I. OVERVIEW
   a. Function
      i. Modulate cerebral cortex outputs - suppress unnecessary actions
      ii. No direct innervation → lesions never produce paralysis, only imbalance
      iii. Comparison to cerebellum:
           1. Cerebellum receives input from only motor centers, output to both motor cortices and all subcortical centers
           2. Basal ganglia receive input from entire cortex, output only to motor cx
   b. Deep telecephaic nuclei (noncortical gray matter)
      i. Amygdala – see limbic system
      ii. Caudate and putamen = “striatum”
         1. Developmentally identical; cannot be distinguished in lower mammals
         2. In primates, separated by internal capsule
      iii. Globus pallidus = “pallidum”
      iv. Claustrum – no known function
   c. Associated nuclei
      i. Diencephalon: ventral anterior thalamic nucleus, ventral lateral thalamic nuc, central median nuc, subthalamic nuc
      ii. Mesencephalon: substantia nigra
         iii. NOT red nucleus, reticular formation

II. CONNECTIONS
   a. Caudate and putamen
      i. Caudate = projections mostly from prefrontal, temporal, parietal assoc areas
      ii. Putamen = from motor, somatosensory cortices
      iii. Inhibitory to Globus pallidus (GABAergic)
         *Ventral striatum (nucleus accumbens – rec orbitofrontal) to ventral pallidum
   b. Globus pallidus
      i. External segment (GPe) – inhibitory (GABA) to Subthalamic nucleus
      ii. Internal segment (GPi) – inhibitory (GABA) to VL/VA, CM of thalamus (balances excitatory input from dentate nucleus of cerebellum)
      iii. Substantia nigra pars reticulata – part of internal segment – same connections
      iv. 2 pathway to thalamus: via ansa lenticularis (around cerebral peduncle) or lenticular fasciculus (through internal capsule)
         *ventral pallidum to MD of thalamus
   c. Subthlamic nucleus
      i. Excitatory to internal globus pallidus (GPI) (inhibits thalamus → cortex)
      ii. Receives strong excitatory projection from motor cx (net inhibition of cortex)
   d. Substantia nigra pars compacta – DA efferents to caudate/putamen
      i. D1 = excitatory, D2 = inhibitory
      ii. Projects to pallidum, VL/VA = indirect/direct influence
   e. Afferents from thalamus to Cortex
      i. VL → primary motor, premotor
      ii. VA → motor cortices; diffuse to prefrontal, parietal, temporal, occipital cortices
iii. CM → somatosensory cortex; diffuse to cerebral cortex
   *MD → prefrontal, limbic cortices

f. Other descending pallidal efferents
   i. small projections to midbrain reticular form. → modulate ReST (muscle tone)
   ii. small projections to tectum → tectospinal system (orienting)
   iii. small proj to habenula → limbic system (species-preserving behaviors)

III. PATHWAYS (SUMMARY OF CONNECTIONS)
   a. Direct pathway
      i. Cortex (+) → caudate/putamen (-) → GPi/SNpr (-) → VA/VL (+) → Cortex
      ii. Net excitatory effect on cortex (2 inhibitions cancel - disinhibition)

b. Indirect pathway
   i. Cortex (+) → caud/put (-) → GPe (-) → STN (+) → GPi (-) → VA/VL (+) → Cortex
   ii. Net inhibitory effect on cortex

IV. CLINICAL CONSIDERATIONS
   a. Damage to basal ganglia – classical symptoms:
      i. Increased motor tone – rigidity
      ii. Dyskinesias – tremors, other involuntary movement
      iii. Bradykinesia/Akinesia – slowing/ almost absent voluntary movement

b. Hemiballismus
   i. Damage to subthalamic nucleus or its connections to GPi (unilateral)
   ii. Involuntary, irregular flinging of contralateral extremity (usually upper)

c. Huntington’s disease
   i. Early degeneration of the striatum
   ii. Involuntary movements “choreiform” - writhing

d. Parkinson’s disease
   i. Damage to SNpc (depletion of DA in striatum)
   ii. Rigidity and tremor, brady/akinesia
   iii. Reflects disruption of cortical - basal ganglia - cortical loop:
      1. Direct pathway: loss of DA1 → decrease inhibition of GPi... less net excitation of cortex
      2. Indirect pathway: loss of DA2 → more inhibition → less net excitation of cortex
      3. Result is akinesia
   iv. Imbalance of excitatory (D1) and inhibitory (D2) effects of pathway → treat by restoring balance:
      1. increasing efficacy of dopamine release (administer L-DOPA)
      2. lesions to block GPi/STN activity
      3. transplant dopaminergic neurons

*Pyramidal and Extrapyramidal syndromes → implies anatomical-functional relationships that don’t reflect actual organization (damage is caused by damage to motor cortex, not pyramids or pyramidal tract)