HOW THE BODY WORKS
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Good coaches are always looking for that competitive “edge” which will be the positive difference in a close contest. It may very well be physical conditioning which provides it, especially when individual and team skills are relatively equal.

The coach who understands how the body responds to intense physical activity will undoubtedly be capable of preparing athletes to perform in any situation.

Chapter Review

- recognize the human body as a cooperative of intricate systems;
  - Muscular system,
  - Cardiovascular system,
  - Energy system,
- understand the three energy systems and the energy demands of hockey,
- identify the role of the support systems in response to activity,
- recognize age considerations in planning for off-ice training.

Physical conditioning is a necessary component in developing optimal performance in athletes. It is important to plan off-ice training programs to bring about changes in the players’ endurance, strength, power and flexibility. As well, it is important to realize that training programs need to be modified to meet the age, sex, and physiological development of your players.

The information in this chapter will form the base of knowledge that you will need to design effective and appropriate training programs.
The Muscular System

There are over 600 muscles attached around the human skeleton. The major muscle groups and their functions are illustrated in Figures 1 and 2.

Figure 1: The Skeletal Muscles
Figure 2: The Skeletal Muscles

- Extensors: straightens wrist and fingers
- Triceps: straightens elbow
- Deltoid: raises arm
- Trapezius: raises shoulder and pulls head back
- Latissimus Dorsi: draws arm backwards and turns it forwards (also draws on stretched arm downwards)
- Gluteals: move the hip-joint; also move leg outwards
- Hamstrings: bend knee and straighten hip joint
- Gastrocnemium: bends knee and turns foot downwards
- Achilles Tendon: turns foot and toes downwards

*Adapted from: *Medical Illustrations by Anne Widger and Joanne; Copyright 1993. Used with permission of Jones and Bartlett Publishers.
Each muscle is made up of many muscle cells which are triggered by nerves to contract and produce force. The muscles are attached to bone by tendons and when the muscles contract, they exert force on the bones via these tendons.

Most muscles are arranged in pairs with one producing movement in one direction and its partner (antagonist) producing movement in the opposite direction. For example, in the skating stride, the quadriceps extend the knee while the hamstrings flex it during the recovery phase. In this case, the hamstring is the antagonist.

Maximum forces can be achieved if one muscle group contracts and causes stretching of its partner before the partner contracts. Using the same example of the skating stride, the flexors of the knee (hamstrings) stretch the extensors (quadriceps) during the recovery phase before the quadriceps contract in the powerful extension phase of the stride.

If both muscles in a pair contract with the same force but in opposite directions, no movement results. This will occur when one wishes to hold a particular position. However, when movement is required, the nervous system inhibits one muscle group while activating its partner. When working at strength or power training, players must be very careful not to get one muscle of the pair excessively strong in relation to the partner. It can decrease flexibility and make the weaker muscle susceptible to injury.

When muscles contract to produce force, they consume energy in the form of chemical fuels. Fuels must be supplied at the rate at which they are used in order to continue working. The discussion of how this energy balance is attained is presented in the section 12.4 (The Energy System) of this module.

**The Cardiovascular System**

The human body uses the blood to transport nutrients and oxygen to each cell, to transport hormones, to remove wastes, and to act as a radiator in the convection of heat from the core to the surface.

Blood is pumped via a four-chambered heart into blood vessels which direct the blood both to and from working tissues. The amount of blood pumped per minute and the portion going to each area is proportional to the amount of work being done. Thus, active muscle gets more blood flow than inactive and the greater the activity the greater the flow. At rest, the heart pumps five litres per minute and this is increased to over 30 litres per minute during maximal exercise. The flow going to muscles can increase from about 20 percent at rest to over 80 percent during maximal exercise.

Since the supply of fuels and oxygen is important and the removal of wastes is critical for recovery from intense on-ice shifts, a well developed cardiovascular system is a fundamental prerequisite for top performance in hockey.
Figure 3: The Cardiovascular System

- **LUNGS (Right — 3 lobes, Left — 2 lobes)**
  - millions of alveoli
  - $O_2$ breathed into alveoli diffuses into the blood
  - $CO_2$ produced in tissues diffuses out of blood to be breathed out.

