Pain

"Well, I guess that explains the abdominal pains."

"Pain is a component of virtually all clinical strategies, and management of pain is a primary clinical imperative. Opioids are a mainstay of pain treatment."

Goodman & Gilman, 12th edition

Opioid ~~Analgesics~~ Addiction

Opioid ~~Analgesics~~ Addiction

The Dividend, 1916

F.D.A. Likely To Add Reins On Painkillers

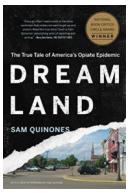
By SABRINA TAVERNISE

Trying to stem the scourge of prescription drug abuse, an advisory panel of experts to the Food and Drug Administration voted on Friday to toughen the restrictions on painkillers like Vicodin that contain hydrocodone, the most widely prescribed drugs in the country.

The recommendation, which the drug agency is likely to fol-

January 26, 2013 • *New York Times*

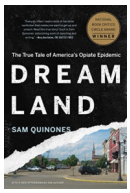
Opioid ~~Analgesics~~ Addiction



A former Purdue sales manager for West Virginia: "They told us to say things like it is 'virtually' non-addicting.

That's what we were instructed to do. It's not right, but that's what they told us to say … You'd tell the doctor there is a study, but you wouldn't show it to him."

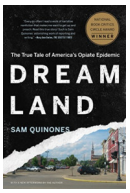
Opioid ~~Analgesics~~ Addiction



"My fellowship director even told me:

'If you have pain, you can't get addicted to opiates because the pain soaks up the euphoria.'

Opioid ~~Analgesics~~ Addiction



"With addicts, their quality of life goes down as they use drugs," one leading pain doctor, Scott Fishman, told New York magazine in 2000.

"With pain patients, it improves. They're entirely different phenomena."

Opioid ~~Analgesics~~ Addiction

HEALTH

C.D.C. Painkiller Guidelines Aim to Reduce Addiction Risk

WASHINGTON — In an effort to curb what many consider the worst public health drug crisis in decades, the federal government on Tuesday published the first national standards for prescription painkillers, recommending that doctors try pain relievers like ibuprofen before prescribing the highly addictive pills, and that they give most patients only a few days' supply.

New York Times, March 2016

Opioid ~~Analgesics~~ Addiction

2014 For the first time in Virginia, more people died from opioid overdoses than fatal car accidents.

2021 Overdose deaths peak in Virginia (2,622). ~6 per day.

- Opioids a factor in about 84% of all overdose deaths in Virginia.
- Synthetic opioids such as fentanyl were involved in about 94% of all opioid overdose deaths.

2023 2,463 overdose deaths in Virginia.

Opioid ~~Analgesics~~ Addiction

Young Victims of the Opioid Epidemic

By THE EDITORIAL BOARD JAN. 16, 2017

Lilli Carré

New York Times, January 2017

Opioid ~~Analgesics~~ Addiction

Young Victims of the Opioid Epidemic

By THE EDITORIAL BOARD JAN. 16, 2017

'I couldn't manage the pain'

'This compound is very sneaky'

'I believed the doctors would know better'

New York Times, January 2017

Opioid ~~Analgesics~~ Addiction

Young Victims of the Opioid Epidemic

By THE EDITORIAL BOARD JAN. 16, 2017

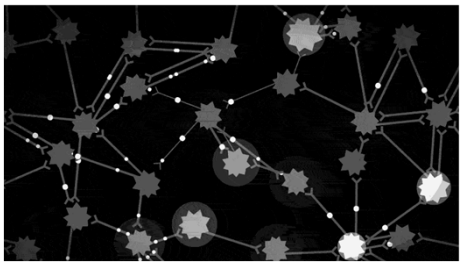
'We need them'

The reporting is one-sided and leaves out how all of these new laws affect chronic-pain patients. We do not abuse these drugs. We need them to function in daily life. Politicians should not make health care decisions. — ***Christiane Warren***, *Kearny, N.J.*

