

# Neural control of the lower urinary tract in health and disease

Jalesh N. Panicker MD, DM, FRCP

Consultant Neurologist and Clinical lead in  
Uro-Neurology

The National Hospital for Neurology and Neurosurgery  
and UCL Institute of Neurology  
Queen Square, London

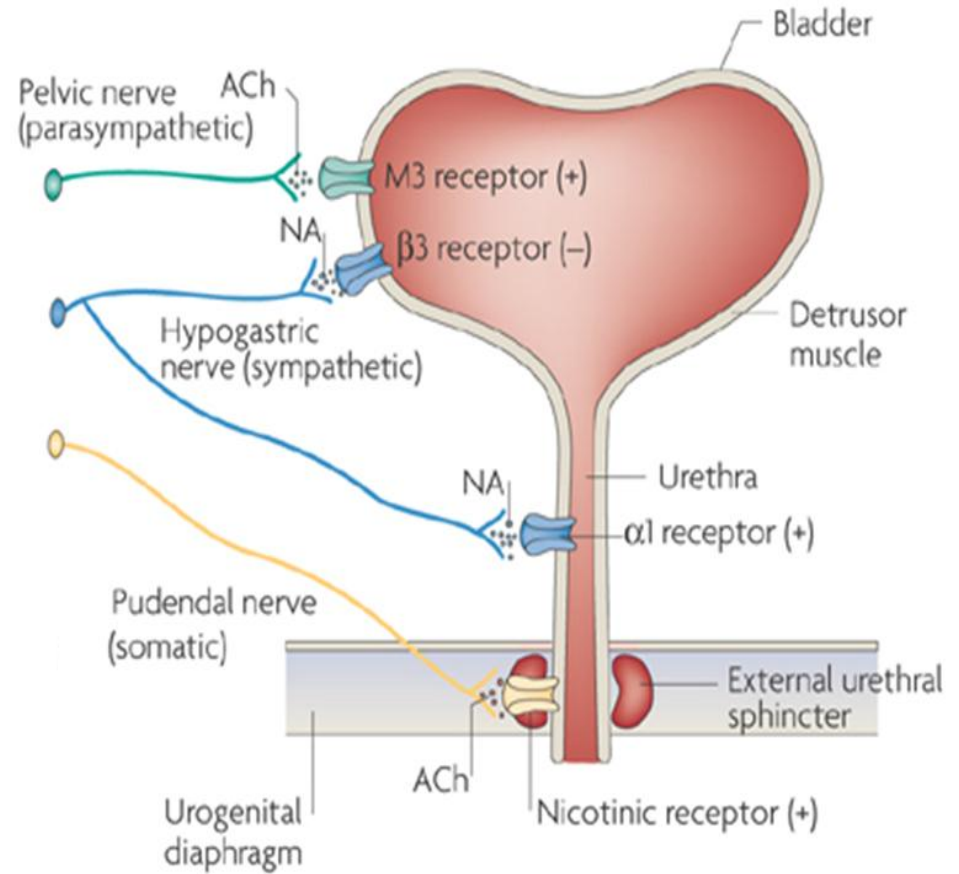
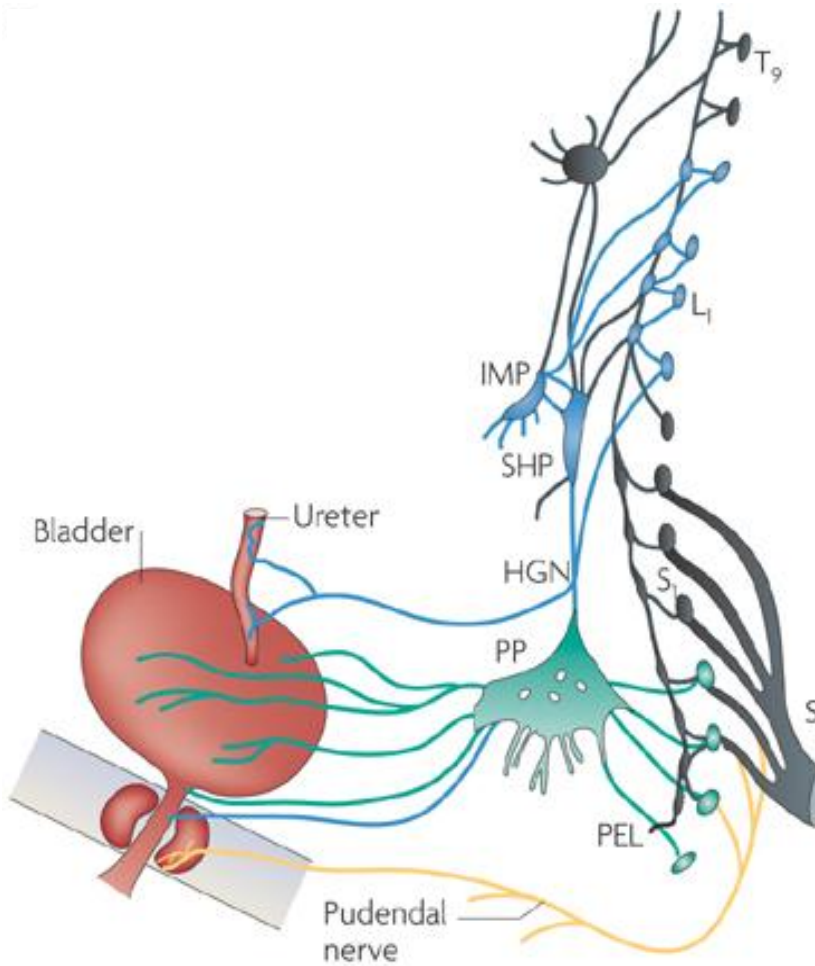


# Outline

- The neural control of the lower urinary tract in health
- What happens following neurological injury

