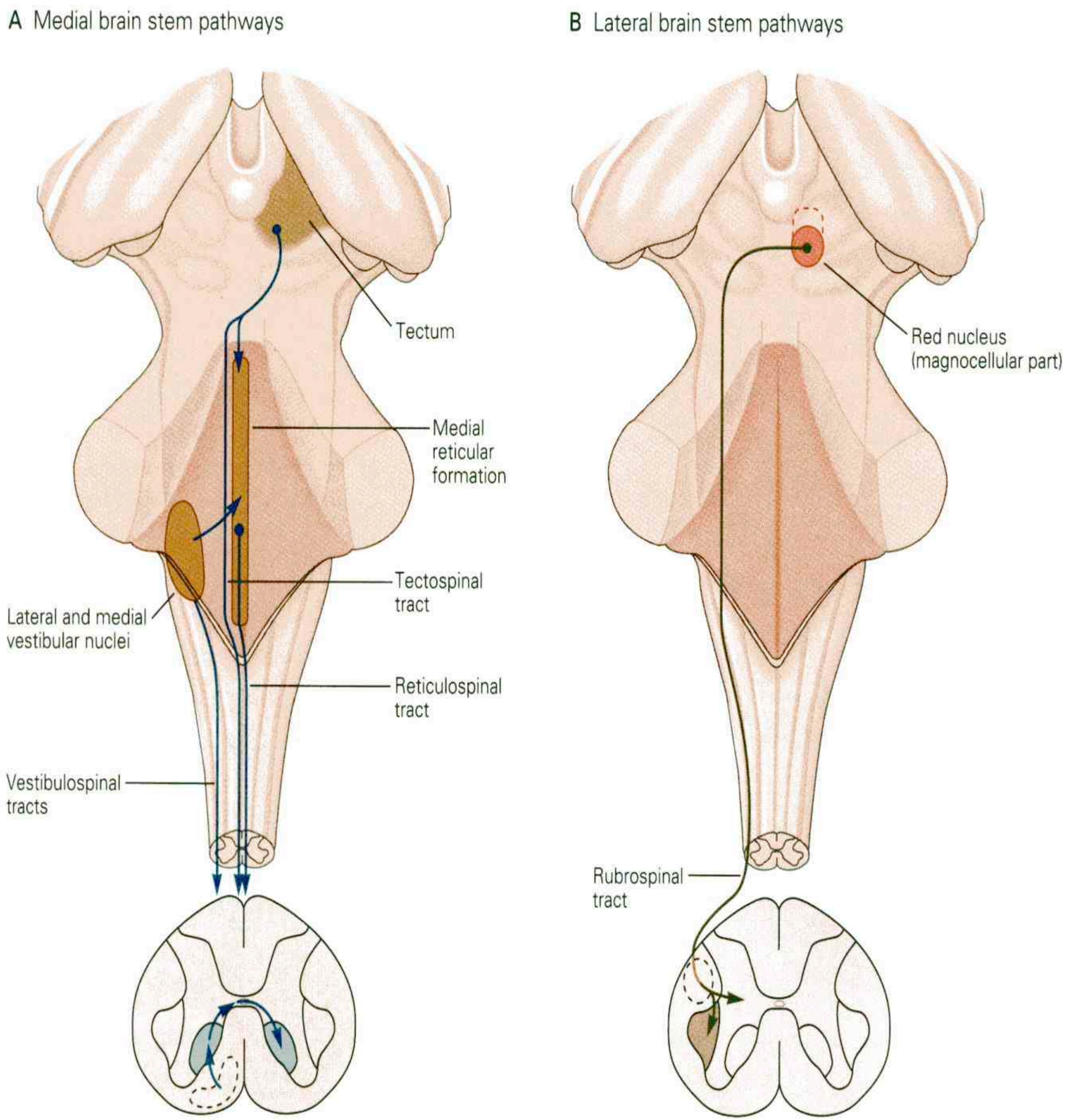
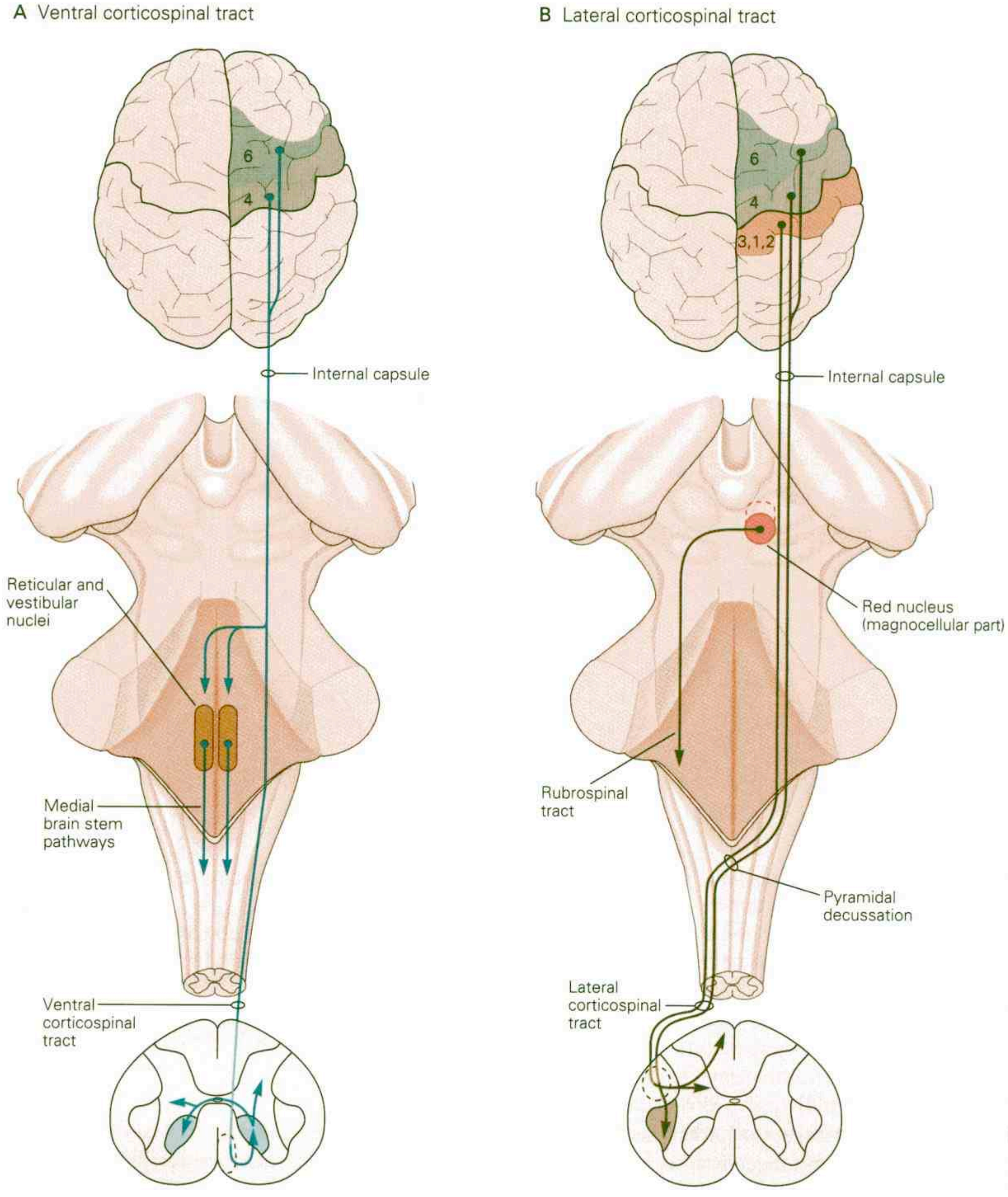


Fig. 33-14

The Cortex Control Motor neurons through desending pathways

Fig. 33-15



Overall View

- Motor commands are organized Hierarchically.
- The cortex can control the Motor neurons by Corticospinal & Corticobulbar pathways.
- The inputs to each component of motor hierarchy create somatotopic map. Then, each level of motor control receives sensory info. , modifing the motor output. Finally, motor program refined continuously by learning.