

Neuronal Control of the Bladder

Seung-June Oh, MD

Department of urology,

Seoul National University Hospital

Seoul National University College of Medicine

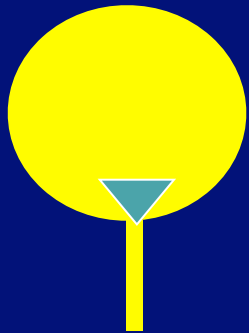
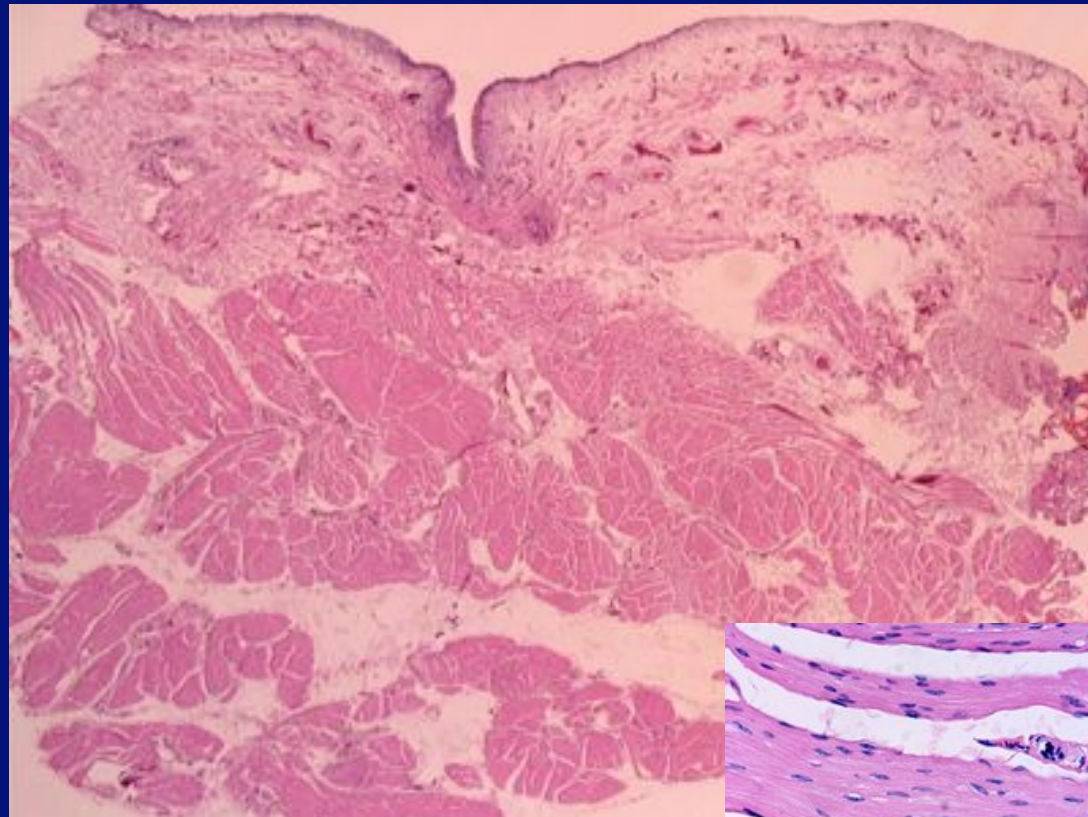
Contents

Relevant end organs and nervous system

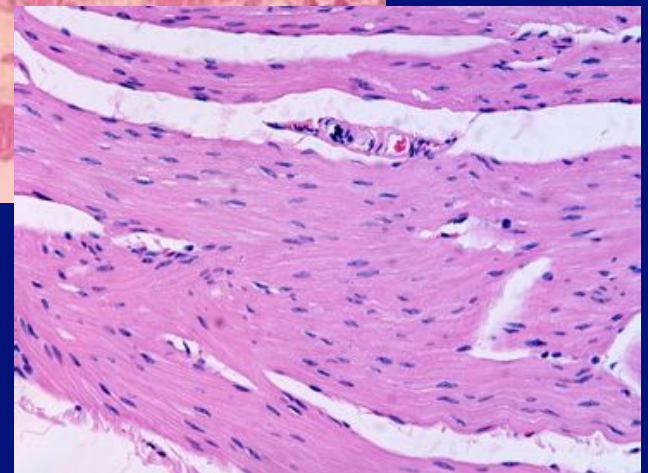
Reflex pathways

Implication in the sacral neuromodulation

Urinary bladder



- body: detrusor
- trigone and bladder neck



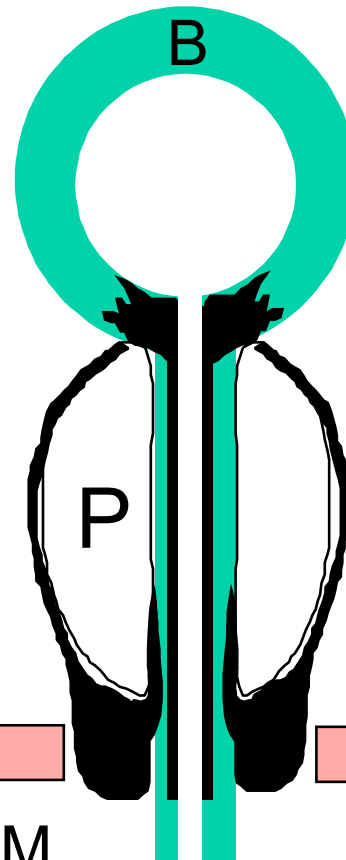
Urethral sphincters

Smooth M. Sphincter

Skeletal M. Sphincter

P-M Striated Sphincter

Periurethral Striated M.



