2011 ANATOMY–TRAINING HANDOUT

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National Rules Committee Chairman – Life Science

DISCLAIMER - This presentation was prepared using draft rules. There may be some changes in the final copy of the rules. The rules which will be in your Coaches Manual and Student Manuals will be the official rules.

- **BE SURE TO CHECK THE 2011 EVENT RULES** for EVENT PARAMETERS and TOPICS FOR EACH COMPETITION LEVEL
- **THE SKELETAL MUSCLE LIST** may be found at [www.soinc.org](http://www.soinc.org) under Event Information

TRAINING MATERIALS:
- **Training Power Point** presents an overview of material in the training handout
- **Training Handout** presents introductory topic content information for the event
- **Sample Tournament** has sample problems with key
- **Event Supervisor Guide** has event preparation tips, setup needs and scoring tips
- **Internet Resource & Training Materials** are available on the Science Olympiad website at [www.soinc.org](http://www.soinc.org) under Event Information.
- A Biology-Earth Science CD as well as the **Division B and Division C Test Packets** are available from SO store at [www.soinc.org](http://www.soinc.org)

BASIC ANATOMY (STRUCTURE AND FUNCTION)
- **Respiratory System** (new)
- **Muscular System**
- **Major diseases**
- **Treatment and prevention of diseases**

PROCESS SKILLS - observations, inferences, predictions, calculations, data analysis, and conclusions.

**Respiratory System**

**FUNCTIONS:**
- Provides oxygen to the blood stream and removes carbon dioxide
- Enables sound production or vocalization as expired air passes over the vocal chords.
- Enables protective and reflexive non-breathing air movements such as coughing and sneezing, to keep the air passages clear
- Control of Acid-Base balance
- Control of blood pH

**PROCESSES:** a collective term for the following processes:
- **Pulmonary ventilation** - movement of air into the lungs (inspiration) and movement of air out of the lungs (expiration)
- **External respiration** - movement of oxygen from the lungs to the blood and movement of carbon dioxide from the blood to the lungs
- **Transport of respiratory gases** - Transport of oxygen from the lungs to the tissues and transport of carbon dioxide from the tissues to the lungs
- **Internal respiration** - Movement of oxygen from blood to the tissue cells and movement of carbon dioxide from tissue cells to blood
PRINCIPAL ORGANS OF THE RESPIRATORY SYSTEM

Nose
Functions
- Provides an airway for respiration
- Moistens and warms entering air
- Filters and cleans inspired air
- Resonating chamber for speech
- Detects odors in the airstream

Anatomical features
- **Vibrissae (guard hairs)** – stiff hairs that filter large particles from the air
- **Nasal cilia** – hair-like projections that propel trapped particles towards the throat for digestion by digestive enzymes
- **Capillaries** - rich supply of capillaries warm the inspired air
- **Nasal conchae** – folds in the mucous membrane that increase air turbulence and ensures that most air contacts the mucous membranes
- **Olfactory mucosa** – mucous membranes that contain smell receptors
- **Respiratory mucosa** – pseudostratified ciliated columnar epithelium containing goblet cells that secrete mucus
- **Mucus** - Stickiness traps inhaled particles and Lysozyme kills bacteria
- **Lymphocytes and IgA antibodies** - protect against bacteria

Pharynx (throat)

Three regions of the pharynx
- **Nasopharynx** – air passage (pseudostratified columnar epithelium)
- **Oropharynx** – passageway for air, food, and drink (stratified squamous epithelium)
- **Laryngopharynx** – passageway for air, food, and drink (stratified squamous epithelium)

Larynx (voice box)

Functions
- Keeps food and drink out of the airway
- Sound production
- Acts as a sphincter during abdominal straining (ex. During defecation and heavy lifting)
Anatomical features:
- Nine e-rings of hyaline cartilage form the framework of the larynx
- Muscular walls aid in voice production and the swallowing reflex
- Glottis – the superior opening of the larynx
- Epiglottis – prevents food and drink from entering airway when swallowing
- False vocal cords – aid in closing the glottis when swallowing
- True vocal cords – produce sound when air passes between them

Note: The shorter and thinner these membranes are, the faster air moves over them – produces high pitched sounds while the longer and thicker these membranes are, the slower air moves over them – produces low pitched sounds

Trachea (windpipe)