New York Times, January 2017

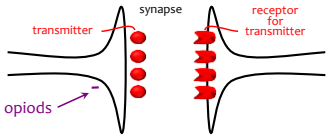
Opioid ~~Analgesics~~ Addiction

Neurons & Activity



Neurons & Activity

A. Neuronal Communication



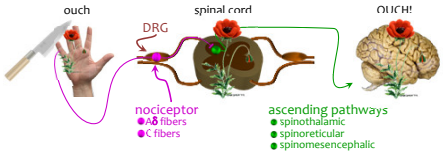
B. Plug into Your Favorite Body Part

"Opioid" Analgesics

- **"opiate"**: compounds structurally related to products found in opium.
  - natural plant alkaloids
  - semi-synthetic derivatives
  - endogenous peptides (e.g. endorphins)
- **"opioid"**: any substance, regardless of structure that has functional/pharmacological properties of an opiate.
- **"narcotic"**: derived from Greek word narkotikos for benumbing or stupor. Word now associated with opiates and often used in legal contexts.

Pain

- **pain**: perception of aversive/unpleasant sensation.
  - nociception: transmission of signals to CNS that provide info about tissue damage.



- **pains**
  - acute nociception
  - tissue injury
    - factors released in injury site (e.g. prostaglandins, bradykinin,etc) activate Aδ fibers
    - hyperalgesia (mildly warm water on a sunburn)
  - nerve injury
    - may involve low-threshold afferents (i.e., Aβ fibers)

Opioids & Their Receptors

Endogenous Opioids

- **3 primary families:**
  - **endorphins**
    - major peptide: **β**-endorphin
    - precursor: prepro-opiomelanocortin (POMC)
  - **enkephalins**
    - major peptides: met-enkephalin & leu-enkephalin
    - precursor: proenkephalin
  - **dynorphins**
    - major peptides: dynorphin A, dynorphin B & neoendorphin
    - precursor: prodynorphin

Receptors

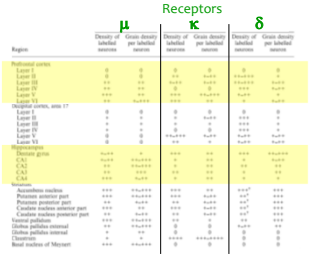
- **3 receptor types (all GPCRs):**
  - **μ** (MOR)
  - **δ** (DOR)
  - **κ** (KOR)
- **Widely distributed in the CNS**
  - Not surprising considering profound effects opioids have on CNS function

Opioid Receptor Distribution

Forebrain

Receptors

μ κ δ



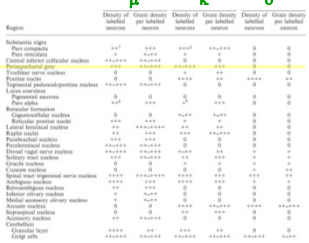
Peckys & Landwehrmeyer, 1999

Opioid Receptor Distribution

Midbrain

Receptors

μ κ δ



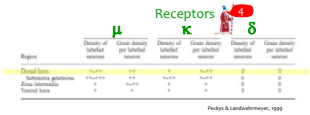
Peckys & Landwehrmeyer, 1999

Opioid Receptor Distribution

Spinal Cord

Receptors

μ κ δ



Peckys & Landwehrmeyer, 1999

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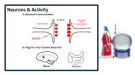
    - major peptides: dynorphin A, dynorphin B & neoendorphin
    - precursor: prodynorphin

Receptors

- **3 receptor types (all GPCRs):**
  - **μ** (MOR)
    - Opens potassium channels
    - Closes calcium channels
    - Inhibits cAMP
- **Widely distributed in the CNS**
  - Not surprising considering profound effects opioids have on CNS function



Opioids & Their Receptors

Endogenous Opioids

Opioid	Receptor		
	μ	**δ**	**κ**
β-endorphin	+++	+++	
met-enkephalin	++	+++	
leu-enkephalin	++	+++	
dynorphin A	++		+++
dynorphin B	+		+++

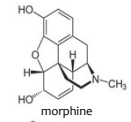
Opioids & Their Receptors

Common Opioid Analgesics

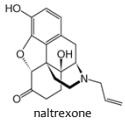
Opioid	Receptor		
	μ	**δ**	**κ**
Morphine	+++		+
Hydromorphone	+++		
Oxymorphone	+++		
Methadone	+++		
Meperidine	+++		
Fentanyl	+++		
Sufentanil	+++	+	+
Alfentanil	+++		
Remifentanil	+++		
Levorphanol	+++		
Codeine	+/-		
Hydrocodone	+/-		
Oxycodone	++		
Pentazocine	+/-		+
Nalbuphine	-		++
Buprenorphine	+/-	-	-
Butorphanol	+/-		+++