Preprostatic S

Passive Prostatic S

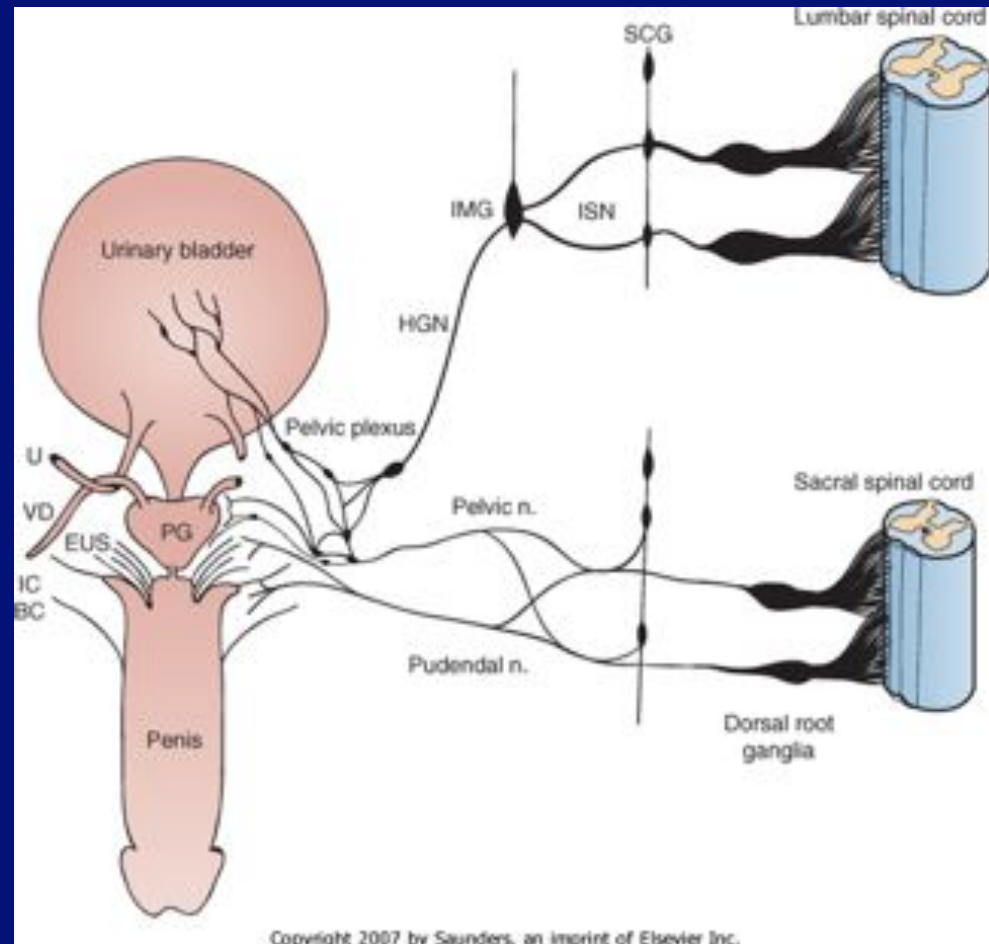
Prostatic SS

Membraneous SS

Pubococcygeous

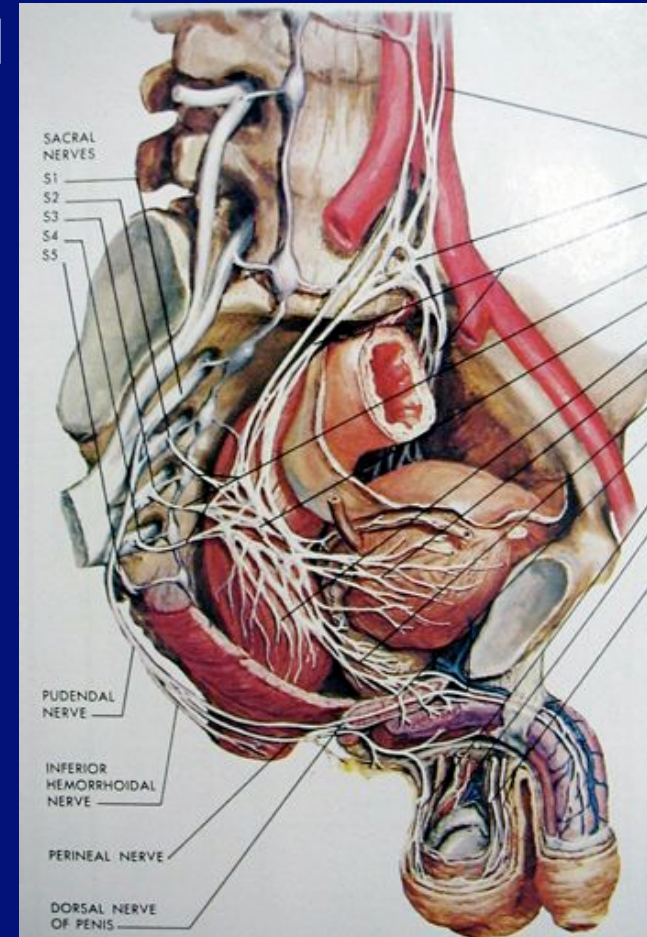
Spinal cord

- **S2–S4 spinal cord**
 - primary parasympathetic micturition center
 - bladder and distal urethral sphincter
- **T11-L2 spinal cord**
 - sympathetic outflow
 - bladder and proximal urethral sphincter



Peripheral innervation

- The lower urinary tract is innervated by 3 principal sets of **peripheral nerves**:
 - parasympathetic -pelvic n.
 - sympathetic-hypogastric n.
 - somatic nervous systems –pudendal n.
- Parasympathetic and sympathetic nervous systems form pelvic plexus at the lateral side of the rectum before reaching bladder and sphincter



Sympathetic & parasympathetic systems

- **Sympathetic pathways**

- originate from the T11-L2 (*sympathetic nucleus; intermediolateral column of gray matter*)
- inhibiting the bladder body and excite the bladder base and proximal urethral sphincter

- **Parasympathetic nerves**

- emerge from the S2-4 (*parasympathetic nucleus; intermediolateral column of gray matter*)
- exciting the bladder and relax the urethra

Sacral somatic system

- emerge from the S2-4 (*Onuf's nucleus; ventral horn*)
- form pudendal nerve, providing an innervation to the striated urethral sphincter
- excite the distal striated urethral sphincter