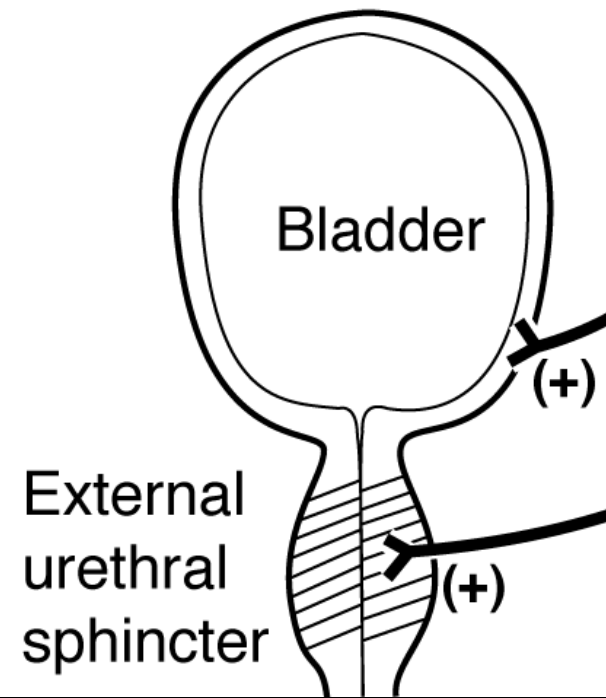
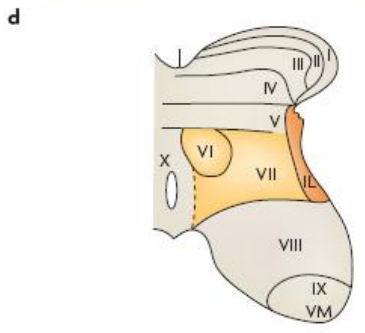
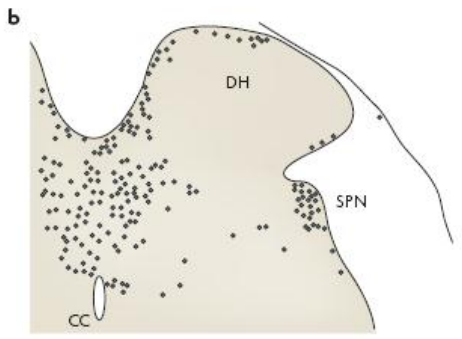
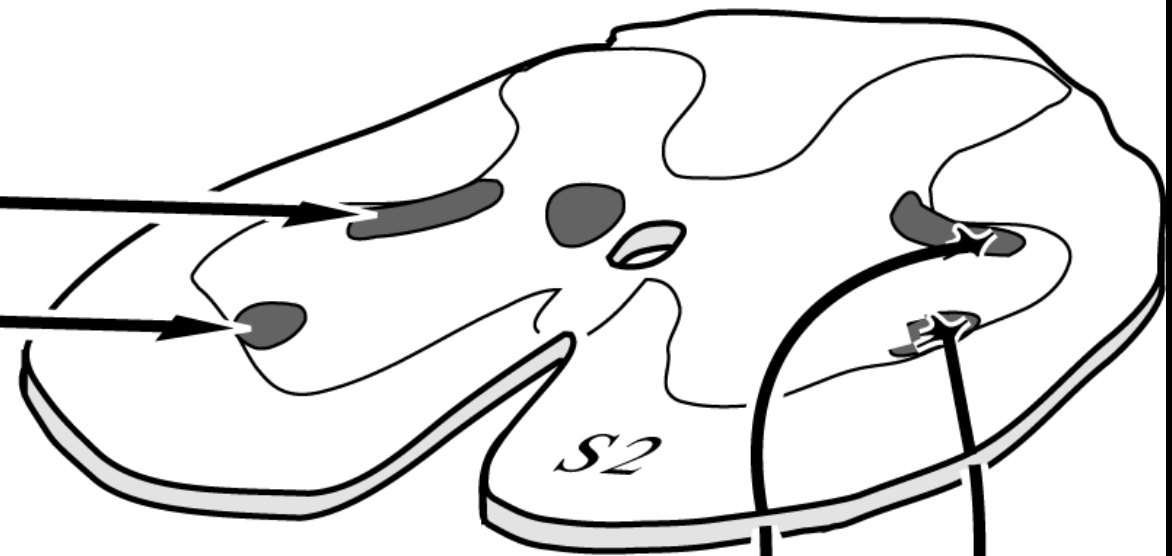
# The neural control of the lower urinary tract..... is unique

- Dependence on the central nervous system
- Element of voluntary control
- Functions depend upon learned behaviour
- Neural circuitry: phasic vs tonic activity



*Bladder motoneurons*

*Onuf's nucleus*



# Spinal control

## Storage

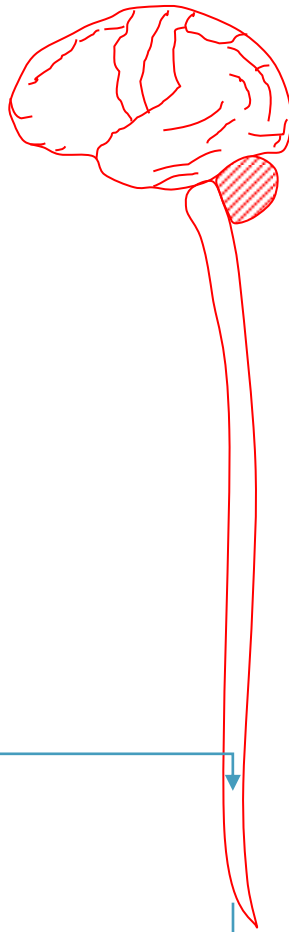
- *Bladder-to-urethra* procontinence guarding reflex
- Sympathetic mediated detrusor relaxation

## Full bladder

- *Bladder-to-urethra* inhibitory reflex
- *Bladder-to-bladder* excitatory reflex
- These form part of the spinobulbospinal reflex which allows higher centres to exert control over voiding

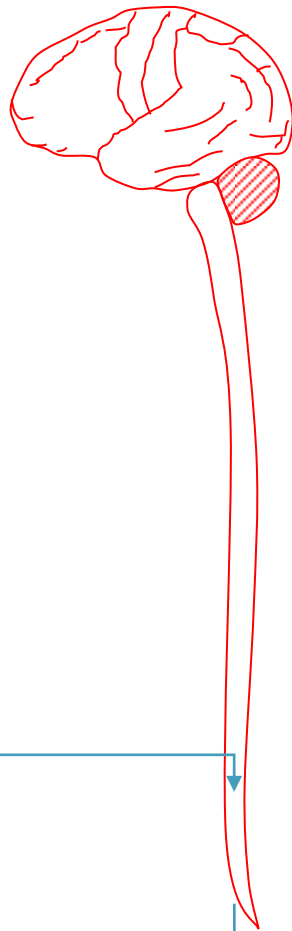
# Emergence of central reflexes controlling LUT functions

