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BIOCHEMICAL PROFILES IN DOMESTIC ANIMALS

INTERPRETATION & DIAGNOSIS

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BIOCHEMICAL PROFILES IN DOMESTIC ANIMALS

INTERPRETATION
&
DIAGNOSIS

Knowledge is that which benefits
not that which is memorised
Imam Al-Shafi'i

Preface

This comprehensive guide is designed to assist veterinary students in mastering biochemical workup procedures, their indications, and interpretations. It also serves as a valuable resource for veterinary colleagues and practitioners in confirming clinical diagnoses across various domestic animal species.

The manual outlines sample preparation techniques for biochemical analysis and elucidates fundamental biochemical and supporting tests, highlighting their diagnostic utility in veterinary medicine.

The primary objective of this document is to equip readers with crucial information for accurate diagnosis based on biochemical test results. However, it emphasises the importance of recognising potential errors arising from suboptimal sampling and sample preservation.

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Abbreviations

ALP:	Alkaline phosphatase
ALT:	Alanine aminotransferase
AST:	Aspartate aminotransferase
BUN:	Blood urea nitrogen
CBC:	Complete blood count
CK:	Creatine kinase
cPLI:	Canine pancreatic lipase immunoreactivity
cTLI:	Canine serum trypsin-like immunoreactivity
EDTA:	Ethylene diamine tetra acetic acid
EPI:	Exocrine pancreatic insufficiency
fPLI:	Feline pancreatic lipase immunoreactivity
fTLI:	Feline serum trypsin-like immunoreactivity
GDH:	Glutamate dehydrogenase
GGT:	Gamma-glutamyl transferase
GLDH:	Plasma glutamate dehydrogenase
HCO_3:	Bicarbonate
IV:	Intravenous
LDH:	Lactic dehydrogenase
PCV:	Packed cell volume
PLI:	Pancreatic lipase immunoreactivity
TAP:	Trypsinogen activation peptide
TLI:	Serum trypsin-like immunoreactivity

Introduction

A chemical profile, or clinical biochemistry, constitutes a critical element of a patient's minimal database. It typically includes urinalysis, chemical profile, and complete blood count (CBC), allowing veterinarians to assess overall organ function.

The general chemistry profile, often the primary diagnostic tool, evaluates liver, kidney, fluid balance, electrolytes, proteins, and acid-base status. Specialised profiles focus on specific organs and, like the liver or kidney, are primarily employed for monitoring treatment efficacy in diagnosis cases. These analyses can be performed on serum, plasma, or whole blood, depending on the analyzer type.

Domestic animals, particularly dogs and cats, routinely undergo various clinical biochemistry tests to evaluate their health status and identify underlying conditions. Result interpretation can be complex due to species-specific variations and environmental factors. Key challenges in veterinary clinical biochemistry include recognising abnormal signs and understanding the effect of toxicants across different species. Veterinary diagnostic laboratories play a pivotal role in results analysis and collaboration with practitioners to ensure accurate diagnoses and inform treatment decisions.

Veterinary toxicologists, with their expertise in veterinary medicine, toxicology, and analytical chemistry, are instrumental in developing and interpreting testing protocols for suspected cases.

Chapter I. Serum Biochemical Analysis: Specimen Collection and Processing Guidelines

I.1 Sample Collection and Handling

Patient preparation

Optimal blood collection from cats and dogs should occur during a fasted state, when possible. Ingestion of food before sampling may result in postprandial lipaemia (which typically resolves 7 to 12 hours after feeding) and can alter the concentration of certain blood analytes (e.g., urea, ammonia, glucose, etc.) *(***Kaneko et al., 2008 ; Meyer & Harvey, 2004***)*.

Mitigate or eliminate stress during and immediately before blood collection: the release of catecholamines and cortisol can markedly elevate blood glucose levels and modify various parameters, including glucose and lactates in cats **(Latimer, 2011).**

Specimen handling

- Clearly label tubes to avoid identification errors.

- Comply with manufacturer-specific volumes, although this is less critical in heparin-containing tubes.

- Immediately homogenise the specimen by gently inverting the tube 8 to 10 times (with slow movements and without excessive agitation) to ensure even distribution of anticoagulants throughout blood collection. This step is unnecessary for blood collected in dry tubes.

- Within one hour of collection, centrifuge tubes for 10 to 15 minutes, at approximately 2000 g, and transfer the separated serum or plasma to a dry tube.