Spinal parasympathetic nucleus

Afferent

visceral/EUS

cutaneous perineal

muscle spindle

genital / visceral
overlap



Efferent

SPN

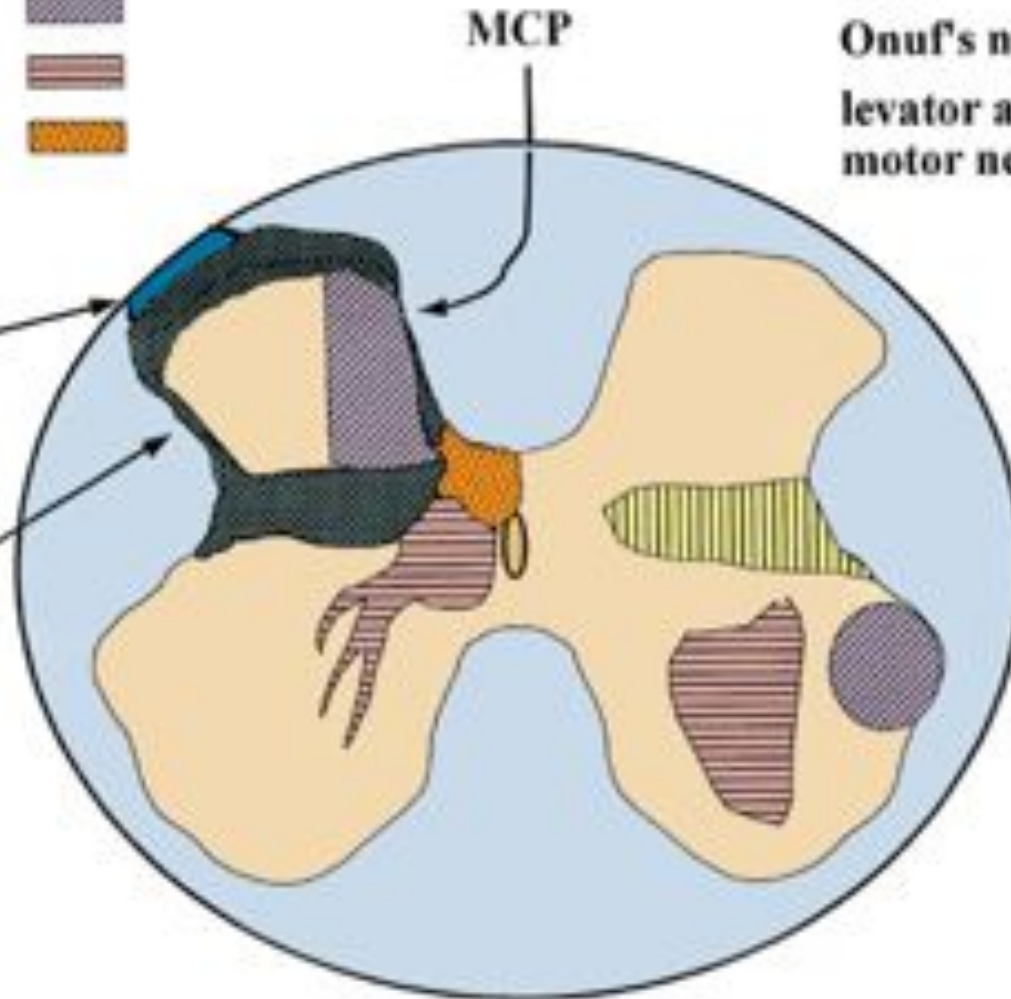
Onuf's nucleus

levator ani
motor neurons



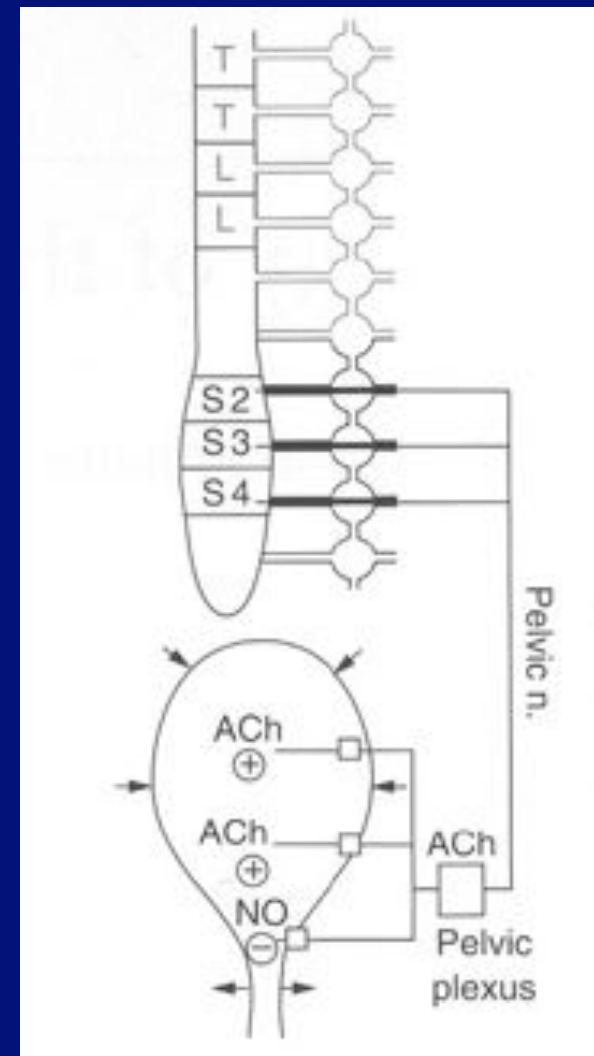
Lissauer's tract

LCP



Pelvic nerve

- Efferent
 - parasympathetic
 - preganglionic: synapses in the pelvic plexus
 - postganglionic:
 - primarily cholinergic
 - innervate detrusor muscle
- Afferent sensory
 - from detrusor muscle
 - glutamate, neuropeptides and nitric oxide

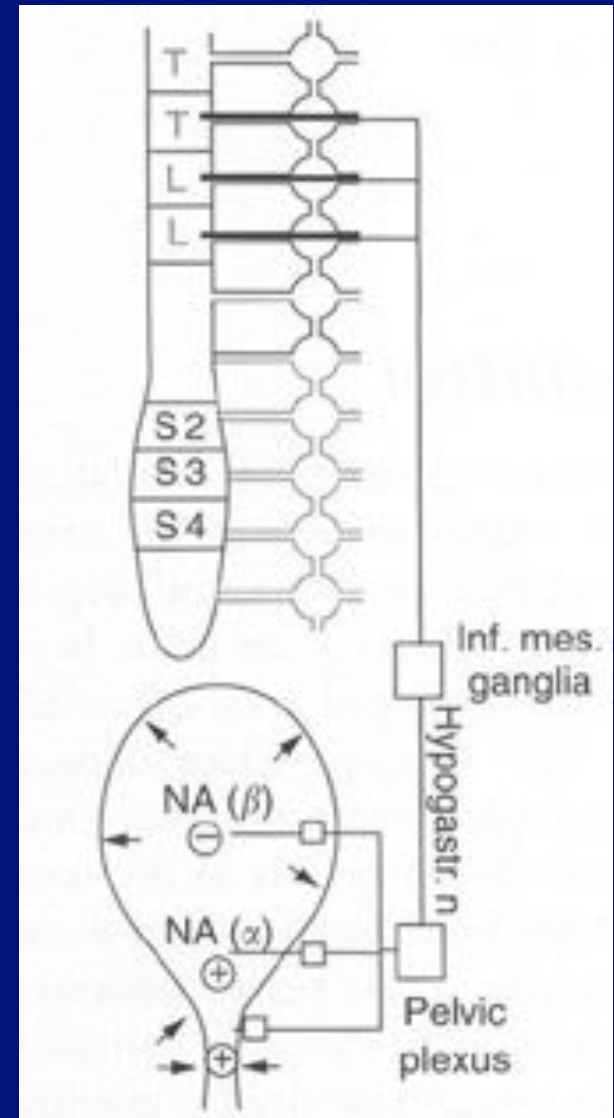


Pelvic nerve afferents

- Myelinated A-delta fibers:
 - mediating normal micturition
 - sensitive to gradual distention of the bladder
- Unmyelinated C-fibers:
 - under normal conditions: do not respond to bladder distention
 - various pathological conditions including SCI:
 - chemoreceptors and mechanosensitive nociceptors from the bladder and urethra become hyperactive
 - can cause overactive bladder and urinary incontinence