Cortical



Sacral spinal cord

# Hierarchical control of LUT functions



**Cerebral cortex-** sensations/  
timing of micturition

**Brain stem-** coordination of reflexes

**Spinal cord-** amplification

**Peripheral nerves-** relay



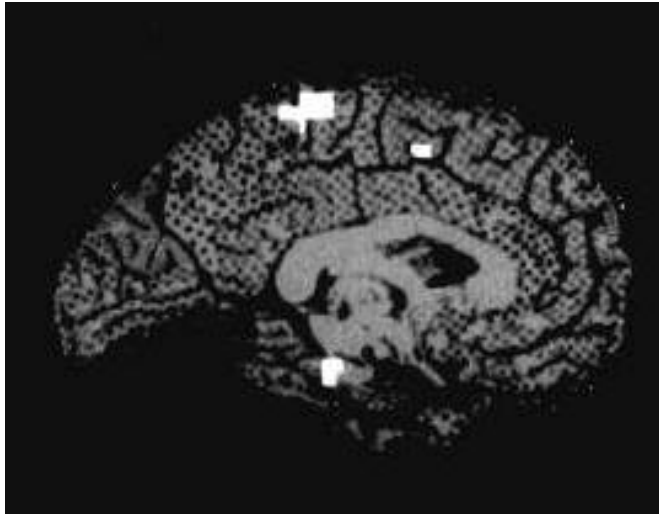


How full is my bladder?  
Is this the right time and place to void?

S2-4 in cauda equina

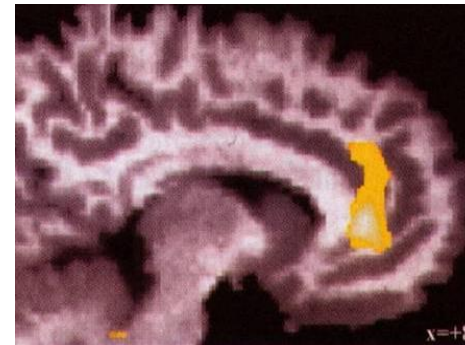
pelvic & pudendal ns

# Functional brain imaging



**SPECT**

Fukuyama et al. *Neuroreport* 1996

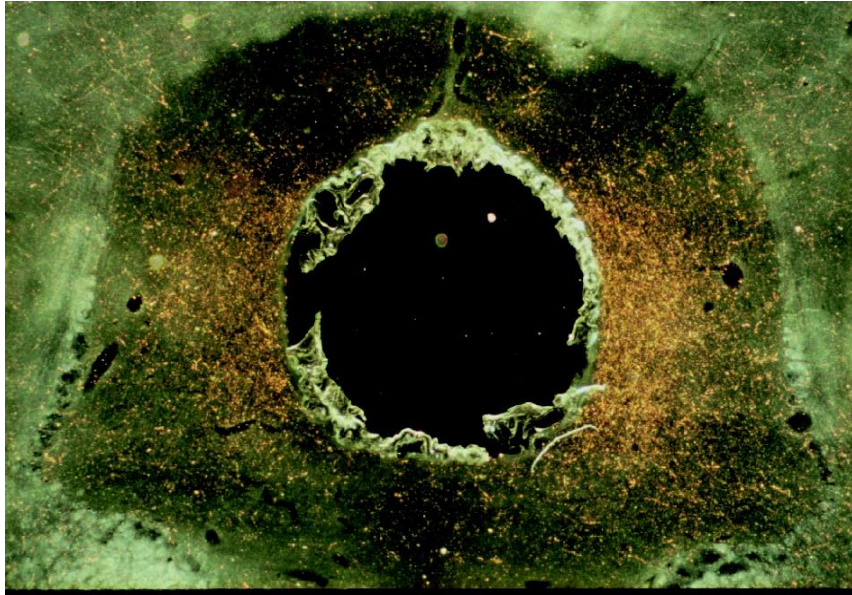


**PET**

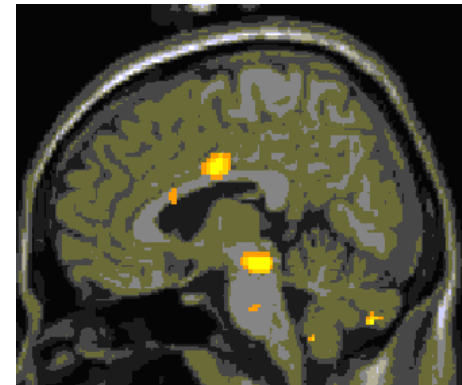
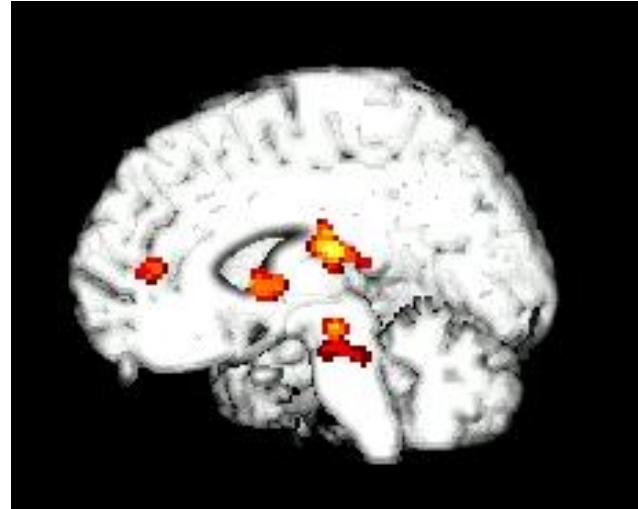
Healthy males,  
Blok et al. *Brain* 1997

- Various paradigms used- repeated PFM contractions on full and empty bladder, alternating bladder filling and emptying
- Changes in cortical and subcortical activity during the micturition cycle

# Perception of bladder fullness



Periaqueductal grey (PAG) of the midbrain  
(courtesy Holstege)

