Hand Therapy Review Course  
Curtis National Hand Center  
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The Use of Physical Agents in Hand Therapy  
Jane Fedorczyk, PT, PhD, CHT, ATC

Methods of Heat Transfer
- Conduction: hot packs, paraffin
- Convection: fluidotherapy
- Radiation: LLLT, Infrared or UV Lamps
- Conversion: Ultrasound
- Evaporation: Spray and Stretch

Comparisons of Physiologic Effects  
Heat Vs. Cold

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Superficial vs. Deep Heat Agents
- Superficial Agents:
  - Can increase tissue temperature changes up to 2 cm in depth
  - Superficial agents work well in the hand
- Deep Agents:
  - Can increase tissue temperature changes up to 5 cm in depth

Superficial Heating Agents
- Warm whirlpool
- Commercial (hot) hydrocollator packs
- Paraffin
- Infrared Lamps
- Fluidotherapy

Proposed Clinical Indications
- Pain Modulation
- Increased Range of Motion
- Reducing Edema/Inflammation
- Promote Healing in Connective Tissues
### Pain Modulation

- **Mechanisms that may explain reduction in pain perception include:**
  - Heat acts as a counterirritant; thermal receptors in target tissue conduct their action potentials faster than nociceptors, so less "pain messages" are recognized (Gate Theory)
  - Increase temperature elevates activation threshold of nociceptors (free nerve endings); may relate to next statement
  - Increased blood flow will remove chemical mediators that sustain and prolong inflammation. These chemical mediators also sensitize or activate nociceptors. If chemical mediators decrease then nociceptor activity will decrease.

### Improving Range of Motion

- ↑ CT extensibility while tissue temp. ↑
- Heat and stretch, especially LLPS enhances time at end of available range.
- Heat application makes it easier or more comfortable to exercise (perception).

### Reducing Edema and Progression of Inflammation

- Increased blood flow may remove chemical mediators that sustain or prolong inflammatory response and edema.
- Increased blood flow also delivers cells responsible for healing including fibroblasts.
- NOT used in acute injury (24-48 hours).
- Hand should be elevated if edema is present when using heat.

### Therapeutic Heat Temperature Guidelines

- < 104°F: mild heating possible
- 104°F - 113°F: therapeutic range
- > 113°F: tissue damage possible

### Precautions/Contraindications

- Absent or impaired thermal sensation
- Compromised peripheral circulation
- Thermoregulatory disorders
- Altered cardiorespiratory status
  - Acute Myocardial Infarction (MI)
  - CHF = Congestive Heart Failure
  - HTN = High Blood Pressure
  - Severe COPD = Chronic Obstructive Pulmonary Disease

### Autonomic Efferents
Precautions/Contraindications

- Recent or potential hemorrhage
- Areas of known malignancy
- Areas of acute inflammation
- Areas of acute, untreated infection (okay to use 24 hrs. after antibiotic therapy initiated)
- Use in combination with liniments, heat rubs, and herbal packs; tissue burns may occur
- Mentation/cognition – Unreliable patient

Cryotherapy: Proposed Clinical Indications

- Pain Modulation
- Decreased Edema/Inflammation

Pain Modulation

- Mechanisms that may explain reduction in pain perception include:
  - Cold acts as a counterirritant; thermal receptors in target tissue conduct their action potentials faster than nociceptors, so less “pain messages” are recognized (Gate Theory)
  - Decreased blood flow may minimize or eliminate chemical mediators that sustain inflammation. These chemical mediators also sensitize or activate nociceptors. If concentration of chemical mediators decreases then nociceptor activity will decrease.

Decrease Edema and Inflammation

- Decrease vasodilation
- Decrease blood flow
- Decrease tissue/cell permeability
- Decrease metabolic activity
  - decrease enzyme function

Normal Response to Cold

Sensory changes:
- COLD ⇒ Burning ⇒ Pain ⇒ Tingling ⇒ Numb

Skin appearance:
- Hyperemia (red) – delivery of warm blood to surface

Precautions

- Absent or Impaired Thermal Sensation
- Impaired circulation
- Thermoregulatory Disorders
- Altered Cardiorespiratory Status
  - Angina
  - HTN (hypertension)
  - CAD (coronary artery disease)
  - Transient change in BP
**Precautions**
- Prolonged cold exposure – nerve damage, ischemia, frostbite
- Aversion to cold
- Presence of open wounds