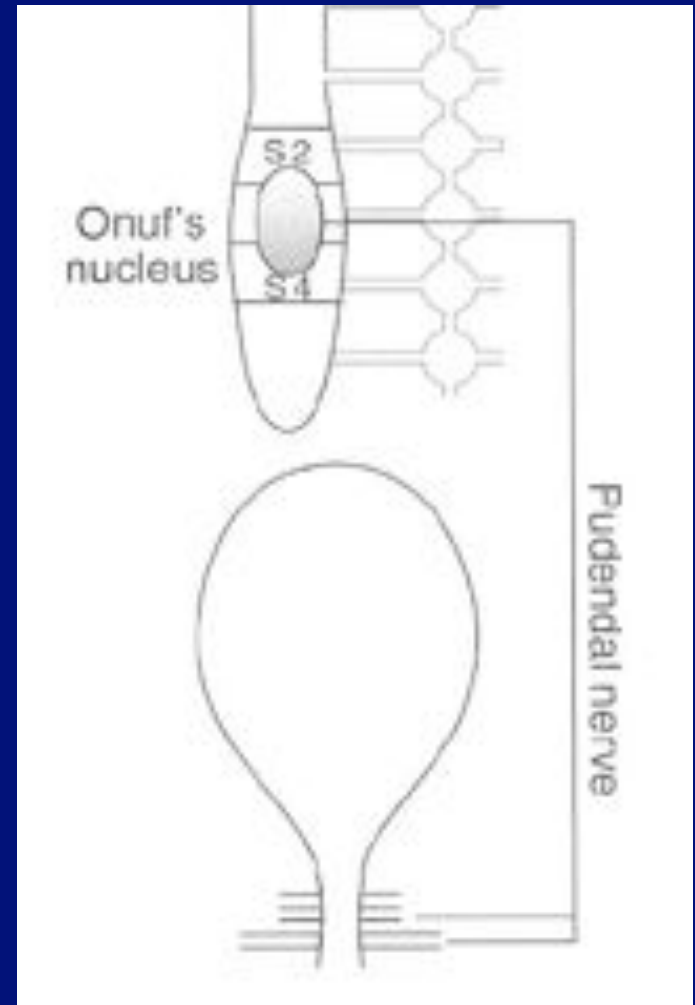
Hypogastric nerve

- sympathetic
- postganglionic: primarily noradrenergic
- innervating primarily longitudinal and circular smooth muscle layers in the bladder neck and proximal urethra



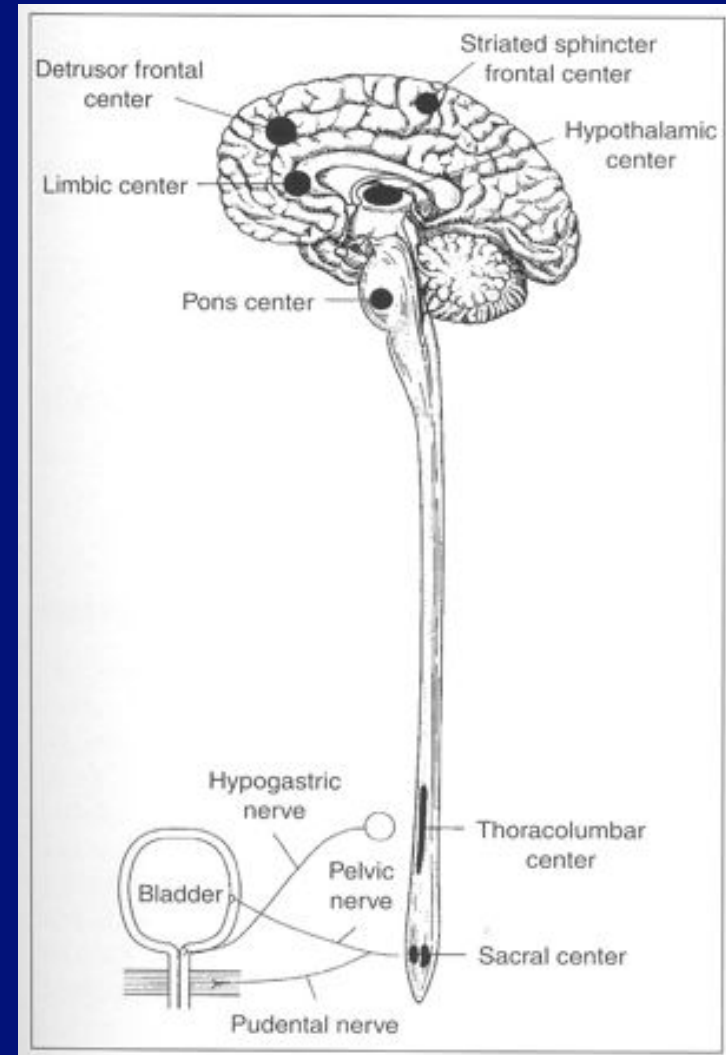
Pudendal nerve

- Efferent
 - Innervates the urethral rhabdosphincter as well as the external anal sphincter and some perineal muscles
- Afferent sensory
 - from urethra as well as the rectum, clitoris or penis and perineal skin
 - contain glutamate and neuropeptides, similar to pelvic afferent fibers