- **BLOOD (5 to 6 liters)**
  - transports $O_2$ in combination with hemoglobin (Hb); blood carries approximately 200 ml of $O_2$ in every liter of blood when Hb is 15 g/l/100 ml of blood
  - transports food and waste products and regulating chemicals such as hormones

- **HEART (a double pump)**
  - total blood volume pumped per minute called the Cardiac Output (a product of the heart rate or beats/min times the stroke volume per beat)

- **CIRCULATORY CONTROL**
  - of blood flow to each tissue by nerves and hormones, altering size of arterioles — dilation or constriction

- **VENA CAVA**

- **PULMONARY (LUNG) CIRCULATION**

- **SYSTEMIC CIRCULATION**
  - to Organ systems such as Brain, Liver, Digestive Tract, Kidney, Skin

- **MUSCLE TISSUE**
  - muscle cell chemical machinery utilizes $O_2$
  - in combination with food (fuel) stored in the muscle or delivered to blood
  - $CO_2$ produced in the aerobic breakdown of fuel
  - slow twitch fibers with rich capillary network to supply $O_2$ and fast twitch fibers of fewer capillaries and low $O_2$
The Energy System

The body during activity can be thought of much like a car during motion. The car’s engine consumes fuel in order to generate the power necessary to move the vehicle. The muscles in the body must also consume digested fuels (carbohydrates, fats) in order to generate the forces to perform work.

The refined automobile fuel must be supplied to the engine in order for it to be used. Small amounts of this refined fuel are stored in the storage tank. When this fuel runs out, we cannot lift the hood of the car and request “just one more kilometre and I’ll give you an extra litre."

The operation of muscle is very much the same as that of the car engine. The form of fuel which the muscle can use is very refined. It is called Adenosine TriPhosphate-ATP. It is stored in limited amounts in the muscle cells and for the muscles to be able to continue to work at a certain rate, the rate of supply of ATP must be equal to its rate of consumption. The importance of the balance between energy (ATP) production and energy consumption is illustrated in Figure 4.

Figure 4: Balance Between Energy Production (ATP) and Energy Consumption
The Three Energy Systems

Muscle can consume energy from very high rates (e.g., during high speed or high force types of effort) to very low rates (e.g., walking, jogging, or other low intensity efforts). In order to meet these different demands, refining systems must supply the fuel (ATP) at the rate it is being used, otherwise the limited stores will be depleted and the rate of work can no longer be maintained.

Fortunately, muscle has three different energy supply systems designed to meet the different demands. These different energy supply systems are illustrated on the right of Figure 5:

- this supply system represents an immediately available but limited store of ATP and high energy phosphates in the muscles;
- a high rate refinery for rapid production of ATP;
- a low rate but high capacity refinery for slow supply of ATP.

These energy supply systems are often categorized according to whether or not they use oxygen in the process and whether or not lactic acid is produced as a by-product. If oxygen is used, it is termed aerobic, if not, anaerobic. If lactic acid is produced, it is termed lactic, if not, alactic. The three energy systems are:

- Anaerobic Alactic
- Anaerobic Lactic
- Aerobic

“Rocket Figure”

The energy supply systems can be seen as a 3-stage Rocket.
The energy systems have different capacity and effect.

The Energy Supply Systems

Stage 3
Combustion Motor
> 4 Minutes

Stage 2
Auxiliary Motor
> 20-120 Seconds

Stage 1
Starting Motor
> 5-8 Seconds

Figure 5: A comparison of the three stages of muscle “Motors”
**Anaerobic Alactic - Stage 1**

Immediate stores are available instantly but only last for 10-20 seconds at high rates of use. This includes the store of ATP and another high energy phosphate called creatine phosphate (CP) which restores ATP immediately. As oxygen is not used and lactic acid is not produced by these stores, it is called the anaerobic alactic system and supplies ATP at the highest rate. This system would provide extra energy for the high speed bursts during a shift.