**Contraindications**
- Compromised peripheral circulation
- Cold Sensitivity Symptoms
  - Cold Uticaria (Wheals)
  - Cryoglobulinemia
  - Raynaud’s phenomenon
  - Paroxysmal cold hemoglobinuria

**Cold Uticaria**
- Develops local "wheals"; hives from a histamine reaction
- Erythematous (red) raised borders with blanched centers – warm to touch
- Systemic: flushing of face, increase HR, sharp decrease in BP; syncope/lightheaded

**Cold Sensitivity Symptoms**
- Raynaud’s Phenomenon
  - Vasospastic disorder – cycles of pallor, cyanosis, rubor, and normal color of the digits
  - Accompanied by numbness, tingling or burning
  - Idiopathic, SLE, TOS, trauma,
  - Attacks precipitated by cold or emotional stress

**Cryoglobulinemia**
- Abnormal blood protein forms gel – results in ischemia/gangrene
- Associated with multiple melanoma, infections, chronic liver disease, RA, SLE

**Paroxysmal Cold Hemoglobinuria**
- Occurs with local or general exposure
- Hemoglobin is released from damaged RBC which shows up in urine

**Types of Cold Applications**
- Commercial Cold Pack
- Ice Pack
- Ice Massage
- Ice Bath
- Cold Spray
- Cryocuff
- Cold Whirlpool

*Choice of Agent depends on:*
- Accessibility
- Body part treated – presence of adipose
- Size of area
- Tolerance to cold
Ultrasound: Theoretical Basis and Clinical Application

Types of Waves

Frequency of Ultrasound

- Depth of tissue penetration determined by frequency not by intensity
  - 1 MHz - transmitted through superficial and absorbed in deeper tissues 2-5 cm
  - 3 MHz – energy is absorbed in more superficial layers 1-2 cm

Frequency

- Also dictates how quickly tissue is heated
  - Draper et al., JOSPT, 1995
  - 3 MHz heats about 3x greater than 1 MHz
    - NOT as deep, but faster

Standing Wave Form

- “HOT Spots”
- Reflected waves superimposed on incident waves
- Unlikely if soundhead is kept moving
- Potentially harmful
- Periosteal pain – heats up periosteum covering bone - Ü risk with 3 MHz

Production of Sound: Conversion

- Electric current from wall
- Crystal in transducer changes electrical energy to sound wave via reverse piezoelectric effect
Transducer

- Piezoelectric crystal: quartz or synthetic ceramic
- 3 mm thick

ERA essentially same size as sound head
ERA much smaller than sound head

Collimated: like a flashlight

- Focus of beam
- Less divergent
- Larger the diameter of the sound head, the more collimated the beam
- Beam from US at 1 MHz is more divergent than US at 3 MHz

BNR 2:1 VS. BNR 6:1

Continuous US

Pulsed Ultrasound
Duty Cycle

\[ \text{Duty Cycle} = \frac{\text{Duration of Pulse (on time)}}{\text{Pulse period (on time + off time)}} \times 100 \]

- Unclear of physiological effects may occur at a particular duty cycle
- Majority of US units use 20% and 50%

Intensity

- Rate at which energy is delivered
- Strength of US
- All factors held constant the greater the intensity, the greater the temperature elevation
- Spatial-Averaged Intensity:
  - Intensity averaged over the area of the transducer – W/cm²

Intensity

- Temporal average intensity – important with pulsed US
- Average of power during both on time and off time
- 2.0 W/cm² with a duty cycle of 20% - the temporal average intensity would be .4 W/cm²

Thermal Effects of Ultrasound

- Increase collagen extensibility
- Elevation of pain threshold
- Increase in circulation
- Changes in nerve conduction velocities
- Changes in contractile properties of skeletal muscle
- Increase in enzymatic activity

Non-Thermal Effects of Ultrasound

- Can result in increased cell membrane permeability and ionic exchange
- Stable Cavitation
- Unstable Cavitation = tissue damage
- Acoustical Streaming
Clinical Indications for US

- Increasing ROM
- Pain Modulation
- Tissue Healing
- Inflammatory Conditions?