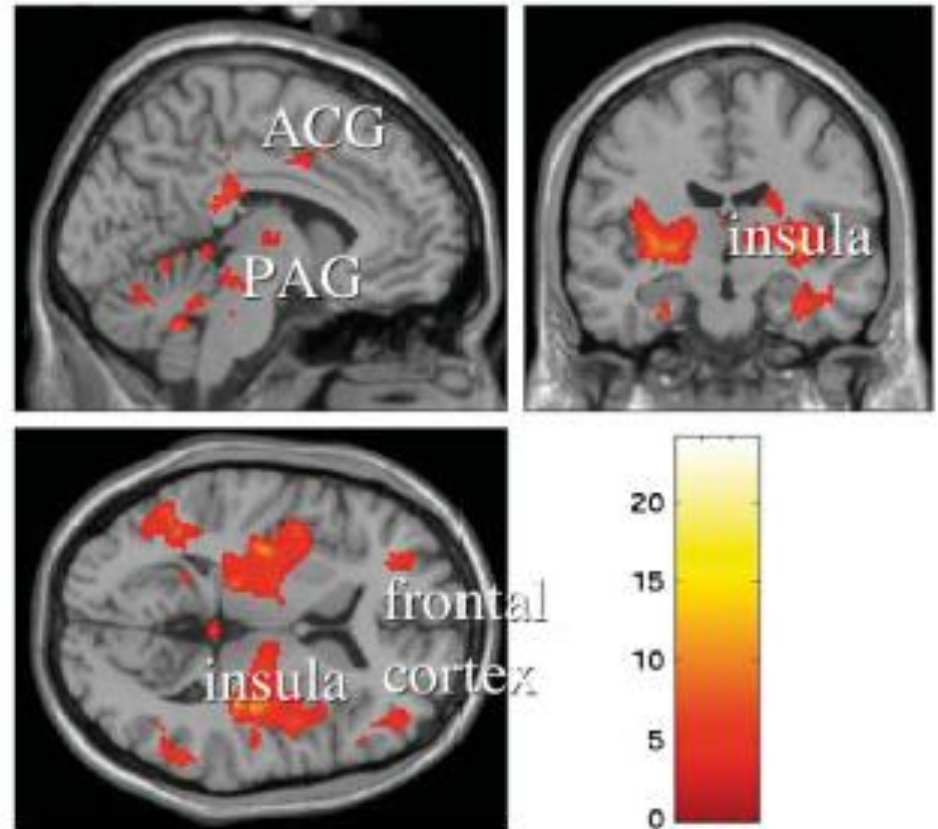


Matsuura et al, 2002  
Athwal et al, 2001

# Changes in brain activity with bladder filling-healthy controls

- Good bladder control
- Small volume infused
- Mild sensations

## • Baseline normal

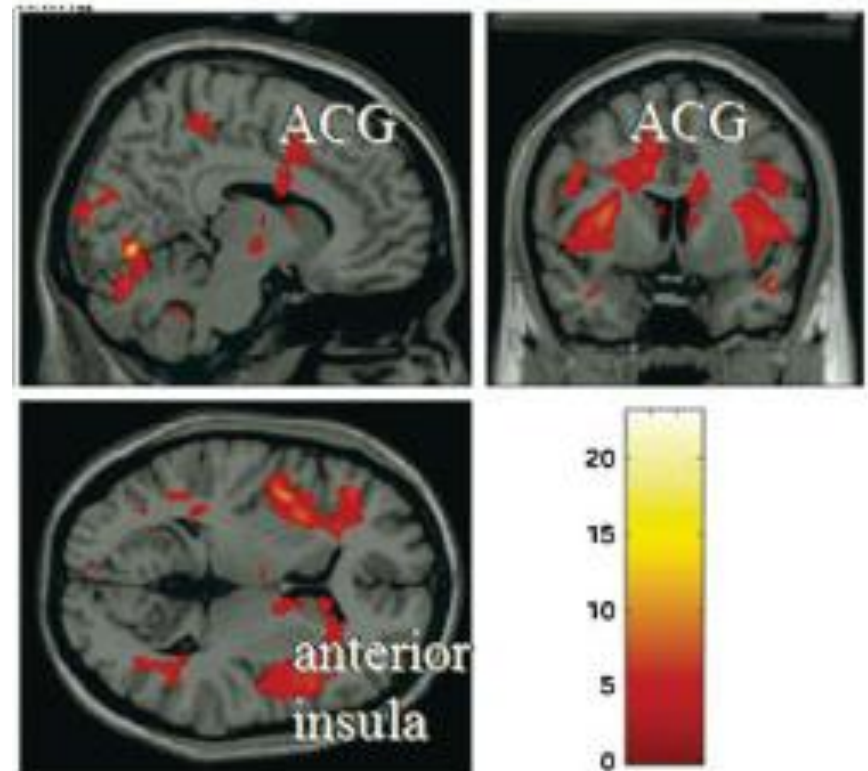


(n=6)

# Changes in brain activity with bladder filling-healthy controls

- Good bladder control
- Large bladder volume
- Strong desire to void

- Strong desire (large volume)



(n=6)