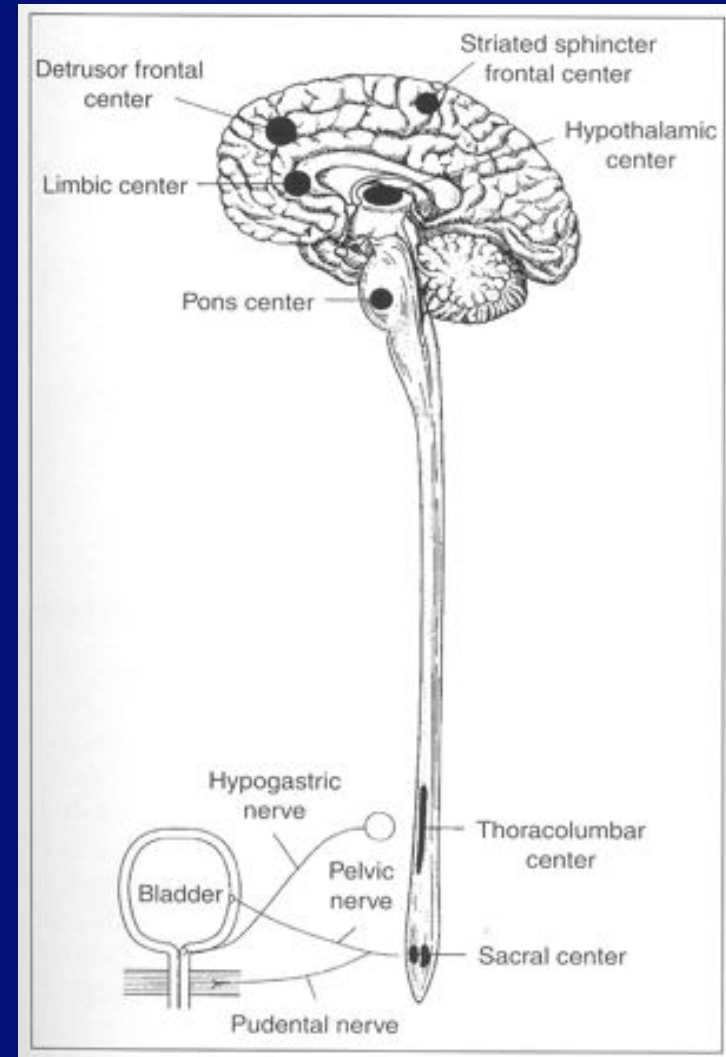
Pons

- important control center
- **pontine micturition center** (PMC; Barrington's nucleus; M region)
- directly excites bladder neurons and inhibits the urethral sphincter
- resulting **coordination** of the bladder contraction and sphincter relaxation at the same time to empty the urine



Cerebral cortex

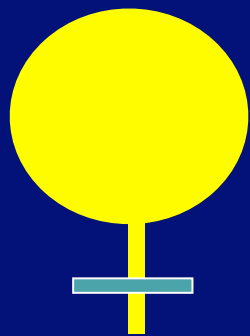
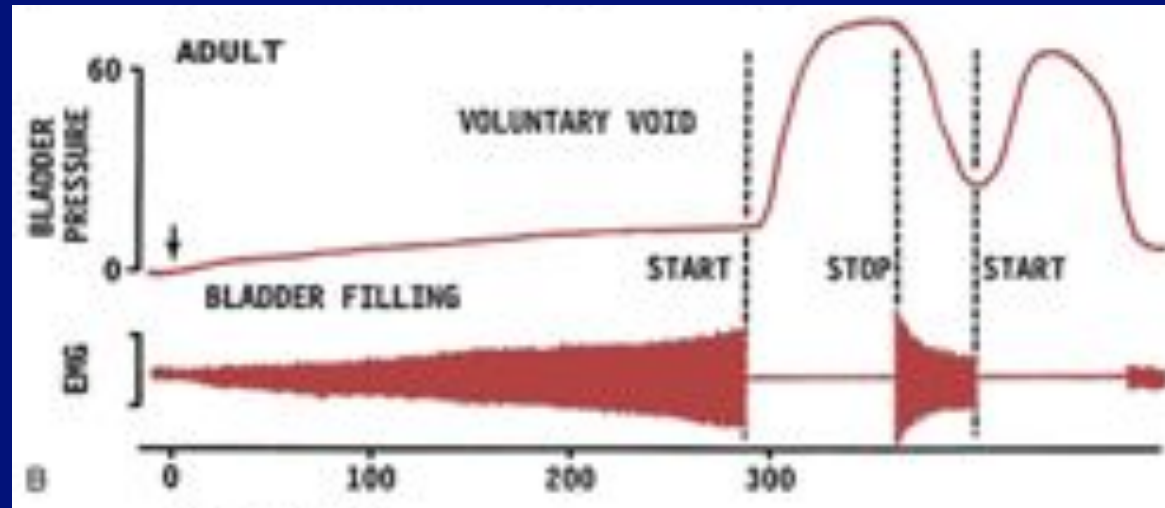
- appears to be involved in **inhibiting** lower centers of micturition
- primary neurologic control of the bladder and urethral sphincters depends on multiple levels of the nervous system, especially the sacral segments and the pons



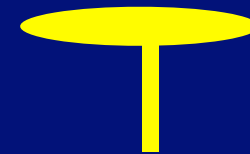
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- ③ Relevant end organ and nervous systems
- ③ Reflex pathways
- ③ Implication in the sacral neuromodulation

