



# How to read a Blood Test

The basic purpose of measuring blood biochemistry is to assess the current status of the body--- how well different substrates are being produced and utilized, whether by-products are being efficiently eliminated, whether the different organ systems are doing their job at the right time and at the correct rate. Blood panels will also often give indicators that something isn't quite right long before outward signs appear. Does the horse have an infection brewing somewhere? Dehydrated? Are the muscles or kidneys having trouble keeping up with the workload? Is the liver damaged?

**MUSCLE ENZYMES - CPK, LDH, SGOT/AST** Levels of specific enzymes help indicate the presence of muscle injury or disease, its severity and progression. Measured blood levels, along with the observation of other clinical signs, such as lameness, pain or dark urine, help tell the veterinarian whether, when and to what extent muscle damage has occurred. It is extremely important to consider whether any increased enzyme levels were measured before, during or after exercise; as well as whether any other stressful events (a ride last weekend, an unplanned midnight gallop through camp, even recent vaccinations) may have contributed to chemistry results. High---even very high---enzyme levels after a long ride are not necessarily the voice of doom in predicting muscle damage. In some cases, however, obtaining a consultation with your veterinarian and possibly a follow-up blood panel to measure subsequent increases or decreases is often a good idea.

**CPK** - refers to creatine kinase (also called CK), a muscle enzyme produced during exercise. While horses suffering from exertional rhabdomyolysis (tying up) will demonstrate increased levels, other studies have shown that prolonged endurance exercise can result in very high levels (> 30,000 IU/liter) without signs of clinical muscle damage(1). Distance and intensity of exercise are significant factors, so that one horse who completes slow 100 miles may have higher CK levels than an equally fit horse who finishes a brisk 50, with neither suffering clinical damage. An elevated level during or following an endurance ride (or other stressful event) indicates the horse has had a long, hard day, but should not necessarily be interpreted as "muscle damage" without considering other clinical signs. Elevated levels in a resting horse that has not exercised intensively for several days, however, may indicate disease such as infection, electrolyte imbalances or chronic rhabdomyolysis(2).

**AST/SGOT** - refers to aspartate aminotransferase (the SGOT refers to an earlier term for the same enzyme), an enzyme released by both skeletal and cardiac muscle, as well as the liver as the result of protein metabolism. As with CK, AST levels may rise significantly as a result of prolonged exercise without necessarily indicating damage(1,3). AST levels rise more slowly, and remain for a longer period, than do CK levels. Elevated ASTs in a horse with normal CK would suggest that the horse has undergone intense muscular stress sometime during the prior week. High AST and CK levels in a horse that has not recently exercised at an intense or prolonged



level may indicate an ongoing disease process occurring in the muscles. High AST levels in a horse that has not exercised recently, without a concurrent increase in CK levels, may be indicative of liver disease(2,4).

**LDH** - refers to lactate dehydrogenase, yet another enzyme released by both cardiac and skeletal muscle cells during stress. Although LDH levels are used to diagnose cardiac disease, elevated levels without other characteristic signs of heart trouble are almost certainly due to its release from skeletal muscle(2). As with the other muscle enzymes, increased levels may only indicate that the horse has undergone an intense and prolonged bout of exercise, without necessarily indicating damage. Interpretation of enzyme results should include consideration of other clinical signs such as muscle pain or myoglobin in the urine, as well as the horse's immediate and past clinical history. Likewise, clinical signs similar to tying-up without concurrent increases in enzyme levels may be indicative of other diseases such as laminitis or colic.

**LIVER FUNCTION - GGTP, BILIRUBIN, ALKALINE PHOSPHATASE** **GGTP** - refers to gamma glutamyltransferase, an enzyme involved with liver function. GGTP levels, along with bilirubin are used to indicate the presence of liver damage or disease. As seen in the muscle enzyme discussion, some enzyme levels may increase for variety of reasons, but GGTP is indicative of liver function only---not cardiac or skeletal muscle activity. Therefore, increases above the normal range of 3-30 IU/liter during or after an endurance ride, possibly concurrent with increases in bilirubin and alkaline phosphatase, are not due simply to prolonged exercise, but may indicate liver disease such as an obstruction of the bile duct(5). If your lab report indicates significantly increased levels, a follow-up examination by your regular veterinarian is *strongly* recommended.