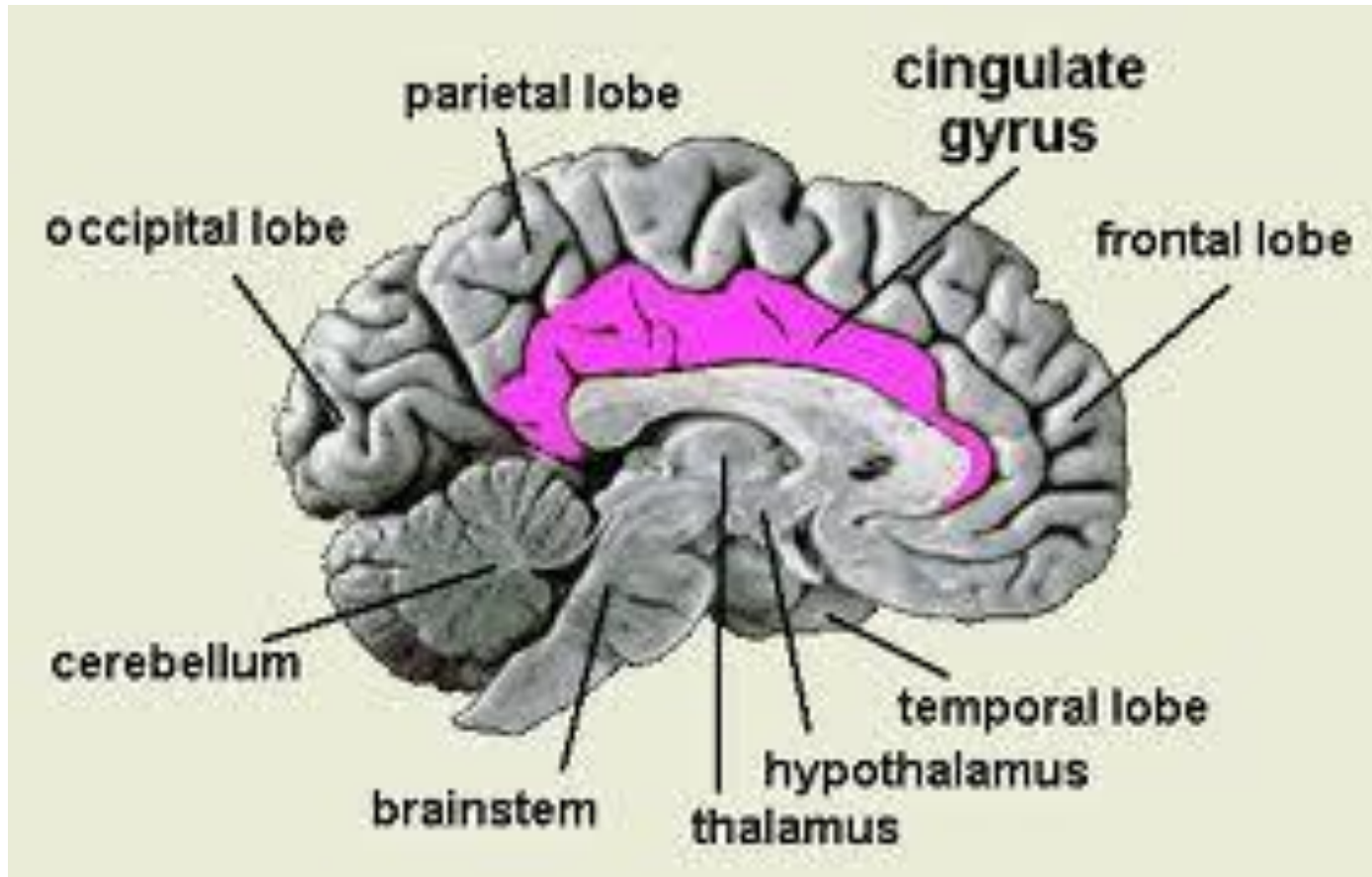
# Insula

## **Insula = interoceptive or homeostatic afferent cortex**

- The homeostatic afferents are the “missing” sensory limb of efferent autonomic nervous system
- Interoceptive sensations are associated with an affective, motivational aspect, hence their value in homeostasis.
- Afferents from PAG are mapped in the insula
- Basis of bladder sensations



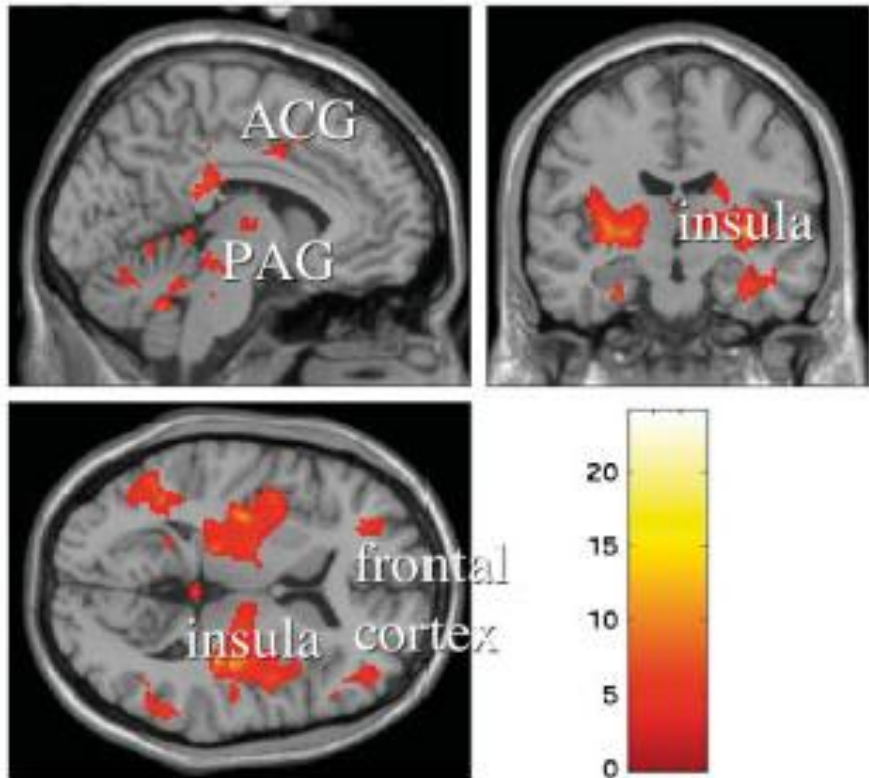
# Cingulate cortex



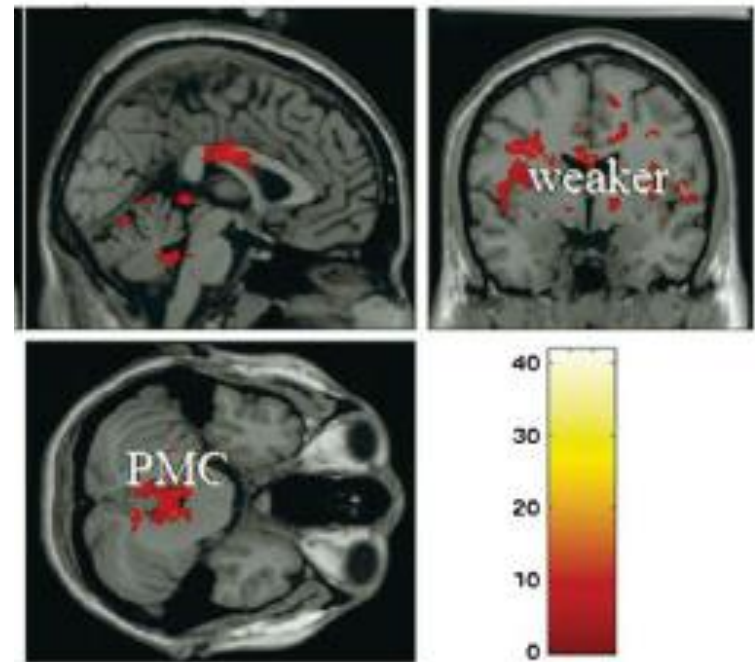
- ACC associated with motivation and affective aspect of interoceptive sensations
- Output correlates with sympathetic activation
- Insula= “limbic sensory cortex”
- Anterior Cingulate Cortex = “limbic motor cortex”
- Both frequently co-activated
- Monitoring and control as bladder is filling
- Inhibits voiding through the PAG
- With filling, activation shifts anteriorly- associated with “unpleasantness”