- Limited Evidence for US for these indications
- Superficial Heating may accomplish same therapeutic effect as US in elbow, wrist, and hand.

Heat and Stretch

- Absorption of US is good in tendon, capsule
- Increase collagen extensibility – decreased joint stiffness or tendon tightness
- Penetration of deeply placed structures
- Increase tissue temperature temporarily
- Need to stretch either during US or 2-3 mins following application
- Greater the intensity greater the vibration greater the kinetic energy ⇒ HEAT

Pain Modulation

- Heat as counterirritant
- Heat activation of large diameter fibers
- Elevate threshold of activation of nociceptors
- Decrease muscle spindle activity to decrease muscle spasm

Tissue Repair/Wound Healing

- Increases blood supply through thermal and non thermal effects to bring in monocytes, fibroblasts and endothelial cells
- Releases of growth factors from macrophages
- Increases secretion of collagen from fibroblasts
- Increases angiogenesis
- Increases tensile strength through reorganization of collagen and increased tissue extensibility

Inflammatory Conditions

- Increasing blood flow to promote healing
- Increase ability to washout chemical mediators of inflammation
- Decrease pain by elevating threshold
- Enhance cell membrane permeability
- Enhancing transdermal drug delivery (phonophoresis)

Ultrasound

- How do we apply it?
  - Need to decide on:
    - Coupling
    - Frequency
    - Area to be treated
    - Intensity
    - Duty Cycle
Coupling

• US will not pass through air or air/tissue interfaces
• 99.9% reflected at soft tissue/air interface
• Need for coupling
  • Eliminates air between transducer and skin \( \rightarrow \) maximizes amount of US entering body.
  • Types:
    • Direct
    • Indirect

Frequency

• Also dictates how quickly tissue is heated
• Draper et al., JOSPT, 1995
  • 3 MHz heats about 3x greater than 1 MHz
  • NOT as deep, but faster

Area To Be Treated

• Appropriate size of the area to be treated is 2-3 times sized of the ERA

  Peak temp in muscle during 10 mins of 1 MHz US
  • "2 Xs ERA" group’s temp increased 3.6°C
  • "6 Xs ERA" group’s temp only increased 1.1°C

  Reid and Cummings in 1973

What’s the Right Intensity?

• Unclear; guidelines only (0.2 – 2.0 W/cm²)
• WHO restricts upper limit to 3.0 W/cm²
• Desired effects to be achieved?
  • Thermal versus Non-thermal
  • ERA versus treatment area
• Do NOT assume that if you increase the intensity, you increase the depth of penetration!

Intensity

• ↑d intensity, ↑d temperature elevation
• At 1 MHz: rate of increase/minute @ 2x ERA
  • .04°C at .5 W/cm²
  • .16°C at 1.0 W/cm²
  • .33°C at 1.5 W/cm²
  • .38°C at 2.0 W/cm²

  Draper et al, JOSPT, 1995

Intensity

• So….
  • How long will it take to raise the temperature of tissue by 4.0°C when using 2.0 W/cm² ultrasound at 1 MHz and a treatment area of 2 times ERA?
  
  @ 11 minutes = 4.0°C
  0.38°C/min
**Intensity**

- ↑'d intensity, ↑'d temperature elevation
- Frequency has some influence
- At 3 MHz: rate of increase/minute @ 2x ERA
  - .3°C at .5 W/cm²
  - .58°C at 1.0 W/cm²
  - .89°C at 1.5 W/cm²
  - 1.4°C at 2.0 W/cm²

Draper et al, JOSPT, 1995

**Intensity**

- So.....
- How long will it take to raise the temperature of tissue by 4.0°C when using 2.0 W/cm² ultrasound at 3 MHz and a treatment area of 2 times ERA?