**Bilirubin** - a breakdown product of hemoglobin, the molecule which transports oxygen in blood. High levels may be an indication of liver dysfunction, or may related to hemolysis, the process by which red blood cells are destroyed. As many different processes may cause hemolysis, including toxicity, drugs, immune deficiency and infectious disease(6), increased bilirubin levels must be considered along with other factors such as GGTP and alkaline phosphatase.

**Alkaline phosphatase** - an enzyme used to help identify liver dysfunction. Although AP levels alone do not define hepatic problems, when supported by other clinical signs, may help confirm a diagnosis, especially when bile duct obstruction is suspected(6). AP is also essential in bone remodeling, the process by which bone tissue is continually responding to the stresses of exercise. Increased serum levels are a general indication of osteoblast activity, the cells involved in building new bone tissue(7). When high levels of GGTP and/or bilirubin accompany serum increases of AP, a follow-up examination for liver dysfunction is very highly recommended.

**ELECTROLYTES - SODIUM, POTASSIUM, CHLORIDE, CALCIUM** Electrolytes are a critical element in cellular metabolism, muscle contraction, nerve transmission and enzyme reactions. Imbalances or deficits lead to impaired athletic performance at best, and life-threatening



metabolic disruption or death at its worst. While electrolytes are closely regulated by the body, many are lost in the sweat or otherwise depleted during exercise and hence are an important parameter in monitoring a horse's status.

**Sodium, chloride, potassium** - the electrolyte ions lost to the greatest extent in sweat production, although diarrhea, kidney dysfunction and other pathologies can also be a cause of electrolyte imbalance. Sodium is a primary ion in the body involved in virtually every metabolic process from glucose transport to neural transmission. The body does not store reserves of these electrolytes in tissue (as is the case with some minerals such as calcium), therefore losses during exercise which are not replaced through supplementation or other dietary intake will result in a progressive depletion. Measurements of high serum levels of sodium or chloride almost always only reflect recent intake before the kidneys have filtered out and disposed of excess ions in the urine. Low levels indicate depletion and are often a predisposing factor, along with dehydration, in muscle cramps, colic, synchronous diaphragmatic flutter ("thumps"), diarrhea and other symptoms of exhausted horse syndrome(8). High serum levels of potassium generally not a concern and often reflect nothing more serious than a delay between blood collection (when potassium is actively sequestered inside cells) and sample measurement (after potassium has had time to "leak" from inside the cells out into the plasma or serum).

**Calcium** - one of the most highly regulated ions in the body, and essential for muscle contraction. Normally, adequate serum levels of ionized calcium (the physiologically active form) will be maintained by mobilizing reserve stores in bone. However, supply may not be able to keep up with sweat or urine losses, especially during prolonged exercise under hot conditions, resulting in a progressive depletion of available serum calcium. It should be noted that low serum calcium is not an indication that the horse is lacking in calcium in bone stores, simply that the body may be unable to mobilize calcium from bone into the bloodstream quickly enough(7). As depletion of calcium, as well as for other electrolytes, progresses, the muscle cells lose their ability to contract and relax, resulting in thumps, muscle cramps and poor gut motility(8,9). Therefore, as with other electrolytes, progressively decreasing levels of calcium throughout a ride may provide hints to explain muscle fatigue or poor recoveries, as well as avenues of management by which performance may be improved. High serum levels of calcium are unusual, but if measured in conjunction with abnormal levels of other electrolytes and phosphorus, could possibly be indicative of kidney disease.