Functions
- Air passageway
- Cleans, warms, and moistens incoming air

Anatomical features
- Rings of hyaline cartilage – reinforce the trachea and keep it from collapsing when you inhale
- Ciliated pseudostratified epithelium – traps inhaled debris and propels mucus up to the pharynx where it is swallowed

Bronchi

Function
- Solely an air passageway

Anatomical features
- Left and right primary bronchi branch off from trachea Once the left and right primary bronchi enter the lungs they are subdivided into smaller tubes:
  - Secondary bronchi (one for each lobe) → tertiary bronchi → bronchioles → terminal bronchioles → respiratory bronchioles → alveolar ducts → alveolar sacs
  - Alveolar sacs are clusters of alveoli - the site of gas exchange

Cell populations present in alveoli
- Type I alveolar cells – allow for diffusion of gases (simple squamous epithelia)
- Type II alveolar cells – secrete surfactant (simple cuboidal epithelia)
- Dust cells – alveolar macrophages (leukocytes)

Other tissue types present in the alveoli
- Smooth muscle rings aid in resistance to air flow
- Elastic connective tissue fibers aid in expelling air from the lungs

Lungs

Left Lung: Divided into 2 lobes; Smaller than the right lung because the cardiac notch accommodates the heart
Right Lung: Divided into 3 lobes

Note: Each lobe is separated by connective tissue and has its own arteries and veins which allows for compartmentalization, esp. when portions of the lungs are diseased. Serous membranes cover the entire surface of the lungs and produce pleural fluid which enables the lungs to expand and contract with minimal friction
Two phases of Pulmonary Ventilation – involves diaphragm, Intercostal muscles, Pectoralis minor muscle and the gas laws.

Physiology of Pulmonary Ventilation & the Gas Laws
Airflow is governed by basic pressure, flow, and resistance principles. Atmospheric pressure is the weight of the air is the force that moves air into the lungs. Boyle’s law - at constant temperature, the pressure of a given quantity of gas is inversely proportional to its volume. Charles’ Law - the volume of a given quantity of gas is directly proportional to its absolute temperature. As the inhaled air is warmed, it expands and inflates the lungs.

Inspiration, or inhalation – a very active process that requires input of energy
Air flows into the lungs when the thoracic pressure falls below atmospheric pressure. The diaphragm moves downward and flattens, when stimulated by phrenic nerves. External (inspiratory) intercostal muscles and thoracic muscles can be stimulated to contract and expand the thoracic cavity.

Expiration, or exhalation – a passive process that takes advantage of the recoil properties of elastic fibers. Air is forced out of the lungs when the thoracic pressure rises above atmospheric pressure. The diaphragm and expiratory muscles relax. The elasticity of the lungs and the thoracic cage allows them to return to their normal size and shape. To exhale more than usual, internal (expiratory) intercostals muscles and other muscles can be stimulated.

Physical factors influencing pulmonary ventilation
Resistance to airflow
Pulmonary compliance – the ease at which lungs expand. Compliance can be reduced by degenerative lung disease, such as tuberculosis.
Diameter of bronchioles – controlled by smooth muscle
Bronchoconstriction – reduce airflow
Bronchodialation - increase airflow
Alveolar surface tension – surfactant reduces the surface tension in the alveoli and keep them from collapsing during expiration.
Neural control of pulmonary ventilation
Control centers in the brainstem
Respiratory control centers – found in the pons and the medulla oblongata
Control breathing
Adjusts the rate and depth of breathing according to oxygen and carbon dioxide levels
Afferent connections to the brainstem
Hypothalamus and limbic system send signals to respiratory control centers
Chemoreceptors in the brainstem and arteries monitor pH, oxygen, and carbon dioxide levels
Vagus nerve (X) transmits sensory signals to the respiratory centers when irritated by smoke, dust, noxious fumes, etc.
Inflation reflex – prevents the lungs from over-inflating
Voluntary control – controlled by the motor cortex of the cerebrum
Very limited voluntary control exists

Patterns of Breathing
Apnea – temporary cessation of breathing (one or more skipped breaths)
Dyspnea – labored, gasping breathing; shortness of breath
Eupnea – normal, relaxed, quiet breathing
Hyperpnea – increased rate and depth of breathing in response to exercise, pain, or other conditions
Hyperventilation – increased pulmonary ventilation in excess of metabolic demand
Hypoventilation – reduced pulmonary ventilation
Orthopnea – Dyspnea that occurs when a person is lying down
Respiratory Arrest – permanent cessation of breathing
Tachypnea – accelerated respiration