Note: Minimise the time between sample collection and analysis. Analyte stability varies depending on storage conditions; most analytes remain stable for several hours

under refrigeration. However, exceptions such as ammonia or blood gases require immediate post-collection analysis.

Sample Analysis

- Before proceeding with the analysis, inspect the specimen for anomalies (clots, discolouration, etc.), document any observations, and obtain a new sample if necessary.

- For refrigerated or thawed specimens, ensure thorough homogenisation by inverting several times and allowing equilibration to room temperature before analysis.

Caution: When using Eppendorf-type conical tubes, vigorous agitation is necessary to incorporate the portion of the specimen located in the cone tip.

- For all analyses, strictly adhere to the operating procedures established by the receiving laboratory **(Thoresen et al., 1992).**

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I.2 Anticoagulant and Storage Considerations

The presence of anticoagulants in plasma samples can lead to erroneous increases or decreases in test analyte values. For instance, potassium-EDTA contamination artifactually elevates potassium levels while reducing calcium concentrations **(Ceron et al., 2004)**. Consequently, serum is generally the preferred specimen type for most analyses. However, heparinised plasma may be necessary or acceptable in certain situations **(Kaneko et al., 2008)**. For non-standard tests or species, it is recommended to seek guidance from the laboratory before sample collection

Serum and plasma compositions are very similar, with the primary distinction being the presence of anticoagulants and coagulation factors in plasma. Most studies generally recommend the use of heparinised serum or plasma for routine biochemical tests, while

fluorinated plasma is preferred for analysing unstable molecules like glucose or ketone bodies. In most biochemical assays, serum and heparinised plasma yield comparable results. When preparing serum samples, blood should be collected in a serum or separator tube and maintained at ambient temperature for 20-30 minutes to facilitate clot formation and retraction. Subsequently, the clot should be separated and centrifuged at moderate speed for 10 minutes. If using a serum tube, transfer the sample to a clean tube to minimise artefacts. Serum should be stored under refrigeration or frozen until analysis.

I.3 Sample Conservation

Many biochemical analytes remain stable or undergo minimal changes when stored for one or two days. For example, in bovine samples, creatine kinase (CK) levels increased by only 10% after 12 hours. However, light-sensitive analytes such as bilirubin or carotenes require dark storage conditions. Unstable analytes like catecholamines, adrenocorticotropic hormone (ACTH), and other peptides necessitate rapid refrigeration. Nonetheless, conflicting results have been reported in some cases, such as ammonia levels in dog samples, showing both increases or decreases during storage.

Many serum or plasma biochemical constituents exhibit poor stability when frozen at -20°C for extended periods. These include alkaline phosphatases, alanine aminotransferase (ALT), amylase, aspartate aminotransferase (AST), CK, gamma-glutamyl transferase (GGT), Plasma glutamate dehydrogenase (GLDH), lactic dehydrogenase (LDH), bile acids, calcium, cholesterol, creatinine, and fructosamine **(Thoresen et al., 1995)**. Some analytes, such as CK, remain stable only at very low temperatures (-70°C) **(Braun et al., 2015)**.

I.4 Interference Factors

Lipemia is a common blood collection artefact that can exacerbate haemolysis in samples and compromise test results. To mitigate lipemia, animals should be fasted for at least 12 hours before blood collection. Unfortunately, this crucial step is frequently overlooked in veterinary practice. Veterinarians should prioritise communicating the importance of fasting to clients and provide strategies to minimise patient distress during transport. Proper fasting can prevent falsely elevated levels of protein, haemoglobin, blood urea nitrogen (BUN), phosphorus, creatinine, glucose and sodium, as well as falsely decreased levels of phosphorus and potassium.

Hemolysis, another prevalent blood sample condition affecting test results, often stems from improper collection and handling techniques. Factors contributing to hemolysis include freezing whole blood samples, insufficient or delayed centrifugation after clotting, use of inappropriate needle-syringe combinations, inadequate blood collection and rough sample handling during mixing. Hemolysis interferes with coagulation panels, artificially increases haemoglobin values, decreases haematocrit values and disrupts numerous biochemical assays **(Braun et al., 2010; Boyd, 1984)**.

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1.5 Recommendations

Veterinarian diagnostic laboratories employ specialised protocols and tests for sample collection and submission, subject to periodic updates. Effective collaboration between practitioners and lab staff is crucial for optimising diagnostic efforts and service quality. While most labs provide user guidelines, standard recommendations typically include submitting a comprehensive case history.

