Wrong! At least in the case of electricity as a stimulating current.

“To understand how current flow effects biological tissue, you must first be familiar with some of the principles that describe how electricity is produced and how it behaves in an electrical circuit.”
Components of Electrical Current

- Ions
- Tend to move from an area of higher concentration to an area of lower concentration
- Electrical force creates electrical potentials
- The more ions present, the greater the potential

Components of Electrical Current continued

- Electrons
- Electrical current
- Flow of electrons is always from high potential to low potential
- Ampere
- Coulomb

Components of Electrical Current continued

- Electrons will not move unless an electrical potential difference in the concentration of these charged particles exists between 2 points
- Electromotive force (volt)
- Voltage
- 110 V or 220 V
Components of Electrical Current continued

- Path of least resistance
- Conductors
- Insulators
- Resistance
- Ohm’s law

Electrotherapeutic Currents

- Direct (DC)
  - Monophasic
- Alternating (AC)
  - Biphasic
- Pulsed
  - Polyphasic

Direct Current

![Diagram of Direct (DC) monophasic current](image)
Alternating Current

Pulsed Current

Generators of Electrotherapeutic Currents

- Regardless of current type, all are transcutaneous electrical stimulators
- TENS
  - Transcutaneous electrical nerve stimulator
- NMES (EMS)
  - Neuromuscular electrical stimulator
- MENS
  - Microcurrent electrical nerve stimulator
Generators of Electrotherapeutic Currents continued

- No relationship between the type of current being delivered by the generator and the type of current used as a power source for the generator

Components of Electrical Generator

- Transformer
- Rectifier
- Filter
- Regulator
- Amplifier
- Oscillator

Waveforms

- Graphic representation of the shape, direction, amplitude, duration, and pulse frequency of the electrical current being produced by the electrotherapeutic device, as displayed by an oscilloscope
Pulse, Phase, Direction of Current Flow

- Pulse – Individual waveform
- Phase – portion of the pulse that rises above or below the baseline for some period of time
  - Monophasic
  - Biphasic
  - Polyphasic

Pulse Intervals

- Interpulse interval – Interruptions between individual pulses or groups of pulses
- Intrapulse interval – Period of time between individual pulses

Pulse Amplitude

- Amplitude – Intensity of current flow as indicated by the height of the waveform from baseline
- Amplitude = Voltage = Current intensity
**Phase Charge**

- Total amount of electricity delivered during each pulse
- Monophasic always greater than zero
- Biphasic is = to the sum of the phase charges
  - Symmetrical = zero
  - Asymmetrical = net pulse charge is greater than zero

**Rise and Decay Times**

- Rate of rise – How quickly a waveform reaches its maximum amplitude
- Decay time – Time required for a waveform to go from peak amplitude to zero volts
- Rate of rise and accommodation
- More rapid the rate of rise, the greater the currents ability to excite nervous tissue

**Pulse Duration**

- Duration of each pulse indicates the length of time current is flowing in one cycle
- Monophasic – phase duration = pulse duration
- Biphasic – pulse duration is determined by the combined phase durations
- Pulse period – Combined time of the pulse duration and the interpulse interval
Pulse Frequency

- Indicates the number of pulses per second
- Increase in frequency, amplitude tends to increase and decrease more rapidly
- Muscular and nervous system responses depend on the length of time between pulses and on how the pulses or waveforms are modulated

Stimulators

- Clinically speaking
  - Low frequency generators
  - Medium frequency generators
  - High frequency generators
- In general, all stimulators are low-frequency generators
Current Modulation

- Continuous – Amplitude of current remains the same for several seconds or minutes
- Interrupted – on time, off time
- Burst – combined set of 3 or more pulses
- Ramped – current builds gradually to some maximum amplitude

Series Circuit

- Circuit in which there is only one path for current to get from one terminal to another
- Components are placed end to end
- Resistance to flow is equal to the resistance of all the components in the circuit added together
  \[ R_T = R_1 + R_2 + R_3 \]
- Voltage decreased at each component
  \[ V_T = V_{D1} + V_{D2} + V_{D3} \]
Parallel Circuit

- A circuit in which 2 or more routes exist for current to pass between the two terminals
- Component resistors are side by side, and the ends are connected
- Same voltage to each resistor
- Current flow depends on resistance at each component

**Total voltage is exactly same as voltage at each component**

- \( V_1 = V_2 = V_3 \)
- Adding alternative pathway improves ability of current to flow from one point to another
- Path of least resistance
- Resistance and Ohm’s law
  - \( \frac{1}{R_1} = \frac{1}{R_2} + \frac{1}{R_3} \)
Circuits

- Series have higher resistance and less current flow
- Parallel have lower resistance and higher current flow

Electrical Modalities

- Make use of combined series and parallel circuits
- Current through skin = series circuit
- Once through skin and fat, current comes into contact with many other tissues
  - Parallel circuit

Body Circuit
Electric Stimulation Currents

Electrodes
- Electrode-skin interface
- Conducting mediums
- electrode size

Electrode Placement
- Stimulation points
  - Motor
  - Trigger
  - Acupuncture
- Bipolar technique
- Monopolar technique
- Quadripolar Technique
Current Flow Through Biologic Tissue