#### **KIDNEY FUNCTION AND HYDRATION STATUS - BUN, CREATININE, PHOSPHORUS, TOTAL PROTEIN, ALBUMIN AND HEMATOCRIT**

**BUN, creatinine** - BUN refers to blood urea nitrogen, a nitrogenous waste by-product of protein metabolism, which is filtered out and excreted almost exclusively by the kidneys. Creatinine is a normal by-product of muscle metabolism that is also cleared exclusively by the kidneys. Both of these substances are normally present in measurable quantities in the blood, and increased levels, usually in relationship to each other, are used to assess kidney function. However, it is important not to see increased levels and automatically assume kidney damage. Increased urea alone may simply be in response to a recent meal high in protein, such as a rich alfalfa hay, and the body's attempts to excrete excess nitrogen(9). Increased creatinine levels may indicate the onset of exertional rhabdomyolysis



(tying-up), but may also occur during dehydration. The two substances are often related to each other by dividing BUN levels by the creatinine level. A ratio of approximately 10:1 is normal, while ratios of 20-30:1 are often seen in horses after a high-protein meal. A normal ratio, increased levels of both BUN and creatinine, and increased levels of albumin and total protein would generally indicate dehydration. Increased BUN/creatinine, with normal protein levels might indicate impaired kidney function(11).

**Phosphorus** - Unlike sodium, chloride, potassium and calcium, phosphorus is not lost through sweating and thus does not require supplementation during a ride. Like calcium, serum phosphorus levels are a poor indicator of the total phosphorus content of the body(7). High serum phosphorus is often used to help diagnose renal (kidney) failure in mature horses. In young horses, high serum phosphorus is nothing more than an indication of rapid bone growth.

**Total protein, albumin** - Measuring the amount of protein in the serum provides an index of hydration status, as well as indices of infection, inflammation, increased protein loss or decreased protein production. Increased protein levels in athletic horses are usually due to dehydration, although can also be due to increased levels of globulins (antibodies to fight infection). Low protein levels are unusual, but if detected, should be further investigated to rule out possible sites of protein loss, such as via the kidneys or gastrointestinal tract due to inflammation or parasites(11).

**Hematocrit** - a measurement of the relative amount of red blood cells present in a blood sample. After blood is drawn, a small tube is filled and centrifuged to separate the heavier blood cells from the lighter white blood cells and the even lighter fluid (plasma or serum) portion. A higher than normal reading generally indicates dehydration (same number of cells in less plasma volume). A low reading *may* indicate anemia, though not invariably(4).

**ACID-BASE STATUS - pH, TCO<sub>2</sub>, HCO<sub>3</sub>** Kidneys, adrenal glands, lungs and special regions in the brain all work together in an amazingly complex system to maintain the internal chemistry within acceptable limits. There are many causes of acid-base disturbance, but in the exercising endurance horse, acid-base changes generally indicate that an exercising horse is working somewhat beyond his immediate capacity. Depending on the type and extent of changes, it may mean that the horse needs to slow down, cool off, or may be indicative of major metabolic changes. Significant changes in a resting horse that has not undergone recent exercise may indicate a disease process.

**pH** - Most people are somewhat familiar with the concept that pH is an indication of a solution's acidity. The lower the pH, the more acidic a solution is; the higher the pH, the less acidic (and therefore more alkaline or "basic"). The normal pH range of blood is between 7.32 - 7.4412. Most systems in the body only operate efficiently within this narrow pH range. If blood pH is either too low or too high, the horse's condition is referred to as "acidosis" or "alkalosis", respectively. Under endurance conditions, low pH (acidosis) is a good indication that the horse has recently been exercising beyond his aerobic capacity, and lactic acids of muscle metabolism are accumulating faster than the body can dispose of them. The lower the pH, the further the



horse has been pushed beyond his limits. As with all other blood parameters, it's important to look at the total picture---if the horse has recently raced into the finish line, pH levels may be temporarily somewhat decreased due to the release of lactic acid from hard-working muscles. Or it may indicate nothing more than muscles that have not yet warmed up and fully shifted into aerobic metabolism. However, a low blood pH observed along with other acid-base indicators, elevated muscle enzymes, muscle stiffness and other clinical signs help the veterinarian identify ongoing disease processes, such as tying-up or exhausted horse syndrome.