# Changes in brain activity with bladder filling- patients with poor bladder control

- Baseline normal



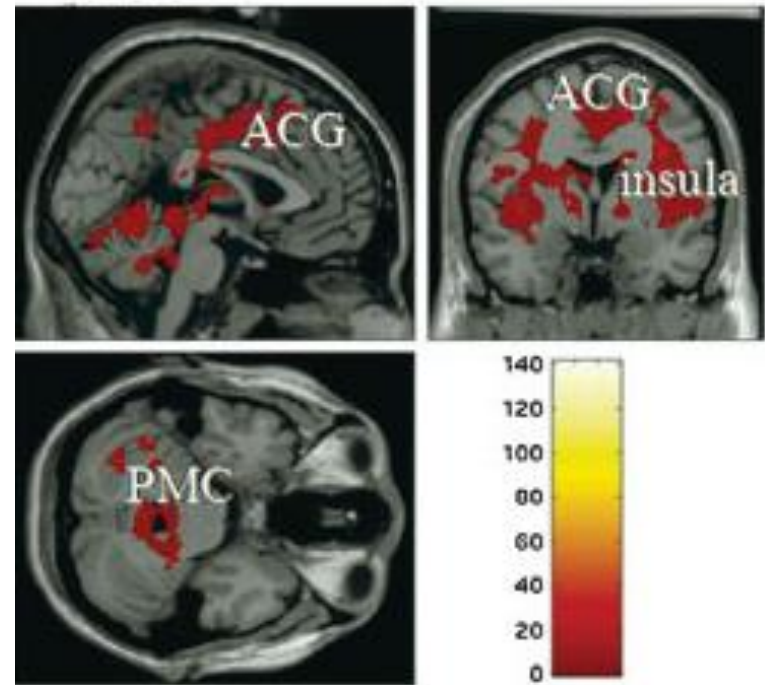
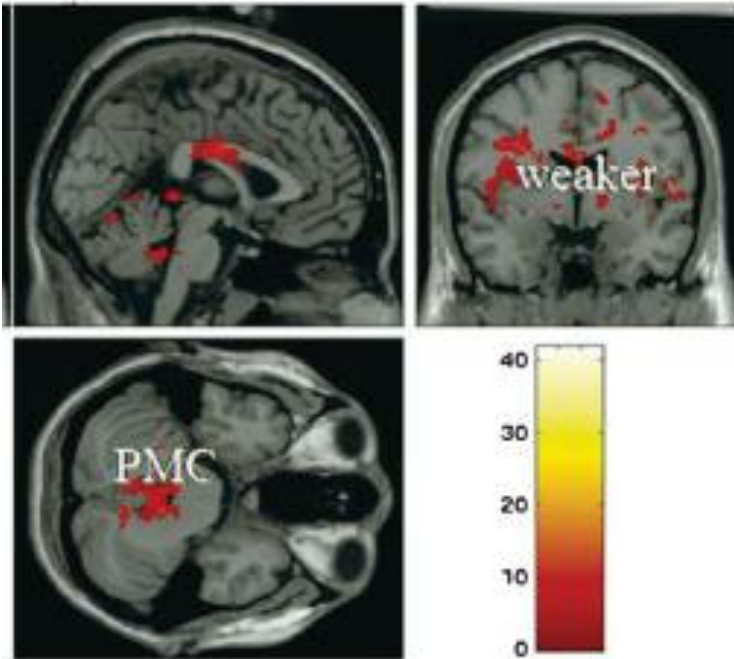
- Poor control
- Small bladder volume



# Changes in brain activity with bladder filling- patients with poor bladder control

- Poor control
- Small bladder volume

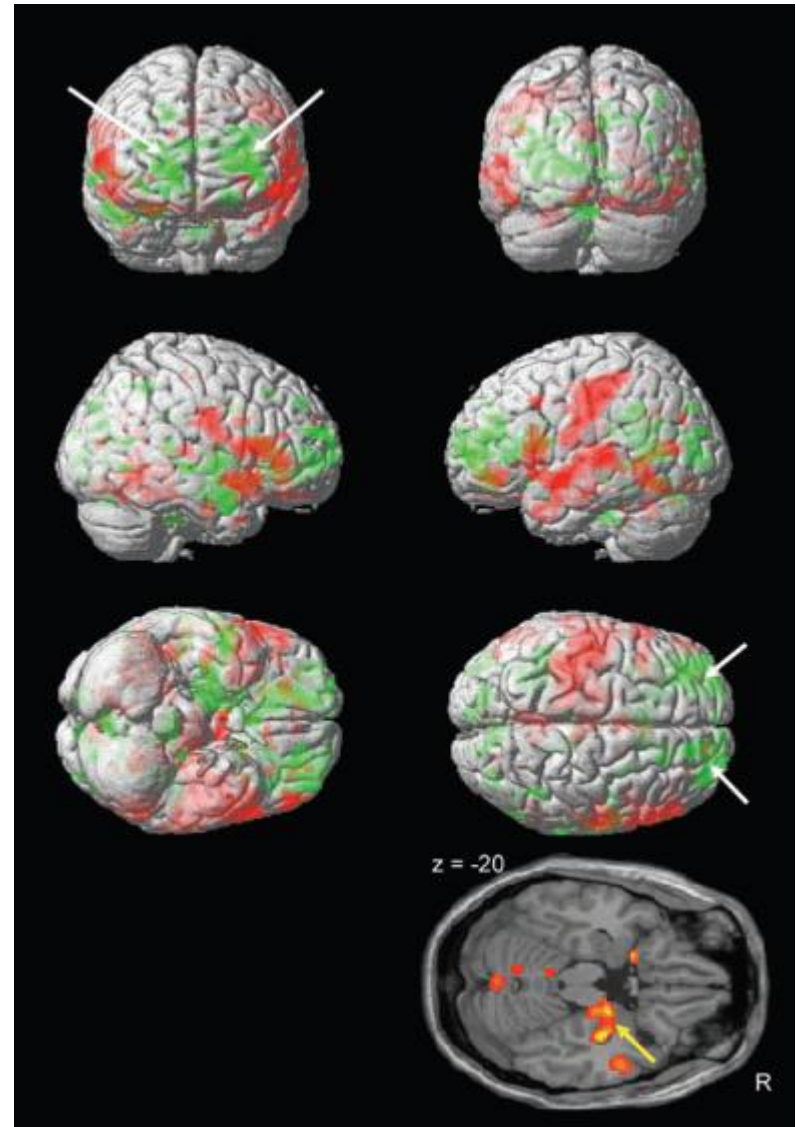
- Poor control, strong desire to void, no actual DO



(n=5)

# Changes in brain activity with bladder filling- DO during scanning

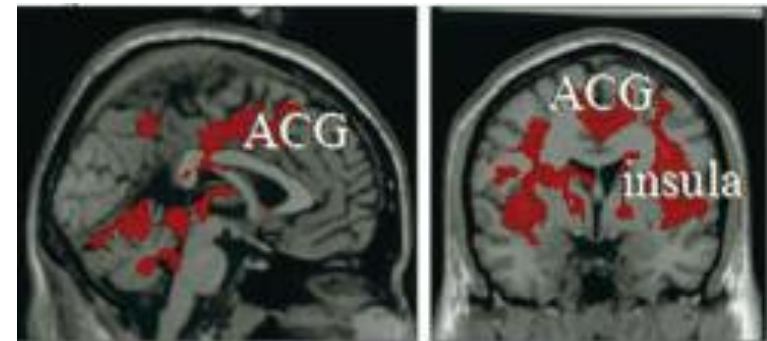
- Women with urinary urgency
- DO in the scanner