@ 3 minutes = 4.0°C
1.4°C/min

**Duty Cycle**

- Used for pulsed application
- Determines the percentage of time the US is “on”
- Physiologic effects of different duty cycles have never been determined
- Most common = 20%

**Transducer Movement**

- Should you move?
  - YES!!
- Ideal: 1-4 cm/s
  - Assuming acceptable BNR
- Too fast → limit heating effect

**Contraindications**

- Eyes, heart, testes
- Pregnant uterus
- Malignancy
- Epiphyses
- Thrombophlebitis

**Precautions**

- Compromised sensation/circulation
- Metal implants
  - Safe but may need to lower intensity due to refractory effects
Electrotherapy Foundations

Clinical Indications
- Pain Modulation
- Muscle Re-education:
  - Muscle Weakness
  - Disuse or Denervation Atrophy
  - Decreased ROM
  - Muscle Spasm or Guarding
  - Spasticity
  - Orthotic Substitution
- Tissue Healing
  - Edema Control
  - Wound Healing
  - Iontophoresis

Direct Current
- Continuous unidirectional flow of charged particles, direction of flow is determined by polarity selected
- Circuit closed: current flows
- Circuit open: current flow stops
- Will see effects of polarity
- Use has been primarily wound healing, muscle stim for denervated muscle, and iontophoresis

Alternating Current
- Uninterrupted bi-directional flow of charged particles
- May be symmetrical or asymmetrical wave
- Type of current used for interferential current and “Russian” stimulation

Pulsed Current
- Unidirectional or bi-directional flow of charged particles that periodically ceases for a finite period of time before the next electrical event
- Does NOT equate with on and off times used for muscle stimulation
- A waveform is the visual representation of pulsed current on a current/time or voltage/time graph

Frequency
- = Pulse Rate
  - Pulses per second (pulsed current)
  - Beats per second (interferential current)
  - Cycles per second (alternating current)
Pulse Duration

- Pulse width
- Only on pulsed current units
- Fully adjustable or preset within the device

Amplitude

- Intensity
- Full adjustable on any device and any current type

- Peak Amplitude: largest amplitude value within a phase – controlled by intensity
- Peak to Peak: sum of peak amplitudes of both phases of a pulse

Take Home Message

These three parameters can be manipulated to produce one of three desired clinical responses:

1. Tingling
2. Twitching
3. Tetanizing muscle contraction

Current Modulators

- Ramp
  - Gradual increase to peak clinical response
  - Prevents Startle Response
  - Although it seems like amplitude or intensity is increasing, most ramping occurs by increasing pulse duration – an engineering concern

Current Modulators

- Minimize accommodation during sensory level electroanalgesia
  - Amplitude
  - Pulse or Phase Duration
  - Frequency

Timing Modulators

- On-Off Times – used for NMES
Electrode Size
Proportional to treatment area
• Overflow
• Current density

Electrode Placement: spacing
How far apart you place them matters too!

Electrode Application
• Decrease resistance
• Clean skin
• Shave prn
• Use coupling medium
  • Gel
  • Water

Contraindications: areas to avoid
• Thoracic Region of Body
• Carotid Sinus (anterior neck)
• Trunk of Pregnant Female
• Excessive Adipose Tissue

Contraindications: patient conditions
• Areas of Malignancy, Infection, or Peripheral Vascular Disease
• Not directly stated by FDA, but concern that effects on circulation may aggravate these conditions
• Hypotensive or Hypertensive Patients
• Autonomic responses may effect control of blood pressure

Contraindications: patient conditions
• Patient Unable to Provide Feedback
• Infants or Small Children
• Patients with Cognitive or Mental Disorders
Contraindications: devices
- Demand Cardiac Pacemakers
- Phrenic Nerve Stimulators
- Urinary Bladder Stimulators
  - Current may interfere with normal operation
  - Close Proximity to Diathermy Unit

Adverse Skin Reactions
- Irritation at the Skin-Electrode Interface
- Allergic Reaction to Adhesive Polymers of Commercial Electrodes
- Direct Current or Unbalanced Pulsed Current Waveforms May Cause Burns, Blisters, or Skin Irritation

Precautions
- Block pain when serving a protective function
- Area of excessive adipose tissue
  - Tingling ok; twitch, tetany be cautious
- Patient Unable to Provide Feedback
  - Infants or Small Children
  - Patients with Cognitive or Mental Disorders

Electroanalgesia
- The outcome of electrical stimulation for pain modulation
- TENS
  - 3 types
    - Sensory
    - Motor
    - Noxious