Blood pH level higher than normal often indicates that an endurance horse is overheated and is panting to help with excess heat dissipation. During rapid breathing or "hyperventilating", the body will lose significant amounts of carbon dioxide, which in turn raises blood pH (more alkalotic or basic). The normal TCO<sub>2</sub> (total carbon dioxide) concentration is 28 mEq/liter, and also contributes to the 'big picture' of acid-base status.

TCO<sub>2</sub> levels of 20-27 mEq/liter indicate a mild acidosis as described above; TCO<sub>2</sub> of less than 20 mEq/liter indicate severe, possibly life-threatening, acidosis(12).

HCO<sub>3</sub> refers to bicarbonate, a buffer released by the kidneys to help prevent changes in the acid-base balance. A normal value is between 24-30 mEq/liter. Although the pathways within the body for regulating bicarbonate within the body are far too complex for these few pages, low levels during endurance exercise would contribute to a diagnosis of metabolic acidosis. Levels slightly above normal indicate mild alkalosis, and might be expected in horses exercising under hot conditions(12).

**OXYGEN TRANSPORT SYSTEMS - pO<sub>2</sub>, pCO<sub>2</sub>, sO<sub>2</sub>, Hb** During strenuous exercise, the amount of oxygen inspired is not nearly as important as the amount that actually reaches the tissues. Various forces and barriers have an effect on this delivery system, including infections or obstructions that compromise respiratory function; dehydration, which thickens the blood and forces the heart to work harder to circulate it; or anemia, which results in fewer red blood cells to actually transport oxygen and carbon dioxide.

**pO<sub>2</sub> and pCO<sub>2</sub>** represent the amount of dissolved oxygen and carbon dioxide circulating in the bloodstream. "Normal" levels of each vary depending on the fitness of the individual horse, but levels of approximately 39 mmHg and 47 mmHg for oxygen and carbon dioxide, respectively, would be considered normal for average, healthy horses. Oxygen levels higher than this might be one indication of a horse who is aerobically very fit. Low levels of pO<sub>2</sub> might indicate some barrier preventing adequate movement of oxygen from the lungs into the bloodstream---for example, respiratory infection, partial paralysis of the larynx (often seen in thoroughbred racehorses) or even horses bred for 'teacup' muzzles and accompanying small nostrils. Decreased oxygen levels would be perfectly normal at high altitudes, where lower atmospheric pressure is available to help drive oxygen across respiratory membranes. As intensity of exercise increases, circulating oxygen tends to decrease, while CO<sub>2</sub> tends to increase. pO<sub>2</sub> levels between 30 - 16 mmHg, and pCO<sub>2</sub> levels of 50 -96 mmHg, respectively, as speed increased from a slow trot to a fast gallop would not be abnormal<sup>13</sup>. Observing relative levels



before, during and after a ride gives a good indication of how aerobically stressed the horse was at this intensity of exercise.

**Hb** refers to hemoglobin, a component of red blood cells which actively binds and transports oxygen from the lungs to the peripheral tissues. Normal levels in a healthy horse are between 10 - 18 g/dl. Low hemoglobin levels, along with a low hematocrit, might indicate anemia, a decrease in the number of circulating red blood cells.

**sO<sub>2</sub>** levels represent a measurement of how many of the available hemoglobin molecules are currently involved in transporting oxygen. For example, an sO<sub>2</sub> level of 78 would indicate that 78% of the available hemoglobin is being utilized to transport oxygen and that the horse is still exercising at less than his maximum aerobic capacity. Horses with low hemoglobin levels could usually be expected to have higher sO<sub>2</sub> levels during exercise (and therefore a reduced aerobic capacity), simply because a larger proportion of available hemoglobin are being utilized to transport oxygen.