A detailed case history should include the following elements:

- owner's full name
- species
- breed or size/weight (for unknown breeds)
- sex
- age
- animal identification
- pertinent clinical signs
- macroscopic appearance (including size and anatomic location) of lesions
- prior treatments and their outcomes (if applicable)
- results of relevant diagnostic procedures, such as CBC, serum biochemical analysis, cytologic and histologic assessments, and imaging studies
- morbidity and mortality rates for population health investigations

I.6 Sample Handling

The majority of biochemistry analyses can be conducted using either serum or heparinised plasma. However, certain tests (eg, insulin) specifically require serum, while potassium measurement is best performed on heparin plasma separated immediately after collection. Glucose determination necessitates the use of fluoride/oxalate plasma. Appropriate collection tubes, both with and without anticoagulants, are commercially accessible. Plastic tubes suffice anticoagulant blood samples, whereas clotted blood must be collected in either glass tubes or specially coated plastic tubes to prevent clot adhesion to the container walls.

Prompt separation of samples intended for biochemical analysis is crucial to minimise artefacts caused by hemolysis and leakage of intracellular fluid components (eg, potassium) out of the cells. Anticoagulant samples can be centrifuged immediately, but clotted samples require a minimum of 30 minutes for clot formation. Fluoride/oxalate samples are particularly susceptible to hemolysis due to cellular respiratory inhibition, emphasising the importance of timely separation. Proprietary gels or plastic beads, which may be pre-incorporated into collection tubes or added before centrifugation, facilitate the separation process.

Larger bucket-type centrifuges accommodate a wide range of tube types or sizes but require careful rotor balancing. These should be operated at 3,000 rpm for 10 minutes. For in-practice use, dual-purpose, high-speed microhematocrit centrifuges are preferred due to their rapid sample separation capabilities and ability to measure packed cell volume (PCV). However, these devices are limited to processing a specific range of small-volume tubes.

Some “gel-tube” products may provide permanent separation of serum or plasma; otherwise, manual transfer to a fresh, properly labelled tube is necessary. Subsequently, samples can be dispatched to a professional laboratory or analysed within the practice setting.

Chapter II. Biochemical Profiles

II.1 Factors Influencing Blood Constituent Variations

Beyond pathological conditions, numerous factors have been identified as having substantial effects on blood component concentrations.

Although rhythmic and seasonal variations exist, they generally account for only a minor portion of the total variance in blood components. Many metabolites demonstrate a clear age-dependant relationship. Variations are evident in neonates and very young animals, as well as in geriatric subjects. While age-related changes are typically of limited significance to dairy cattle, they warrant consideration by veterinarians treating companion animals.

In addition to the alterations observed in young and old animals, well-documented changes occur in adult animals **(Kaneko et al., 2008)**. A long-established negative correlation exists between inorganic phosphorus and age in dairy cattle **(Braun et al., 2010)**. Total serum protein levels exhibit a significant age-related increase, mainly attributable to an elevation in the gamma-globulin fraction **(Médaille & Briend-Marchal, 2008)**.

. Research has shown that protein-bound iodine decreases with age in dairy cattle. A notable example is the marked change in inorganic phosphorus in the serum of dogs and horses. Studies have demonstrated that stimulation during sampling can elevate total protein and inorganic phosphorus levels in cattle.

Prior to sample collection, clinicians should compile a list of differential diagnoses based on patient history and clinical examination. This approach facilitates the

inclusion of additional relevant tests to supplement the basic panel outlined below **(Latimer, 2011)**.

II.2 Basic Test Panel

Most veterinary laboratories offer a standard panel of tests, representing a minimal investigation suitable for most general **cases (Meyer & Harvey, 2004; Médaille & Briend-Marchal, 2008)**. For small animals, this typically includes total protein, albumin, globulin (derived from the difference between the first two analytes), urea, creatinine, ALT, and alkaline phosphatase (ALP). The presence of yellow plasma colouration should prompt bilirubin measurement. This panel may be adjusted for other species; for instance, glutamate dehydrogenase (GDH) and/or gamma-glutamyl transferase (GGT) are more appropriate "liver enzymes" for horse and farm animal assessment, while emphasis on muscle enzymes (CK and AST) may be more suitable for athletic animals **(Siliart & Nguyen, 2007)**.

Total protein levels rise due to dehydration, chronic inflammation, and paraproteinemia. Decreases may result from overhydration, severe congestive heart failure (with edema), protein-losing nephropathy, protein-losing enteropathy, hemorrhage, burns, dietary protein deficiency, malabsorption, and certain viral conditions (particularly in horses).