Storage and emptying



Storage

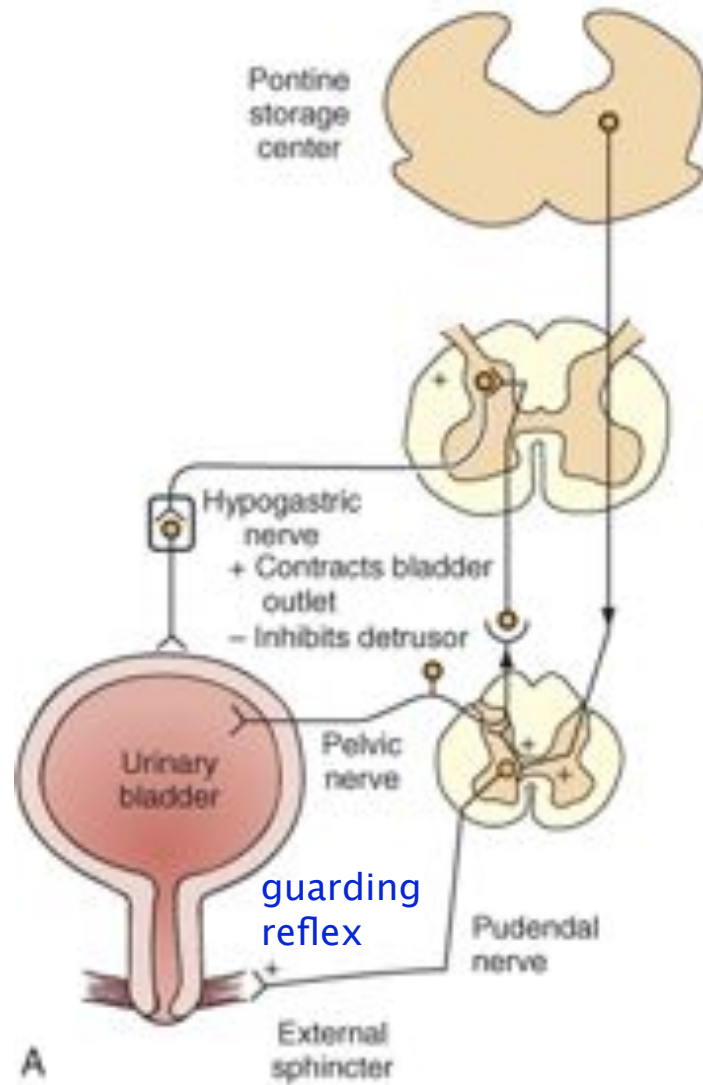


Emptying

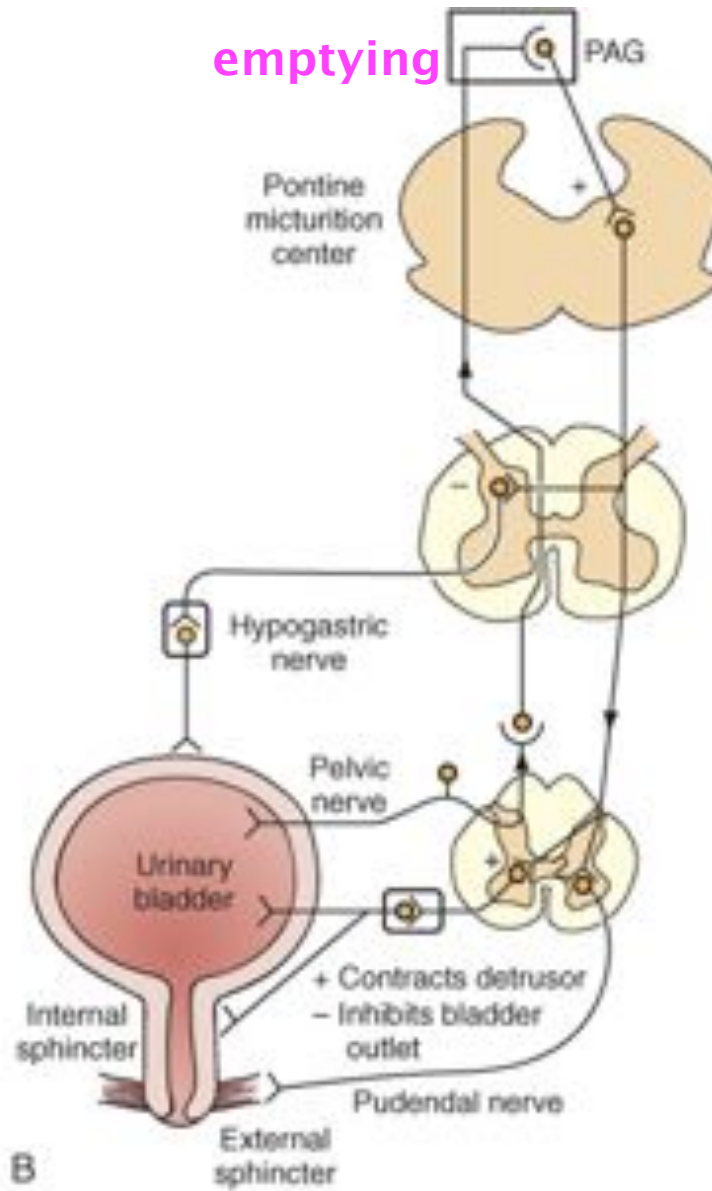
Pathways

<i>Afferent Pathway</i>	<i>Efferent Pathways</i>	<i>Central Pathway</i>
<i>Urine Storage</i>		
Low-level vesical afferent activity (pelvic nerve)	<ul style="list-style-type: none"> External sphincter contraction (somatic nerves) Internal sphincter contraction (sympathetic nerves) Detrusor inhibition (sympathetic nerves) Ganglionic inhibition (sympathetic nerves) Sacral parasympathetic outflow inactive 	Spinal reflexes
<i>Micturition</i>		
High-level vesical afferent activity (pelvic nerve)	<ul style="list-style-type: none"> Inhibition of external sphincter activity Inhibition of sympathetic outflow Activation of parasympathetic outflow to the bladder Activation of parasympathetic outflow to the urethra 	Spinobulbosacral reflex

storage



emptying



Nervous control of micturition

- Local Reflex Pathways
 - Storage reflex
 - Sympathetic storage reflex
 - Somatic storage reflex (guarding reflex)
 - Micturition Reflex
 - Somatic micturition reflex (urethra-to-bladder reflex)
 - Spinal vesicovesical micturition reflex: pathologic reflex
- Supraspinal Vesicovesical Micturition Reflex Pathway

Sympathetic storage reflex

- **Synonyms**

- pelvic-to-hypogastric reflex
- bladder-to-sympathetic reflex_

- **Activation mechanism**

- triggered by afferent activity induced by distention of the bladder

- **Role:** primarily urine storage mechanism

- (contracting the muscle) stimulating $\alpha 1$ adrenergic receptors in the urethral smooth muscle: -> promotes closure of the urethral outlet
- (relaxing the muscle) stimulating $\beta 3$ adrenergic receptors in the detrusor smooth muscle: -> inhibits neurally mediated contractions of the bladder

Somatic storage reflex

- **Synonyms**
 - pelvic-to-pudendal reflex
 - guarding reflex
 - continence reflex
 - bladder-to-sphincter reflex
- **Activation mechanism:**
 - triggered by a sudden increase in bladder pressure, such as during a cough, laugh or sneeze
 - it activates striated urethral muscle
- **Role**
 - during normal urine storage this pathway is tonically active
 - a more rapid somatic storage reflex: during sudden unexpected increase in bladder pressure, it becomes dynamically active to contract the rhabdosphincter