- Current flow through path of least resistance
- Tissue high in water content = high ion content = best conductor of electricity
- Skin is insulator
  - The greater the impedance of the skin, the more voltage needed
- Blood is best conductor

Physiologic Responses to Electrical Currents

- Electricity will have an effect on each cell and tissue that is passes through
- Type and extent of response dependent on:
  1) Type of tissue and its response characteristics
  2) Nature of the current applied

Goals of Electric Stimulation

- Muscle contraction
  - Pulse amplitude
  - Pulse frequency
  - Phase duration
- Pain control
- Control and reduction of edema
  - Sensory-level stimulation
  - Motor-level stimulation
Goals Continued
- Wound healing
- Strength augmentation
- Fracture healing

TENS
- Transcutaneous Electrical Nerve Stimulation
- Process of altering the perception of pain through the use of an electrical current
- Gate theory
- Endogenous opiate
- Setup dependent

TENS
- Pain reduction is primarily through modulation of the nervous system
  - May activate the preganglionic and postganglionic neurons, causing mild vasoconstriction
- Caffeine warning
TENS
- Only alters perception of pain
- Little effect on the underlying pathology
- Use with other therapies that attempt to treat source of pain
  - Manual exercise

High Frequency TENS
- Sensory level
- High pulse frequency
  - 60–100 pps
- Short pulse duration
  - Less than 100 μsec
- Activates gate pain modulation at spinal cord level
- Stimulation of large diameter sensory nerve fibers

High Frequency TENS
- Accommodation is concern with long term use
- Current modulation can diminish accommodation
  - Burst & frequency modulation
High Frequency TENS

- Effective for:
  - Pain associated with musculoskeletal disorders
  - Post operative pain
  - Inflammatory condition
  - Myofascial pain

Low Frequency TENS

- Motor level
- Low pulse frequency
  - 2 – 4 pps
- Long pulse duration
  - 150 – 250 μ sec
- 45 minute treatment time

Low Frequency TENS

- Activates small diameter nociceptors and motor fibers
  - Release of β-endorphin
    - Results in narcotic like pain reduction
- Stimulates pituitary gland
  - Release of chemicals that trigger production of pain reducing β-endorphin
Low Frequency TENS

- Actual relief may take some time following treatment
  - Lasts longer than high f TENS
- Uses:
  - Chronic pain
  - Pain due to damage to deep tissues
  - Myofascial pain
  - Pain caused by muscle spasm

Brief – Intense TENS

- Noxious level, motor level
- High pulse frequency
  - Greater than 100 pps
- Long pulse duration
  - 300 – 1000 μ sec
- Treatments lasting a few seconds to a few minutes

Brief – Intense TENS

- Pain relief through activating mechanisms in the brain stem
  - Dampen or amplify pain impulses
- Feedback loop
- High level of analgesia
- Effects tend to be transitory
- Recommended for pre-exercise
IFC
- Interferential current
- 2 ACs on 2 channels
- 1 channel produces constant high frequency sine wave
  - 4000 – 5000 Hz
- Other channel produces a sine wave of variable frequency

IFC
- Two independent channels combine to form an interference wave
  - Frequency of 1 – 100 Hz
- Constructive interference
  - 2 waves in perfect phase collide and form one single larger wave
- Destructive interference
  - 2 waves perfectly out of phase, cancel each other out, producing no wave

IFC
- IFC combines constructive and destructive interference patterns to form a continuous interference pattern
  - Occurs when 2 circuits have slightly different frequency (± 1 Hz)
- Resultant waveform drifts between constructive and destructive interference patterns
IFC
- Rate of change is known as beat pattern
- Difference in frequency between the 2 circuits
- Beat produced elicits responses similar to TENS, but is capable of delivering a greater total current to the tissues (70 –100 mA)

IFC
- Low skin resistance
- Inside tissues, interference between 2 waves reduces the frequency to a level that has biological effects on tissue

IFC and Pain Control
- High beat frequency
  - 100 Hz
  - Sensory level stimulation
  - Gate theory
- Low beat frequency
  - 2 – 10 Hz
  - Motor level stimulation
  - Opiate release
IFC and Neuromuscular Stimulation

- Medium beat frequency
  - 15 Hz
- Muscle pump
- Increased venous and lymphatic return
- Edema reduction


IFC and Time Modulated AC

- AKA Russian wave
  - Theory – 2500 Hz carrier sine wave, burst modulation
  - Dr. Yakov Kots
  - 30 – 40% increase in strength compared to isometric training alone
  - Increased muscular endurance
  - Changes in velocity of contraction
  - These results have never been replicated in USA


High Voltage Pulsed Stimulation

- Monophasic current
- Twin-peaked waveform or Train of 2 single pulses
  - phase duration of 5 to 260 μsec
  - Average current does not exceed 1.5 mA
  - Pulse charge less than 4 microcoulombs
  - Voltage > 150 V needed to stimulate motor and sensory nerves
### Uses
- Muscle reeducation
- Nerve stimulation
- Edema reduction
- Pain control