**IMMUNE FUNCTION - WBC, POLYS, BANDS, LYMPHS, MONOS, EOS** Collectively known as white blood cells or leukocytes, measurement of these parameters evaluate the presence of infection, inflammation and ongoing systemic disease processes in the body.

**WBC** - a total count of all types of white cells (eosinophils, basophils, neutrophils, etc), this count is made so that relative proportions of its subunit cells can be calculated. It also provides a general indication of normal balance between cell production in bone marrow and tissue uptake.

**Poly %** - refers to the proportion of polychromatophilic (immature) red blood cells present. Normal range for horses is between 30-65%. A high proportion of polys indicate that there is an increased demand for red blood cells that the bone marrow is unable to keep up with--- therefore, the release of cells into circulation prior to maturation in the bone marrow. Causes for abnormal increases in red blood cells demand might include blood loss or disease processes causing dysfunctional production or destruction of cells.

**Bands %** - refers to the relative proportion of banded neutrophils. Neutrophils in general are the predominant circulating white blood cell whose function is to seek out, ingest and kill invading microorganisms, such as bacteria. Mature neutrophils are referred to as "segmented", immature neutrophils are referred to as "banded". A range of 0 - 1% of banded neutrophils being present in the total white blood cell is considered normal. Increased levels indicate acute inflammation that have stimulated the bone marrow to release large numbers of neutrophils, including those not yet mature.

**Lymphs** - refers to the relative proportion of lymphocytes, also known as antibodies. Unlike neutrophils, which attack a broad spectrum of invading microbes, lymphocyte differentiate into specialized cells that attack and destroy very specific infecting antigens. Normal range for the horse is between 25 - 70%. Low levels are often an indication of a "stress leukogram", in which





chronic stress results in suppression of the immune system. This condition can also be the result of steroid use.

**Monos** - refers to monocytes, an immature stage of macrophage cells. Like neutrophils, macrophages attack and engulf foreign bacteria, but are also the "clean-up cells" which remove dead tissue wherever damage has occurred, such as a healing wound site. The normal range for horses is between 1 - 5% of the total WBC. Large numbers of circulating monocytes are generally an indication of an increased demand for macrophages, as might be the case following injury.

**Eos** - refers to eosinophils, yet another type of leukocyte with functions similar to those of neutrophils. Eosinophils have a role in the inflammatory response, such as swelling, redness and pain following injury. In addition, they have the major function of control of parasitic control, in that they attack and damage parasites circulating in the bloodstream (such as roundworms during their migratory phase). Normal ranges are between 0 - 11% of the total WBC. Increased levels may be an indication of infection by some species of parasites, or of inflammation in the body, such as gastroenteritis.

**GLUCOSE** - Blood glucose levels, and the manipulation thereof, is probably one of the most controversial subjects in endurance horse management. While horses exercising at typical endurance speeds rely primarily on the oxidation of fatty acids for energy production, a certain amount of glucose is always required for certain metabolic pathways and by certain vital organs. The brain, for example, is unable to utilize any substrate *other* than glucose. At the same time, the animal body is able to store relatively small amounts in muscle and liver tissue, and its depletion during exercise is a major factor in fatigue. Normal levels for a horse with a "full gas tank" range between 69 - 122 mg/dl. As adrenalin also raises blood glucose levels, levels measured in excited horses might normally be at the high end of the normal range.

In other species, very high glucose levels would often indicate diabetes. However, diabetes is extremely rare in horses, and very high levels of blood glucose would generally indicate recent extreme dietary manipulations. Low levels below the normal range may indicate several conditions---if measured fairly soon after the above mentioned glucose "spike", the result may be an "insulin rebound", wherein large amount of insulin are released to sequester the excess glucose, resulting in dramatically lowered glucose levels. If low glucose levels are measured during or after sustained, strenuous exercise, it is more likely due to glycogen depletion, in which the body is rapidly reaching the end of its available glucose store