Somatic micturition reflex

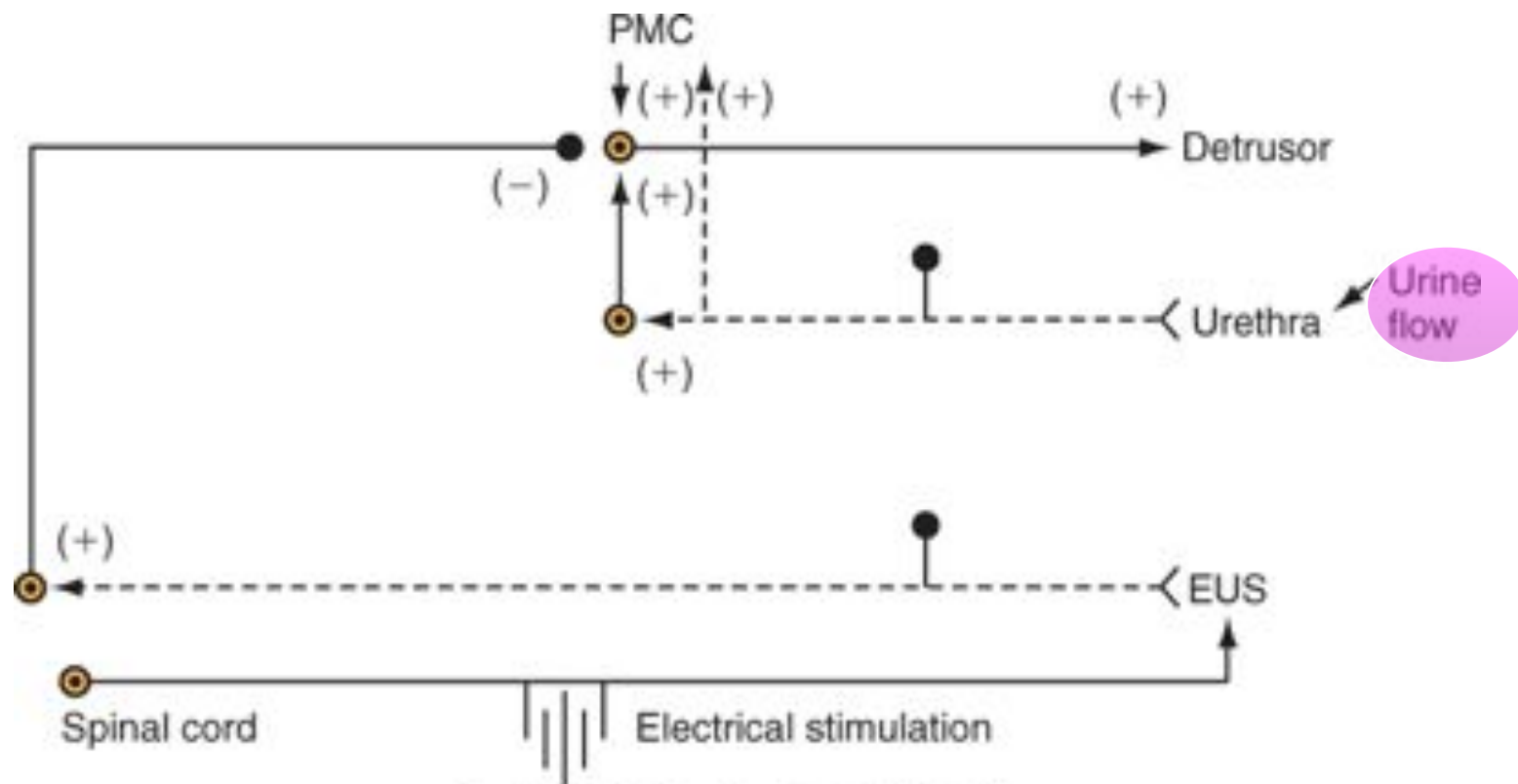
- **Synonym**

- (excitatory) urethra-to-bladder reflex

- **Activation mechanism**

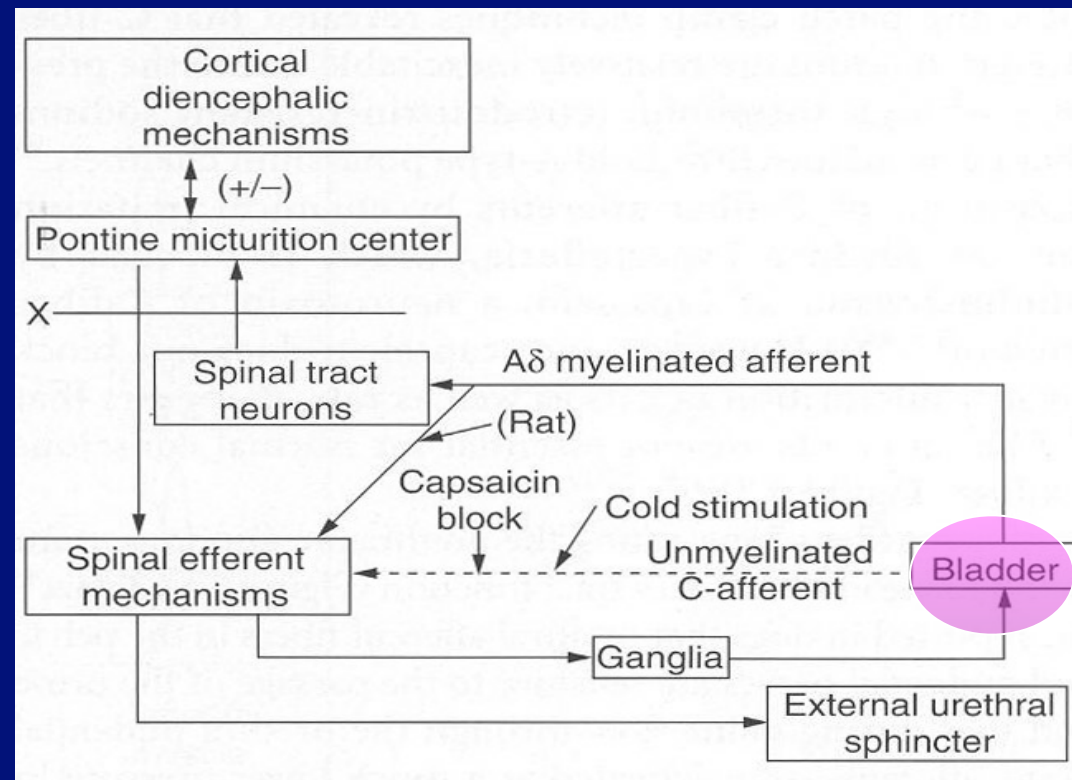
- in response to urethral fluid flow, sensory nerves in the wall of the urethra can fire
- is mediated by afferent inputs traveling through the pudendal nerve to the sacral spinal cord and brain
- is thought to involve a spinobulbospinal pathway like the actions of bladder afferents

Somatic micturition reflex



Spinal vesicovesical reflex: a pathologic reflex

- **Synonym:** C-fiber bladder afferent to bladder efferent reflex
- **Activation mechanism**



Supraspinal vesicovesical micturition reflex pathway: a normal reflex

- parasympathetic reflex outflow to the detrusor has a more complicated central organization
- involving spinobulbospinal pathway passing through a micturition center in the pons
- normal supraspinal, parasympathetic micturition reflex
- **Synonym:** A δ -fiber bladder afferent to bladder efferent reflex