Albumin concentrations increase with dehydration and decrease due to the same factors affecting total protein, as well as liver failure.

Urea levels rise in response to excessive dietary protein, poor-quality of dietary protein, carbohydrate deficiency, catabolic states, dehydration, congestive heart failure, renal failure, urethral obstruction, and bladder rupture. Conversely, they decrease with low

dietary protein, severe sepsis, anabolic hormonal effects, liver failure, portosystemic shunts (congenital or acquired), and inborn errors of urea cycle metabolism. Urea measurement is primarily used to indicate renal disease and, to a lesser extent, liver dysfunction.

Creatinine levels increase due to renal dysfunction, urethral obstruction, and bladder rupture. Conversely, sample deterioration may lead to decreased levels. Animals with substantial muscle mass typically exhibit higher normal creatinine concentrations, while those with reduced muscle mass display lower normal creatinine values. Creatinine measurement serves as a primary diagnostic tool for kidney disorders.

ALT, present in hepatocyte cytoplasm and mitochondria, increases in response to liver cell damage. With a half-life of 2–4 hours, ALT levels rise more rapidly than AST but also normalise more quickly. Minor increases may occur in cases of muscle trauma and hyperthyroidism. ALT activity predominates in hepatic tissues, with dog liver ALT concentrations exceeding plasma levels by a factor of 10,000. Similar hepatic ALT activity is observed in cats, humans, and laboratory rodents, making serum ALT measurement a standard practice for assessing hepatocellular damage in these species. In contrast, horses, cattle, and sheep exhibit lower hepatic ALT activity, precluding routine serum ALT activity assessment in these animals.

ALP levels increase due to various factors, including accelerated bone formation, liver damage, hyperthyroidism, biliary tract disorders, intestinal injury, hyperadrenocorticism, and administration of corticosteroids or barbiturates. Generalised tissue damage, including neoplasia, can also elevate ALP. The most common causes of increased ALP are elevated circulating steroid levels and biliary disease. ALP has a 72-hour half-life in dogs but only 6 hours in cats. Cat ALP levels

are typically much lower than those in dogs, with any increase considered significant. In dogs, ALP levels in the thousands of units usually correlate with increased steroid **levels (Latimer, 2011)**. Even in seven hepatic disease, ALP and ALT levels rarely surpass 1,000 units. In healthy animals, serum ALP primarily originates from the liver and bone. Elevated serum ALP is observed in growing animals or adults with increased osteoblastic activity. In addition, acute and chronic liver disease may result in increased serum ALP activity. More pronounced elevations suggest cholestasis, with the highest serum ALP activities observed in animals with cholangitis, biliary cirrhosis or extrahepatic bile duct obstruction.

GDH levels rise in cases of hepatocellular damage, particularly hepatic necrosis, in equines and ruminants. GDH has proven valuable in assessing liver necrosis in sheep, goats and cattle. GDH activity is highly concentrated in the liver of these species, as well as other domestic animals. Elevated GDH activity has been reported in ruminants experiencing hepatic necrosis associated with parturition and biliary obstruction **(Braun, Trumel & Bézille, 2010)**.

GGT increases in prolonged liver damage and is particularly useful in diagnosing equine conditions (toxic hepatic failure, subclinical hepatopathy, hyperlipemia) and ruminant disorders; in cattle, elevated GGT may indicate ragwort poisoning, fascioliasis lipidosis, fascioliasis metacercariae migrations and chronicity, metacercariae migrations, and Senecio poisoning. In sheep, increased GGT levels may suggest bile duct obstruction, sporidesmin, toxicity, fascioliasis, lupinosis, cobalt deficiency (white liver disease), or Ketosis. In carnivores, elevated GGT levels may be attributed to various conditions. In dogs, these include bile duct obstruction, chronic hepatitis, lipidosis, necrosis, cirrhosis, neoplasia and corticoid therapy. In cats,

increased GGT may result from bile duct obstruction, cholangiohepatitis, cirrhosis, lymphosarcoma or necrosis **(Braun, Trumel & Bézille, 2010)**.

CK, often regarded as the archetypal muscle enzyme, exhibits pronounced increases in cases of rhabdomyolysis and aortic thromboembolism. Mild increases in CK levels have been reported in hypothyroidism. It is noteworthy that even minor muscle trauma, such as bruising or intramuscular injections, can result in elevated serum CK concentrations. In dogs and cats, high CK levels are typically not of clinical significance unless investigating specific muscle disorders **(Siliart & Nguyen, 2007)**.