**Anaerobic Lactic - Stage 2**

This is a high rate refinery system which supplies energy (ATP) at a very high rate but produces a pollutant (lactic acid) during the refining process. This refinery uses only carbohydrate as a raw fuel but does not require oxygen to produce ATP. However, due to the production of lactic acid this refinery can provide energy at a high rate for only 2-3 minutes. Since oxygen is not used but lactic acid is produced by this system, it is called the anaerobic lactic system. This system provides energy during skating over the whole shift.

**Aerobic - Stage 3**

This is a low rate refinery system which supplies ATP at a low rate but burns clean. This refinery uses both carbohydrates and fats as raw fuels and uses oxygen in the refining process. Since this process produces no toxic wastes it can continue for up to 23 hours before running out of raw fuels or ceasing due to over-heating or dehydration. Since oxygen is used and no lactic acid is produced by this system, it is called the aerobic system. This system replenishes the stored ATP during rest intervals and burns lactic acid as a fuel during the recovery phase.

The approximate percent contribution from each of the three energy systems for specific types of activity in hockey is presented in Table 1.

All the stages must work together to achieve the maximum performance level.

<table>
<thead>
<tr>
<th>Type of Activity</th>
<th>Energy System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anaerobic Alactic</td>
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<tr>
<td>5 second bursts</td>
<td>85</td>
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<tr>
<td>10 seconds of hard skating</td>
<td>60</td>
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<tr>
<td>30 seconds of continuous activity</td>
<td>15</td>
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<tr>
<td>1 minute shift of intermittent sprints, coasting, and stops</td>
<td>10</td>
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<tr>
<td>Recovery between shifts/periods</td>
<td>5</td>
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Table 1: Approximate Percent Contribution from each Energy System for specific activities.
Support Systems

The understanding of the energy balance in muscle is fundamental to understanding how the body works during hockey. However, there are also many support systems which permit the energy supply systems and the contractile machinery to operate effectively and to recover between high intensity efforts.

The cardiovascular (heart and blood vessels) and the respiratory (lungs) systems are instrumental in:

- Supplying fuels (e.g., sugar) to the muscle during recovery periods to replace the fuels used during exercise and the hormones (e.g., insulin) to help the muscle store these fuels.
- Supplying building blocks proteins and amino acids to the muscle to help build better refineries and more contractile elements. It also supplies hormones (e.g., testosterone and growth hormone) to augment the building process.
- Supplying oxygen to the muscle during work and recovery so that the aerobic refinery can replenish ATP and CP stores and reconvert lactic acid into carbohydrates.
- Flushing out lactic acid to permit more rapid recovery and therefore more training or better on-ice performance.

Age Considerations for Off-Ice Training

- For pre-pubertal athletes (6-12 years old), little gain in strength can be achieved other than that due to growth. Therefore, the major focus in off-ice training should be on the development of an aerobic base, flexibility, and coordination. These can be developed with the use of games such as soccer with an emphasis on continuous activity over a whole game and the use of relays using long distances (e.g., 800 m with equal time for rest, performing four to five repetitions).
- Bicycling is a very good aerobic activity and it uses similar muscle groups as those used in the skating stride. The duration should be 30-35 minutes if it is a continuous activity.
- Heavy resistance training for strength should be avoided for the young (6-14 years old) and older hockey players (35 plus years) for safety reasons. In the young, resistance work can be damaging to growing bones; whereas in the older group, it can cause rapid increases in blood pressure. Therefore, the focus should be on increased repetitions with low weights.
- It is important to provide adequate cooling and hydration for all age groups when training but especially the young and older players. High body temperatures or dehydration can impair performance and will put additional stress on the heart and circulation.
• A sound stretching program will be advantageous to all ages and should be emphasized with increasing age. Although flexibility does decrease with age, stretching can off-set the decrease.