Lange, 12th Edition

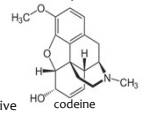
Morphine is the standard



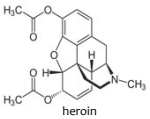
morphine



naltrexone



codeine



heroin

Summary

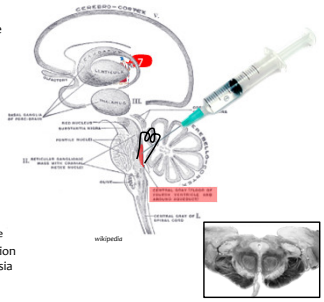
- Decreases pain but highly addictive (addiction potential similar to that of heroin)
- **μ** (MOR) – target of most opiate analgesics
- MORs expressed in the periaqueductal gray (PAG)
- MORs expressed in the spinal cord

"The analgesic actions of opiates after systemic delivery are believed to represent actions in the brain, spinal cord, & in some instances in the periphery."

- Goodman & Gilman

Periaqueductal Gray (PAG)

- mesencephalic structure
- projects to rostral ventromedial medulla
  - constitutes essential neural circuit for opioid-based analgesia
- high density of MORs
- administration of opioids directly into PAG blocks nociceptive responses in all animals (rodents to primates)
  - naloxone blocks response
- direct electrical stimulation of PAG produces analgesia

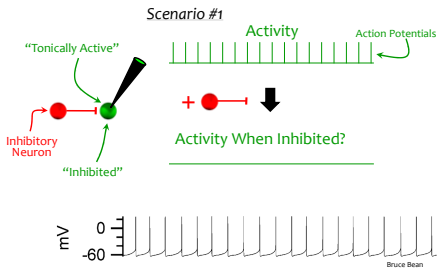


Removing a Brake

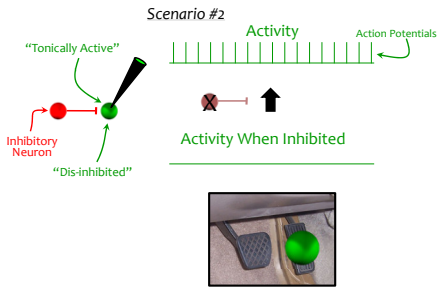
But What's the Point?

Sometimes You're Already to Go, but Something's Stopping You

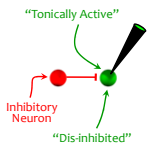
Removing a Brake: Neurons



Removing a Brake: Neurons



Removing a Brake: Neurons



But what's the point?

Neurons Do Not Require Synaptic Excitation to Turn On

Removal of Inhibition (Dis-inhibition) Can Also Turn Neurons On

Periaqueductal Gray (PAG)

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  - constitutes essential neural circuit for opioid-based analgesia
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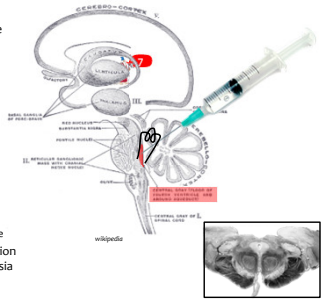
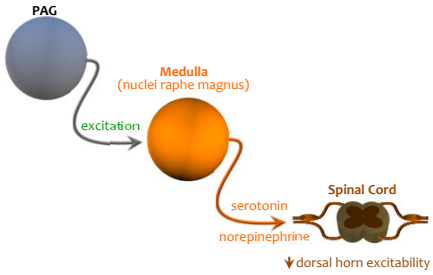
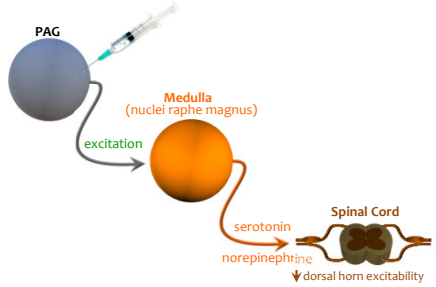