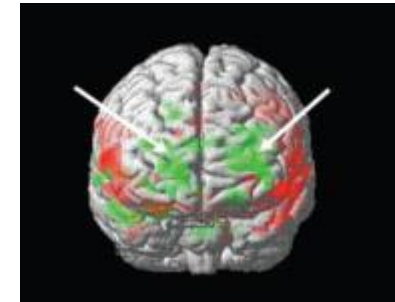
N=3

# Patterns of brain activity in patients with poor bladder control

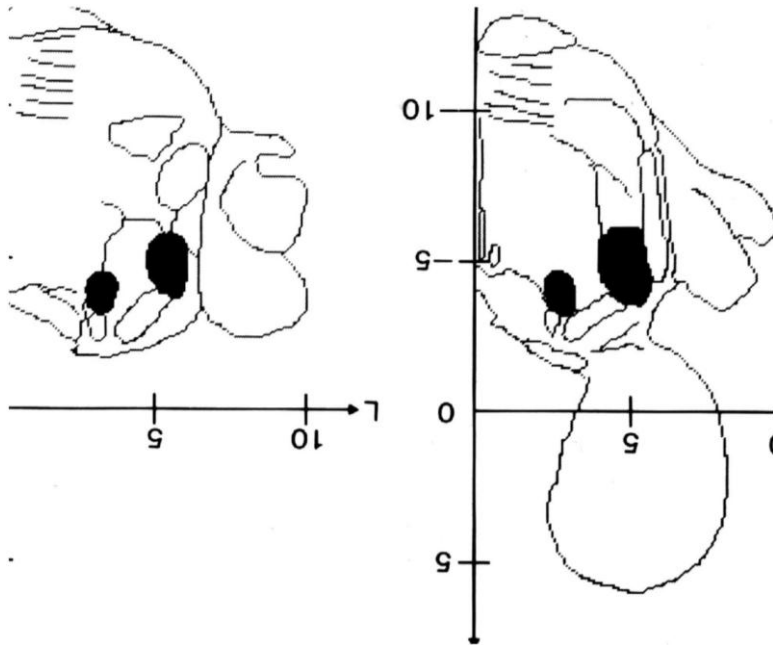
Anterior cingulate- urgency



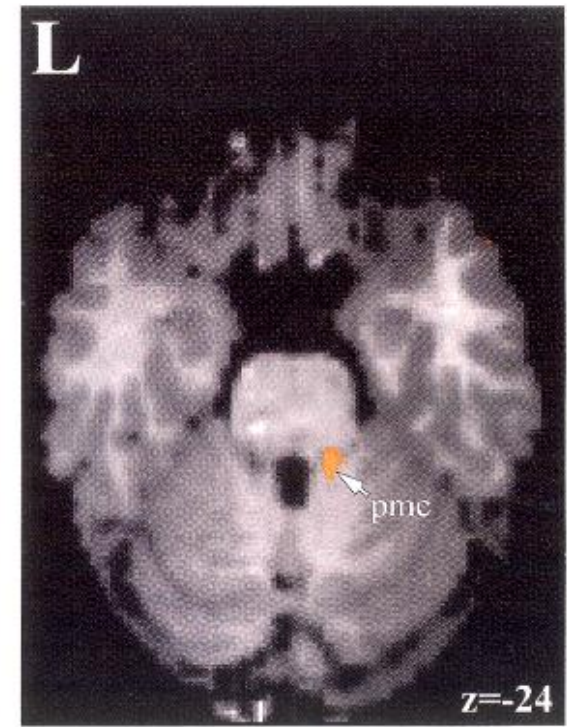
Prefrontal cortex- continence mechanism



# Pontine micturition centre = “Barrington’s nucleus”



Griffiths, Holstege  
et al., 1990 in cat



Blok et al, 1997

# LUT control: two neural programs and a switch

> 99%

**Storage phase**

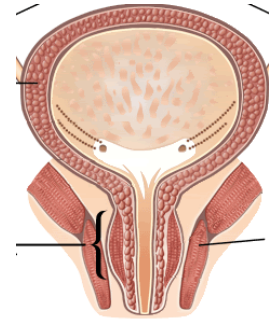


**Voiding phase**

**Detrusor**      **Sphincter**

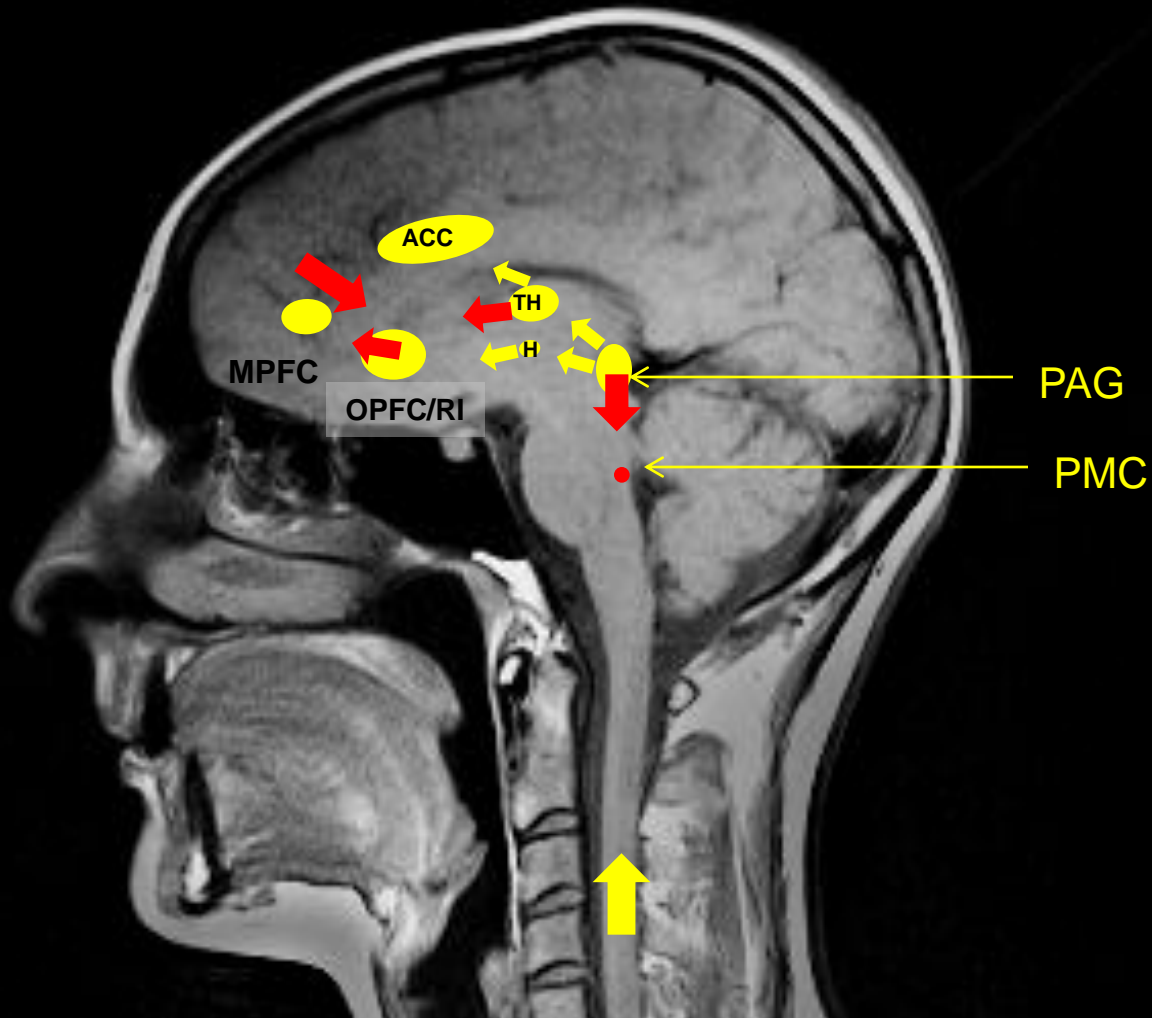
<b>Relaxed</b>	<b>Active</b>
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<b>Active</b>	<b>Relaxed</b>