Measures of Pulmonary Ventilation
Respiratory Volumes – values determined by using a spirometer
Tidal Volume (TV) – amount of air inhaled or exhaled with each breath under resting conditions
Inspiratory Reserve Volume (IRV) – amount of air that can be inhaled during forced breathing in addition to resting tidal volume
Expiratory Reserve Volume (ERV) – amount of air that can be exhaled during forced breathing in addition to tidal volume
Residual Volume (RV) – amount of air remaining in the lungs after a forced exhalation.
**Respiratory Capacities** – values determined by adding two or more of the respiratory volumes

- **Vital Capacity** – maximum amount of air that can be expired after taking the deepest breath possible (VC = TV + IRV + ERV)
- **Inspiratory Capacity** – maximum volume of air that can be inhaled following exhalation of resting tidal volume (IC = TV + IRV)
- **Functional Residual Capacity** – volume of air remaining in the lungs following exhalation of resting volume (FRC = ERV + RV)
- **Total Lung Capacity** – total volume of air that the lungs can hold (TLC = VC + RV)

**Dead Space**

- **Anatomical dead space** – areas of the conducting zone that contains air that never contributes to the gas exchange in the alveoli
- **Alveolar dead space** – alveoli that are collapsed or obstructed and are not able to participate in gas exchange

**Pulmonary Function Tests** - enable obstructive pulmonary disorders to be distinguished from restrictive disorders.

- **Obstructive Disorders** – do not reduce respiratory volumes, but the narrow the airway and interfere with airflow
- **Restrictive Disorders** – disorders that stiffen the lungs and thus reduce compliance and vital capacity

**DISORDERS AND DISEASES OF THE RESPIRATORY SYSTEM**

- **Hypoxia** – deficiency of oxygen in a tissue or the inability to use oxygen
- **Oxygen Toxicity** – excess oxygen, causing the build up of peroxides and free radicals
- **Chronic Obstructive Pulmonary Diseases (COPD)** – long-term obstruction of airflow and a substantial reduction in pulmonary ventilation
- **Chronic bronchitis** – cilia are immobilized and reduced in number; goblet cells increase their production of mucus → mucus clogs the airways and breeds infection
- **Emphysema** – alveolar walls break down and the surface area of the lungs is reduced
- **Asthma** – allergens trigger the release of histamine and other inflammatory chemicals that cause intense bronchoconstriction
- **Lung Cancer** – cancer of the lungs
- **Acute Rhinitis** – the common cold
- **Laryngitis** – inflammation of the vocal folds
- **Pneumonia** – lower respiratory infection that causes fluid build up in the lungs
- **Sleep apnea** – Cessation of breathing for 10 seconds or longer during sleep
- **Tuberculosis** – pulmonary infection with Mycobacterium tuberculosis; reduces lung compliance

**INTERACTION OF RESPIRATORY AND MUSCULAR SYSTEMS:**

The Intercostal Muscles and the Diaphragm work together to allow breathing to occur.
Muscular System

Muscle Function:
- Stabilizing joints
- Maintaining posture
- Producing movement
- Moving substances within the body
- Stabilizing body position and regulating organ volume
- Producing heat– muscle contraction generates 85% of the body’s heat

Characteristics of Muscle Tissue
- Excitability- receive and respond to stimuli
- Contractility- ability to shorten and thicken
- Extensibility- ability to stretch
- Elasticity- ability to return to its original shape after contraction or extension

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<tr>
<th>Location</th>
<th>Skeletal Muscle</th>
<th>Smooth Muscle</th>
<th>Cardiac Muscle</th>
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<tbody>
<tr>
<td>Function</td>
<td>Attached to bone</td>
<td>On hollow organs, glands and blood vessels</td>
<td>Heart to propel blood</td>
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<td>Nucleus</td>
<td>Multiple, peripheral</td>
<td>Single, central</td>
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<td>Cell Shape</td>
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<td>Spindle-shaped</td>
<td>Branched</td>
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- **Skeletal muscle**
- **Smooth muscle**
- **Cardiac muscle**
Skeletal Muscles

There are nearly 650 muscles attached to the skeleton. See muscle list for competitions.

They work in pairs: one muscle moves the bone in one direction and the other moves it back again.

Most muscles extend from one bone across a joint to another bone with one bone being more stationary than another in a given movement. Muscle movement bends the skeleton at moveable joints.

Muscles are anchored firmly to bone by tendons made of dense fibrous connective tissue shaped like heavy cords. Though very strong and secure to muscle, tendons may be injured.