Mechanisms of Opiate Analgesia



Neuroscience Online: UT Health Center

Mechanisms of Opiate Analgesia



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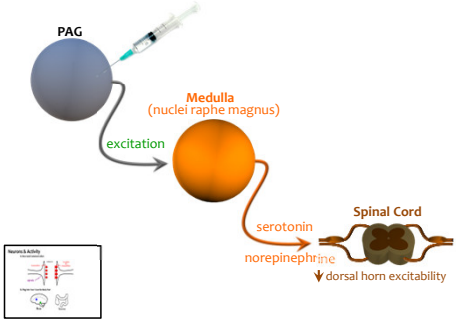
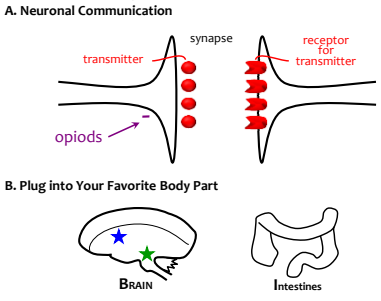


Neurons & Activity



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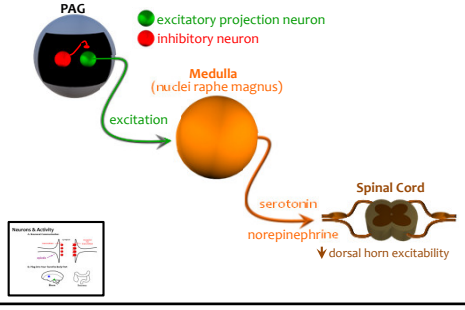

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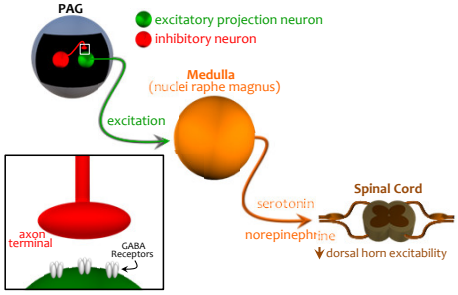

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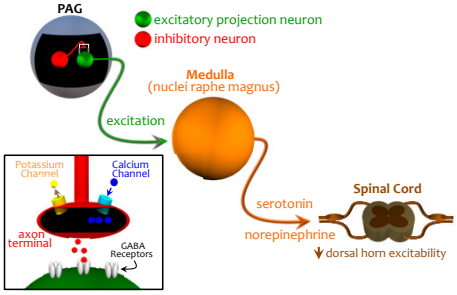

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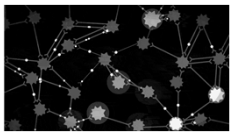

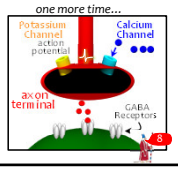

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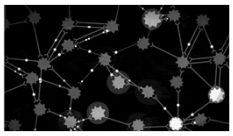
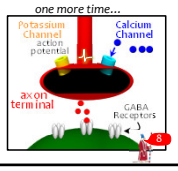
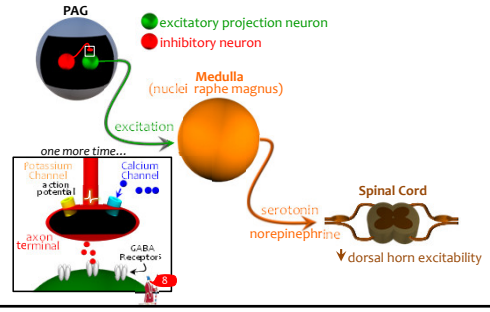




1) Positive change in voltage opens calcium channels
2) Calcium influx triggers vesicle release
3) Opening potassium channels causes negative change in voltage
4) Negative change in voltage: calcium channels *less* likely to open.