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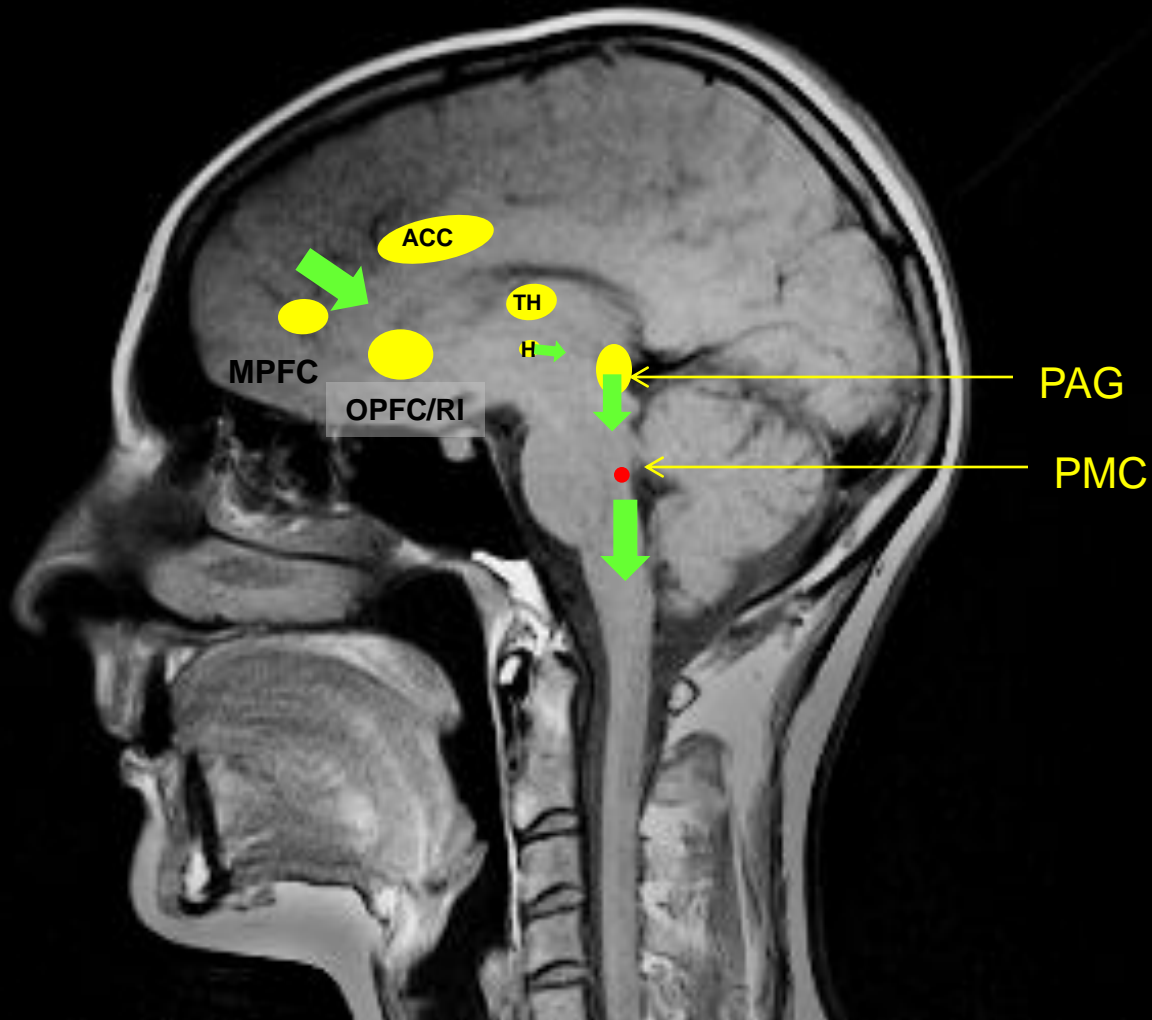




# Storage



# Voiding





PMC

S2-4 in cauda equina

pelvic & pudendal ns

## Suprapontine

Stroke  
Parkinson's Disease  
Tumours  
Trauma  
Dementias

## Spinal

Multiple Sclerosis  
Trauma  
Tumour

## Sacral / Infrasacral

Disc prolapse  
Tumour  
Pelvic nerve injury  
Small fibre neuropathy



- Storage symptoms
- PVR: < 100mL
- Detrusor overactivity

- Storage / voiding symptoms
- PVR: usually elevated
- Detrusor overactivity, detrusor sphincter dyssynergia

- Predominantly voiding symptoms
- PVR: elevated
- Often acontractile detrusor