• On-ice training cannot provide an adequate stimulus to achieve the optimal amount of fitness in all components. Therefore, athletes of all ages must be motivated to train off-ice to avoid injury and to enhance performance.

• Early teens can focus on using body weight as the overload stimulus and perform sit-ups, push-ups, jumping activities, and cycling.

• Mid to late teens can begin to load with heavy resistances off-ice to build strength. They should also perform high speed activity in hockey specific actions to ensure that power gains are related to hockey performance. It is advisable with this age group that specific programs be designed which focus on individual weaknesses.
Table 2 outlines the optimal age of physical development for athletes.

**Optimal Age of Physical Development**

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<tr>
<th>Age</th>
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<th>10</th>
<th>13</th>
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<tr>
<td><strong>Training</strong></td>
<td>Fun games</td>
<td>Basic 1</td>
<td>Basic 2</td>
<td>Development</td>
<td>Performance</td>
<td>High prfm.</td>
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<td>Early Adol.</td>
<td>M.Ad.</td>
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<td>– movement precision</td>
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<td><strong>Agility</strong></td>
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</table>

**Legen**
- Minimal Training Effect
- Average Training Effect
- Optimal Training Effect
For the Coach


To have effective performance in hockey, it is important for the players to have:

- Muscles which can generate high forces and recover quickly for sprint activity.
- Well-developed anaerobic alactic energy supply systems in the muscles to provide energy for the high burst activity such as break-outs and accelerations.
- Well-developed anaerobic lactic energy supply systems in the muscles to provide energy at a high rate for a full shift.
- Well-developed aerobic energy supply systems in the muscle to replenish ATP stores between shifts and between periods and to assist in reconverting lactic acid to valuable carbohydrates. This will enhance recovery from high speed shifts.
- Well developed support systems such as the cardiovascular, respiratory, and endocrine (hormonal) systems to facilitate recovery and, therefore, to enhance both performance and training.

It is therefore important to focus on the development of the energy and support systems when planning the physical preparation of the hockey players. If a system is going to be improved, it must be overloaded beyond what it is normally required to do. As well, the training effect is specific to the muscles and joint actions involved in the training. Therefore, it becomes clear that the muscles must be overloaded in hockey specific actions to generate high bursts of power and to repeat these high power bursts in the presence of lactic acid. As a foundation, the aerobic energy supply systems and the cardiovascular, respiratory, and endocrine support systems must be well-developed to provide for proper recovery.

SELF TEST
(Answers are on the next page)

True or False

1. T F There are over 600 muscles in the body arranged mostly in antagonistic pairs
2. T F Strength and power training should focus on both muscles in a pair
3. T F Energy consumption can exceed production for extended periods and exercise can continue at high rates
4. T F The cardiovascular system is important for hockey players because it transports fuels and removes Heat and wastes in recovery
5 T F Heavy resistance training should be avoided for the young (6-14 years old) and the older 35 plus hockey players
6 T F Overheating and dehydration are not problems in hockey
Match the characteristics in Column II with the appropriate energy supply system in Column I. (Answers are at the bottom of the page)

<table>
<thead>
<tr>
<th>Column I</th>
<th>Column II</th>
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<tbody>
<tr>
<td>1. Anaerobic Alactic</td>
<td>A. Uses oxygen in producing ATP</td>
</tr>
<tr>
<td>2. Anaerobic Lactic</td>
<td>B. Supplies energy immediately</td>
</tr>
<tr>
<td>3. Aerobic</td>
<td>C. Results in the production of lactic acid</td>
</tr>
<tr>
<td></td>
<td>D. Uses only carbohydrates as a fuel</td>
</tr>
<tr>
<td></td>
<td>E. Uses both fats and carbohydrates as fuel</td>
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<td></td>
<td>F. Supplies energy at maximum rate for only 10-20 seconds</td>
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Answers

<table>
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<tr>
<th>Self Test</th>
<th>Energy Systems</th>
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