Strength Duration Curves

Location of Nerve Fibers
Sensory Level

- High Rate or Conventional TENS
- Stimulation of large primary afferents may block nociceptive input from Aβ and C fibers
- Patient usually has immediate response to stimulation
- Electrodes placed on or near site of pain
- Usually first choice of treatment

Sensory Level

- Pulse Duration: 50-100 microseconds
- Frequency: 80-100 pps or bps
- Amplitude: sensory only, perceptible tingling

Sensory Level

- Treatment Duration: variable
- Duration of Analgesia: little residual post-treatment

Accommodation

- Sensory afferents accommodate to constant stimulus
- Occurs with sensory-level electroanalgesia
- Timing and current modulators modify stimulation to minimize accommodation

Motor Level

- Low Rate or Acupuncture-Like TENS
- Visible muscle contraction produced
- Used for non-acute type of pain
- Low amplitudes control pain by “gating”
- Higher amplitudes may activate central mechanisms of pain modulation
- Electrodes placed on motor points that correlate with site of pain or on segmental nerve roots that correlate with site of pain
Motor Level

- Pulse duration: 200-300 microseconds
- Amplitude: strong, twitch contraction

- Frequency: 2-10 pps

Motor Level

- Contraction is achieved by:
  - Stimulation of the intact peripheral nerve
  - Stimulation of the muscle membrane

Treatment Duration: 30-45 minutes
Duration of Analgesia: onset latent; may lasts 2-6 hours

Noxious Level

- Electroacupuncture or Brief Intense TENS
- Pain relief via endogenous opiate-mediated central mechanisms
- Painful stimulation applied with probe electrode usually to acupuncture points; burning sensation perceived
- Electrodes placed over acupuncture points; 70% are also motor points or trigger points
- More chronic conditions; last resort option
Noxious Level

- Pulse duration: in the msec range
- Amplitude: as high as tolerated

Precautions

- Pain Serving a Protective Function
- Sensory level stimulation may be used with controlled exercise, should not be used during functional activities or sports-related activities
- Avoid Trunk of Pregnant Female
- Used during delivery without report of adverse effects; should be fine for other body parts

Indications

- Increase muscle strength
- Increases AROM
- Disuse muscle atrophy
- Muscle Re-education
- Enhance local circulation (tissue repair)
- Edema reduction

Neuromuscular Electrical Stimulation (NMES)

Muscle contraction achieved by stimulation of the intact peripheral nerve
**Motor Unit**

- Motoneuron along with the group of muscle fibers it innervates

**Volitional Muscle Contraction**

- Recruitment Sequence (Size Principle)
  - Small motor units activated first
  - Larger motor units progressively activated to generate greater force
- Rate Coding
  - Firing rate of motor units increases to generate greater force

**Volitional vs. Electrically Elicited**

**Volitional**
- Small motor units recruited first
- Asynchronous firing
- Less fatigue
- Less forceful contraction

**Electrical Stimulation**
- Large motor units recruited first
- Synchronous firing
- More fatigue
- More forceful contraction

**Stimulus Parameters**

- Type of Current: Pulsed or Burst AC
- Pulse Duration: 200 – 700/1000 µsec
- Frequency: 30-75 pps
- Amplitude: Strong Tetanic Contraction
- On:Off Times 1:3 – 1:12 ratios
- Ramp Up/Down @ least 2 seconds

**NMES**

- Higher frequencies → ‘d fatigue

**Stimulus Parameters**

- At least 10 strong contractions
- At least 3 times per week
- Based on quadriceps strengthening for ACL patients (Parker, JOSPT, 2003)
Electrode Considerations

- Bipolar or Monopolar Configuration
- Should “Fit the Muscle”
- Place Over Motor Points
- Skin Preparation
  - Maximize Comfort and Patient Compliance

Monopolar configurations when several muscles located close together such as in the hand and forearm.

Usually Bipolar Configuration Noted here Over the Wrist Extensors

Clinical Considerations For NMES

- Portable vs. line-powered unit?
- Which waveform?
- How much amplitude?
- Monitoring signs of fatigue?
- With increase fatigue, what parameters should be modified?

Upper Extremity Motor Point Chart

When do you choose which waveform?