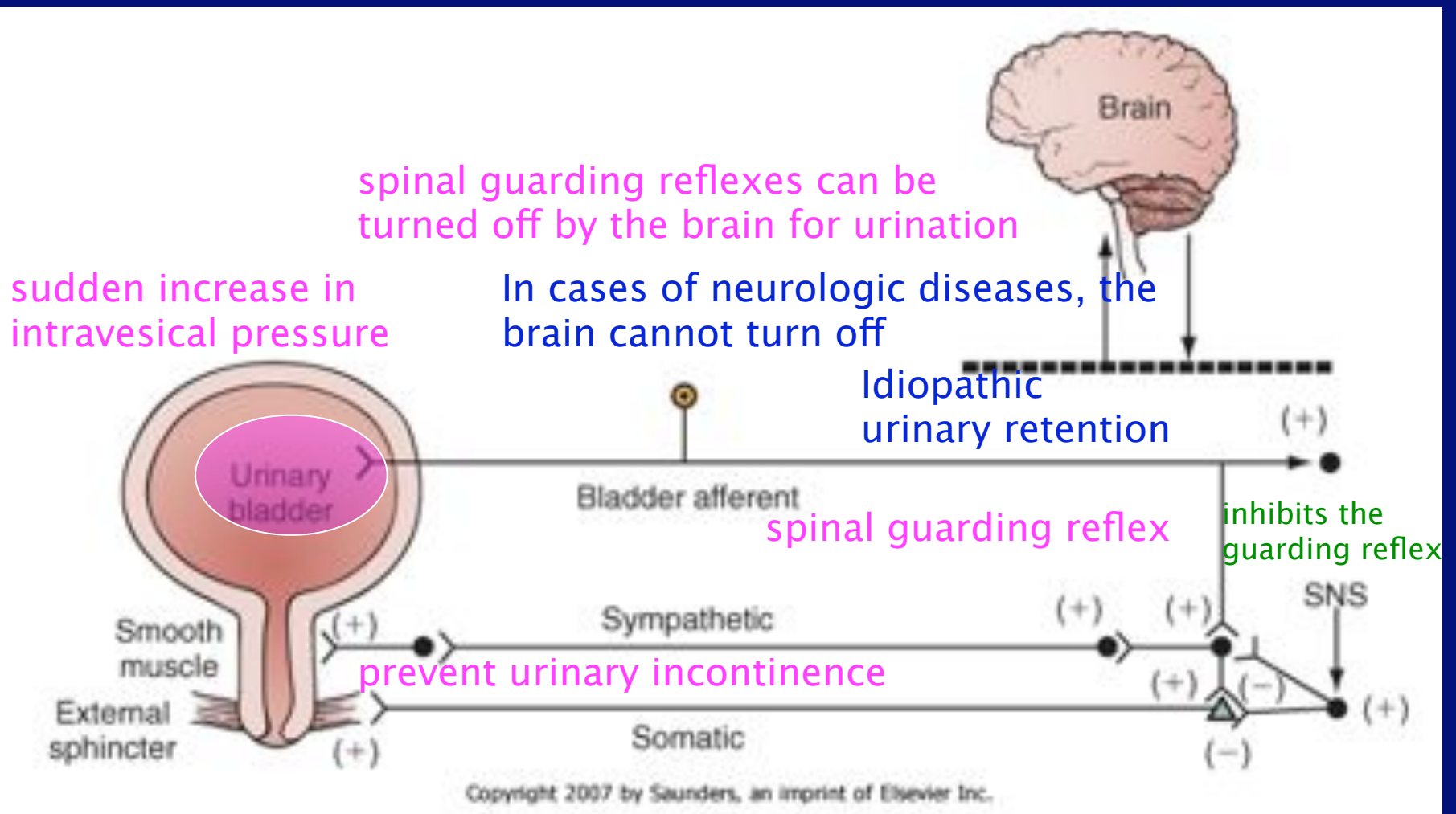
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Hypothesis of mechanism of action of sacral neuromodulation

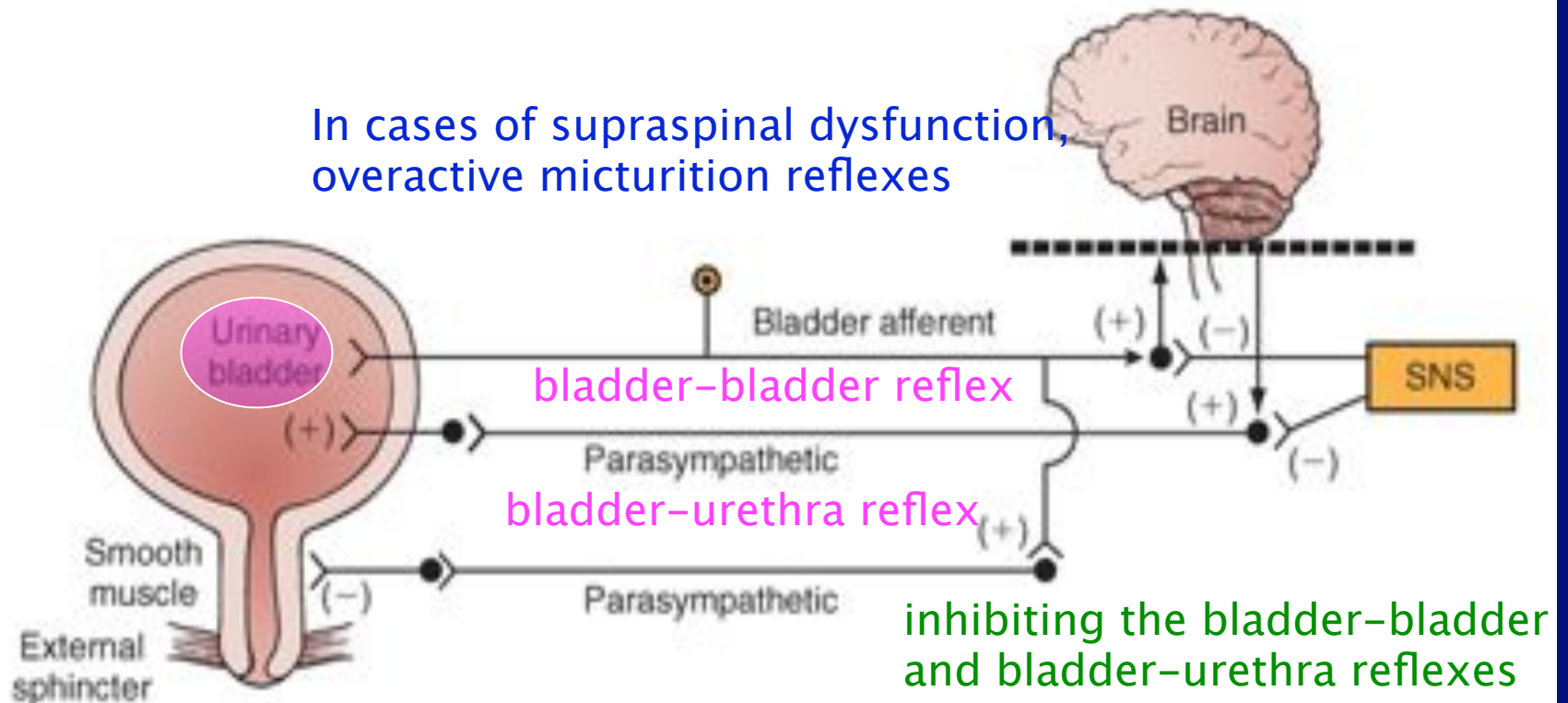
- urinary retention & dysfunctional voiding-overactive guarding reflex
- detrusor overactivity-supraspinally mediated hyperactive voiding
- the most likely target: afferent system
- somatic (pudendal) afferent inhibition of sensory processing in the spinal cord

How do sacral somatic afferents alter lower urinary tract reflexes to promote voiding?



How do sacral afferents inhibit the

In cases of supraspinal dysfunction,
overactive micturition reflexes



Summary

- Storage and voiding is controlled by nervous system of the brain and spinal cord.
- The S2–S4 spinal cord constitutes primary parasympathetic micturition center that innervate the bladder as well as the distal urethral sphincter.
- The T11-L2 spinal segments provide the sympathetic outflow from the spinal cord to the bladder and the proximal urethral sphincter.
- The pons coordinates the activity of the detrusor smooth muscle and urethral sphincter muscle.
- Central and local and reflexes play an important role in the neural control of the lower urinary tract.