Mechanisms of Opiate Analgesia



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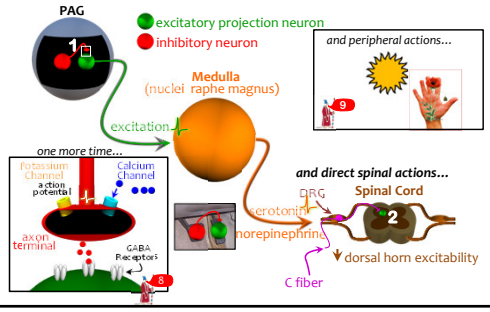

Opioids & Their Receptors

Common Opioid Analgesics

Opioid	Receptor μ	Receptor δ	Receptor κ
Morphine	+++		+
Hydromorphone	+++		
Oxymorphone	+++		
Methadone	+++		
Meperidine	+++	Strong Agonists	
Fentanyl	+++		
Sufentanil	+++	+	+
Alfentanil	+++		
Remifentanil	+++		
Levorphanol	+++		
Codeine	+-		
Hydrocodone	+-	Mild to Moderate Agonists	
Oxycodone	++		
Pentazocine	+-		+
Nalbuphine	–	Mixed Actions	++
Buprenorphine	+-		–
Butorphanol	+-		+++

Langa, 12th Edition

10

Physiological Effects of Morphine

11

- **CNS Effects**
  - **Analgesia**
    - both sensory & emotional components
  - **Euphoria**
  - **Sedation**
    - more common in the elderly
    - more common with the phenanthrenes (codeine, hydrocodone)
  - **Respiratory Depression**
    - all opioid analgesics produce significant respiratory depression by inhibiting brainstem respiratory mechanisms
    - dose-dependent
  - **Cough Suppression**
    - codeine
    - supresses cough reflex
  - **Miosis**
    - valuable for diagnosing overdose
  - **Truncal Rigidity**
  - **Nausea & Vomiting**
  - **Temperature**
    - opioids can produce either hyperthermia (MOR agonists) or hypothermia (KOR agonists)

Physiological Effects of Morphine

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Physiological Effects of Morphine

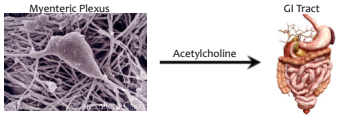
- **Peripheral Effects**
  - **Gastrointestinal**
    - constipation
    - tolerance does not develop (i.e. effect does not diminish)
  - **Biliary Tract**
    - opioids contract biliary smooth muscle
    - can cause biliary colic
  - **Renal**
    - opioids depress renal function
  - **Uterus**
    - opioids may prolong labor

Clinical Uses of Morphine

- **Clinical Use**
  - **Analgesia**
    - severe, constant pain usually relieved
    - sharp, intermittent pain less effectively controlled
  - **Acute Pulmonary Edema**
    - historically used to relieve dyspnea associated with pulmonary edema
    - HOWEVER, recent studies find little evidence in support of this use
  - **Cough**
    - Low dose oral morphine can significantly suppress chronic cough but side effect profile may limit widespread utility
    - Codeine & dextramethorphan: commonly prescribed antitussives
      - Recent studies suggest that these have little/no efficacy relative to placebo in humans with chronic cough
  - **Diarrhea**
  - **Shivering**

Side Effects of Morphine

- **Respiratory depression**
  - Respiration rate is decreased
  - Affects respiratory centers (medulla oblongata & pons)
    - morphine reduces CO_2-dependent activation of respiratory centers
  - Dose threshold for analgesic & respiratory effects are the same
  - Lethal effects of morphine due to respiratory arrest, hypoxia & cardiovascular collapse
- **Decreased gut motility (i.e. constipation)**
  - Inhibits output of the myenteric plexus (also called "Auerbach's" plexus)
    - Reduces propulsive contractions of longitudinal muscles



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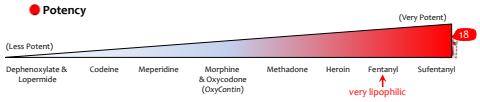
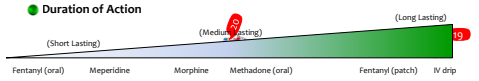
- **Decreased gut motility (i.e. constipation)**
  - Inhibits output of the myenteric plexus (also called "Auerbach's" plexus)
    - Reduces propulsive contractions of longitudinal muscles
- **Difficulty with urination**
  - Inhibits urinary voiding reflex
  - Catheterization may be required after therapeutic doses of morphine
- **May cause orthostatic hypotension**
  - Morphine is a powerful depressant of the medullary vasomotor center
  - Has relatively little effect on blood pressure when recumbant
  - Can produce severe hypotension in patient who has lost blood
- **Allergic reaction**