- Common Waveforms
  - Burst Modulated AC (Russian)
  - Asymmetrical or Symmetrical Biphasic
- Use what you have in the clinic
  - Size of muscle does not matter
  - Appropriate size electrodes
- Muscle strengthening
  - Russian may be more comfortable
  - Biphasic pulsed may produce more torque

Ward et al, PT, 2002
Laufer et al, PT, 2001
How much amplitude?

• Longer phase/pulse charges lead to
  • greater the torque-generating capability
  • higher the contraction intensity
  • greater the strength gains
• Bottom Line: Turn it up!!
  • Need 50-80% of MVC to get strength gains
  • MVC = maximum voluntary contraction

What are the signs of fatigue?

• Poor quality muscle contractions
• Fibrillation of the muscle
If fatigue occurs, what parameters should be modified?
  • Increase off time
  • Decrease on time
  • Decrease frequency but maintain frequency necessary to produce tetany

NMES Precautions/Contraindications

• NMES should not be performed over:
  ➢ thoracic region of the body
  ➢ carotid sinus of the anterior neck
  ➢ trunk of pregnant females
  ➢ area of infection
  ➢ area of malignancy
  ➢ area of excessive adipose tissue
  ➢ area of peripheral vascular disorders - risk of releasing emboli

NMES Precautions/Contraindications

• Patients with demand cardiac pacemakers, phrenic nerve stimulators, or urinary bladder stimulators because the current may interfere with normal operation of these devices.
• Should not be performed on patients that are hypotensive or hypertensive because autonomic responses may adversely affect control of blood pressure.

Iontophoresis

the use of electrical stimulation (direct current) as an enhancer

NMES Precautions/Contraindications

• Should not be used with patients who are unable to provide clear feedback regarding the level of stimulation such as infants, or patients with senility or mental disorders.
• NMES should not be used in close proximity to a diathermy unit.
Likes Repel and Opposites Attract

• Yep this is why we took chemistry!

Suggested Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Type of Current</td>
<td>Direct</td>
</tr>
<tr>
<td>Amplitude</td>
<td>1.0-4.0 ma</td>
</tr>
<tr>
<td>Treatment Duration</td>
<td>10-40 minutes</td>
</tr>
<tr>
<td>Current Dosage</td>
<td>40-80 ma•min</td>
</tr>
<tr>
<td>Ciccone, 1995</td>
<td></td>
</tr>
<tr>
<td>Bélanger, 2002</td>
<td></td>
</tr>
<tr>
<td>4 ma for 10 minutes</td>
<td>Costello and Jeske, 1995</td>
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Effects of Direct Current

**Cathode**: alkaline reaction due to formation of sodium hydroxide

**Anode**: acidic reaction due to the formation of hydrochloric acid

Either can cause skin reaction, but...

*Alkaline reactions more caustic to skin!*

Safety Concerns

• Buffering systems within commercial electrodes to minimize pH changes in skin beneath electrodes.
• The real question is does the buffering system work for both the cathode and anode?
• Current Density- make sure electrode is large enough to minimize risk of burns.

Safety Concerns

• There are text books that show how to make “homemade” out of aluminum foil and gauze.
• Not recommended:
  • No buffering systems.
  • Foil and gauze are not FDA approved
  • Do not adhere well to skin
  • current density is too high

Cathode vs. Anode

• Which is which? Here is an easy way to remember. You’ve known this since kindergarten.
  • Anode – it is positive to get an “A”
  • Cathode – negative to get a “C”
Current Dosage

- Current (ma) \( \times \) Duration (min)
- Not clear if 1.0ma for 40 minutes yields the same current dosage as 4ma for 10 minutes
- Unknown if minimum current amplitude required for ion transfer to occur across skin

Indications for Iontophoresis

- Inflammation
- Pain
- Calcium Deposits
- Scar Tissue and Adhesions

Contraindications

- Drug allergies or reactions
- Adverse reaction to direct current
- Same as for electrical stimulation

Clinical Effectiveness

- Pain measures decrease
- Functional measures increase
- No change after 1st treatment modify treatment or discontinue
- No improvement within three treatments, then discontinue treatment

Physical Agents in Hand Therapy: References


Physical Agents in Hand Therapy: References

- Cameron,MH: Physical Agents in Rehabilitation: From Research to Practice (3rd edition), WB. Saunders (Elsevier), 2008