### Muscle Reeducation

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Strong, comfortable contraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse Frequency</td>
<td>Low (&lt;15 pps) individual contraction</td>
</tr>
<tr>
<td></td>
<td>Moderate (35 – 50 pps) tonic contraction</td>
</tr>
<tr>
<td>Polarity</td>
<td>+ or –</td>
</tr>
<tr>
<td>Electrode placement</td>
<td>Bipolar: proximal &amp; distal to muscle</td>
</tr>
<tr>
<td></td>
<td>Monopolar: motor point</td>
</tr>
</tbody>
</table>

### Pain Control: Gate Theory

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Sensory level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse frequency</td>
<td>60 – 100 pps</td>
</tr>
<tr>
<td>Phase duration</td>
<td>&lt; 100μsec</td>
</tr>
<tr>
<td>Mode</td>
<td>Continuous</td>
</tr>
<tr>
<td>Electrode placement</td>
<td>Directly over painful site</td>
</tr>
</tbody>
</table>
Pain Control: Opiate Release Mechanism

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Motor level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse Rate</td>
<td>2 – 4 pps</td>
</tr>
<tr>
<td>Phase duration</td>
<td>150 – 250 µsec</td>
</tr>
<tr>
<td>Mode</td>
<td>Continuous</td>
</tr>
<tr>
<td>Electrode Placement</td>
<td>Over painful site, trigger point, acupuncture point, or distal to the spinal nerve root</td>
</tr>
</tbody>
</table>

Pain Control: Brief-Intense Protocol

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Noxious</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse rate</td>
<td>&gt; 120 pps</td>
</tr>
<tr>
<td>Phase duration</td>
<td>300 – 1000 µsec</td>
</tr>
<tr>
<td>Mode</td>
<td>Probe (15-60 s at each site)</td>
</tr>
<tr>
<td>Probe placement</td>
<td>Gridding technique</td>
</tr>
</tbody>
</table>

Edema Control: Sensory Level

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Sensory level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse duration</td>
<td>Max duration allowed</td>
</tr>
<tr>
<td>Pulse frequency</td>
<td>120 pps</td>
</tr>
<tr>
<td>Polarity</td>
<td>– electrode over injured tissue</td>
</tr>
<tr>
<td>Mode</td>
<td>Continuous</td>
</tr>
<tr>
<td>Electrode placement</td>
<td>Immersion, grouped</td>
</tr>
<tr>
<td>Treatment duration</td>
<td>4 – 30 min treatments, 60 min rest</td>
</tr>
</tbody>
</table>
Edema Control: Motor Level

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Strong, comfortable contraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse frequency</td>
<td>Low</td>
</tr>
<tr>
<td>Polarity</td>
<td>+ or –</td>
</tr>
<tr>
<td>Mode</td>
<td>Alternating</td>
</tr>
<tr>
<td>Electrode placement</td>
<td>Bipolar: ends of muscle</td>
</tr>
<tr>
<td></td>
<td>Monopolar: course of venous return system</td>
</tr>
</tbody>
</table>

MENS

- Microcurrent Electrical Nerve Stimulation
- Subsensory level
  - < 1000 μA
  - 1/1000 amperage of TENS
  - Pulse duration 2500 x TENS
- Does not excite peripheral nerves
- DC, AC, or pulsed

MENS

- Does it work?
- Theory:
  - Currents below 500 μA increase the level of ATP
  - Increased ATP production encourages amino acid transport and increased protein synthesis
  - Tissue trauma affects electrical potential of injured cells
MENS Theory continued

- Body’s bioelectric current follow path of least resistance
  - Not through injured tissue
- MENS introduces current flow through injured site increasing ATP production

Neuromuscular Electrical Stimulation

- Muscle reeducation
- Spasticity reduction
- Atrophy delay
- Strengthening
- Recruitment order reversed

NMES

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak amperage</td>
<td>To tolerance</td>
</tr>
<tr>
<td>Pulse duration</td>
<td>50 – 300 μsec</td>
</tr>
<tr>
<td>Pulse frequency</td>
<td>1 – 200 pps</td>
</tr>
<tr>
<td>Pulse charge</td>
<td>≤ 10 mQ</td>
</tr>
</tbody>
</table>
Iontophoresis

- Introduction of medication ions into skin using low-voltage, high amperage DC
  - 0 – 5 mA
- Skin impedance
  - 500 ohms – 100 kohms
- Primary path of current/medication flow is through hair follicles and skin pores

- Applied current must be sufficient to overcome skin resistance
- Once medication is in tissue, it spreads via passive diffusion
  - Electric current no longer plays role
- Medication tends to remain highly concentrated within tissues directly below introduction site

- Electrode setup is monopolar
  - Electrode with medication is active electrode
- Biophysical effect obtained is dependent on the medication used
- Typical use is to decrease inflammation
  - Dexamethasone
Iontophoresis Warning

- Burns or severe skin irritation may result due to application of DC
  - Related to hydrogen and hydroxide ions generated by current