Differences Among the Major Opiates

- **Potency**



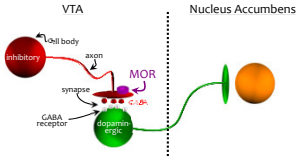
- **Duration of Action**



- **Partial MOR agonists: Pentazocine & Buprenorphine**
  - Used to treat pain
  - Less respiratory depression
    - Can antagonize respiratory depression produced by Fentanyl without completely reversing pain (Buprenorphine)
  - But can cause hallucinations/nightmares (Pentazocine)

Opiate Abuse

- **Opiates have powerful effect on reward pathway**
- **Mechanism: increase dopamine release from the ventral tegmental area (VTA)**



- **Treatment**
  - Medically supervised withdrawal alone is often insufficient to prevent relapse
  - Withdrawal symptoms:
    - Dysphoria, anxiety, restlessness, insomnia
    - High blood pressure, tachycardia, diarrhea

Opiate Overdose

- **Symptoms**
  - Very low respiratory rate
  - Hypotension
  - Hypothermia
  - Pin-point pupils (except when hypoxia becomes severe)
  - Coma
- **Treatment**
  - Ventilation
  - Naloxone (repeated, small IV doses)
    - Opiate receptor antagonist (MOR) …or an inverse agonist?
    - Reverses all effects except whose due to prolonged hypoxia
    - Has very little oral bio-availability
    - Short $T_{1/2}$
    - Naltrexone Comparison. Naltrexone:
      - Longer $T_{1/2}$
      - Can be taken orally
      - Primarily used for long-term treatment of opioid addiction
    - Nalmefene Comparison. Nalmefene:
      - Longer $T_{1/2}$
      - Can be taken orally
      - Expensive
      - More universal antagonist: MOR, KOR, DOR
      - Primarily used for management of alcohol dependence

Novel Approach

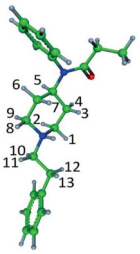
REPORT

PAIN RESEARCH

A nontoxic pain killer designed by modeling of pathological receptor conformations

V. Spahn,[1†] G. Del Vecchio,[1†] D. Labuz,[1] A. Rodriguez-Gazetelumendi,[1] N. Massaly,[1*] J. Temp,[1] V. Durmaz,[2] P. Sabri,[2] M. Reidelbach,[3] H. Machelska,[1] M. Weber,[2‡] C. Stein[1‡§]

Indiscriminate activation of opioid receptors provides pain relief but also severe central and intestinal side effects. We hypothesized that exploiting pathological (rather than physiological) conformation dynamics of opioid receptor-ligand interactions might yield ligands without adverse actions. By computer simulations at low pH, a hallmark of injured tissue, we designed an agonist that, because of its low acid dissociation constant, selectively activates peripheral μ-opioid receptors at the source of pain generation. Unlike the conventional opioid fentanyl, this agonist showed pH-sensitive binding, heterotrimeric guanine nucleotide–binding protein (G protein) subunit dissociation by fluorescence resonance energy transfer, and adenosine 3′,5′-monophosphate inhibition in vitro. It produced injury-restricted analgesia in rats with different types of inflammatory pain without exhibiting respiratory depression, sedation, constipation, or addiction potential.



Quiz

opiate-free

- taking opiates for pain
- never abused opiates

- dependent on opiates
- currently under the influence of opiates

Naloxone

Quiz

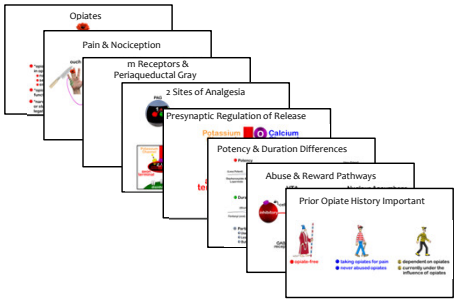
opiate-free

- taking opiates for pain
- never abused opiates

- dependent on opiates
- currently under the influence of opiates

Buprenorphine

Summary



suggested reading

- Basic & Clinical Pharmacology, 12th ed. (chapter 31)
  Bertram G. Katzung, Susan B. Masters, Anthony J. Trevor
- Pharmacological Basis of Therapeutics, 12th ed. (Chapter 18)
  Goodman & Gilman

questions:
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