Attachment to the more stationary bone by tendon closest to the body or muscle head or proximal is the origin and attachment to the more moveable bone by tendon at the distal end is the insertion.

During movement, the origin remains stationary and the insertion moves.

The force producing the bending is always a pull of contraction. Reversing the direction is produced by the contraction of a different set of muscles. As one group of muscles contracts, the other group stretches and then they reverse actions.

Muscle contractions can be short, single contractions or longer ones.
**Skeletal Muscle Anatomy**

Each muscle has thousands of muscle fibers in a bundle running from origin to insertion bound together by connective tissue through which run blood vessels and nerves.

Each muscle fiber contains many nuclei, an extensive endoplasmic reticulum or sarcoplasmic reticulum, many thick and thin myofibrils running lengthwise the entire length of the fiber, and many mitochondria for energy.

The basic functional unit of the muscle fiber is the **sarcomere** which consists of thick filaments with myosin (protein) molecules and thin filaments with actin (protein) molecules plus smaller amounts of troponin and tropomyosin.

When viewed under the microscope, they appear as striations of **dark A bands** and **light I bands**. The A bands are bisected by the H zone with the M line or band running through the center of this H zone. The I bands are bisected by the Z disk or line.

A **sarcomere** consists of the array of thick and thin filaments between two Z disks.

**Sliding-Filament Model**

In the thick filaments, myosin molecules contain a globular subunit, the **myosin head**, which has binding sites for the actin molecules of the thin filaments and ATP.

Activating the muscle fiber causes the myosin heads to bind to actin molecules pulling the short filament a short distance past the thick filaments.

The linkages break and reform (using ATP energy) further along the thick filaments. Thus the thin filaments are pulled past the thick filaments in a ratchet-like action. No shortening, thickening or folding of individual filaments occurs.

As the **muscle contracts**, the width of the I bands and H zones decrease causing the Z disks to come closer together, but there is no change in the width of the A band because the thick filaments do not move. As the **muscle relaxes or stretches**, the width of the I bands separate as the thin filaments move apart but the thick filaments still do not move.
Muscle and Tendon Injuries

**Strains** – injuries from overexertion or trauma which involve stretching or tearing of muscle fibers. They often are accompanied by pain and inflammation of the muscle and tendon. If the injury is near a joint and involves a ligament, it is called a **sprain**.

**Cramps** – painful muscle spasms or involuntary twitches.

**Stress-induced muscle tension** – may cause back pain and headaches.

Muscular Disorders:

**Poliomyelitis** – viral infection of the nerves that control skeletal muscle movement.

**Muscular Dystrophies** – most common caused by mutation of gene for the protein **dystrophin** which helps in attaching and organizing the filaments in the sacromere. Duchenne Muscular Dystrophy and Becker muscular dystrophy are the two most common types. The gene for dystrophin is on the X chromosome so the disorder is sex-linked. Muscle function is impaired.

**Myasthenia gravis** – autoimmune disease affecting the neuromuscular junction. Patients have smaller end plate potentials due to the antibodies being directed against the receptors affecting the ability of the impulse to cause the muscle contraction. Administering an inhibitor of acetylcholinesterase can temporarily restore contractibility.

Effects of Exercise on Respiratory and Muscular System

**Respiratory System**
- During exercise the muscle cells use up more oxygen and produce increased amounts of carbon dioxide.
- The lungs and heart have to work harder to supply the extra oxygen and remove the carbon dioxide.
- Your breathing rate increases and you breathe more deeply. Heart rate also increases in order to transport the oxygenated blood to the muscles.
- Muscle cell respiration increases, more oxygen is used up and levels of carbon dioxide rise.
- The brain detects increasing levels of carbon dioxide - a signal is sent to the lungs to increase breathing.
- Breathing rate and the volume of air in each breath increase - This means that more gaseous exchange takes place.
- The brain also tells the heart to beat faster so that more blood is pumped to the lungs for gaseous exchange.
- More oxygenated blood is gets to the muscles and more carbon dioxide is removed.

**Muscular System**
- Exercise helps muscles become more effective and efficient.
- Tendons will become thicker and able to withstand greater force.
- High intensity exercise for short duration produces strength, size and power gains in muscles.
- Low intensity exercise for long durations will give endurance benefits.
- Trained muscles have better tone or state of readiness to respond.
- Exercise promotes good posture enabling muscles to work effectively and helps prevent injury.