AST levels rise in response to both muscle and liver damage but are considered less informative than ALT in diagnostic assessments. The half-life of AST is 5 hours in dogs and 77 minutes in cats. Elevated AST levels have also been associated with hypothyroidism. While AST activity is substantial in the liver of all domestic species and serum activity is routinely used to assess hepatocellular damage, it is crucial to recognise that AST activity is also significant in renal, cardiac and skeletal muscle tissues **(Boyd, 1984; Braun et al., 2015).** As a result, elevations in serum AST are considered less specific for liver disease compared to increases in serum ALT.

The aforementioned parameters are primarily associated with liver function/dysfunction and are frequently subjected to overinterpretation. In small animals, increases in ALT and ALP levels can reach four times the normal range while only indicating hepatic steatosis, a nonspecific finding that typically does not represent a primary liver disorder. Some laboratories frequently receive hepatic biopsies from dogs exhibiting significant increases in liver enzymes and bile acids exceeding 80, yet displaying normal histologic morphology. The underlying cause for this phenomenon remains unknown. Generally, plasma enzyme levels decrease due to sample

degradation. In rare cases, organ atrophy or fibrosis may result in unusually low plasma activities of the corresponding enzymes.

II.2 Additional Tests

Supplementary tests may be incorporated into the basic panel based on the primary presenting clinical signs to create specialised panels for conditions such as polydipsia or collapse. These panels are designed to reveal patterns of abnormalities characteristic of all probable differential diagnoses relevant to the clinical scenario. For example, a polydipsia panel may include calcium, glucose, and cholesterol. Calcium aids in identifying hyperparathyroidism and other causes of hypercalcemia (which induce polydipsia and renal insufficiency), glucose may indicate diabetes mellitus and contributes to the pattern typical of hyperadrenocorticism, and cholesterol further assists in recognising the “Cushing pattern”. Renal failure is addressed by the tests already included in the basic panel. In contrast, a panel for a "collapsing animal” may incorporate calcium and glucose to screen for hypocalcemia or hypoglycemia. Sodium and potassium are included to detect hypoadrenocorticism or hypokalemia. Analytes that may be considered for inclusion in such expanded profiles are described below.

Sodium levels increase due to Conn syndrome (hyperaldosteronism), restricted water intake, vomiting, and most causes of dehydration. They decrease due to hypoadrenocorticism, loss of high-sodium fluids in certain forms of renal disease, and insufficient sodium provision during intravenous (IV) fluid therapy.

Potassium concentrations increase due to hypoadrenocorticism and severe renal failure (especially terminal stages). They decrease due to Conn syndrome, chronic renal

dysfunction, vomiting, diarrhea, and insufficient potassium provision during IV fluid therapy. Congenital hypokalemia is observed in Burmese cats.

Chloride levels exhibit an increase during acidosis, and in conjunction with elevated sodium levels. Conversely, they decrease in alkalosis, post-prandial emesis, and in association with hyponatremia.

Total bicarbonate (HCO_3) concentrations rise in metabolic alkalosis and decline in metabolic acidosis. This parameter exhibits limited utility in the assessment of respiratory acid-base disturbances.

Calcium levels increase in various conditions, including dehydration (accompanied with increased albumin), primary hyperparathyroidism (parathyroid gland neoplasia), primary pseudohyperparathyroidism (neoplasms producing parathormone-related peptide [PRP], usually perianal adenocarcinoma or certain lymphosarcoma variants), malignant neoplasms bone infiltration, thyrotoxicosis (uncommon), and excessive management of parturient paresis. Decreased levels are observed in hypoalbuminemia, parturient paresis, oxalate poisoning, chronic renal failure (secondary renal hyperparathyroidism), acute pancreatitis (occasionally), surgical intervention of parathyroid glands, and idiopathic (autoimmune) hypoparathyroidism.

Phosphate concentrations increase in renal insufficiency (secondary renal hyperparathyroidism). Decreases are noted in certain recumbent cows and as part of the stress response in horses and small animals.

Magnesium level elevations are rarely encountered, including during acute renal failure. In ruminants, decreases are attributed to dietary deficiency, either acute (grass staggers) or chronic, and diarrhea (uncommon).

Glucose concentrations rise following carbohydrate-rich meals, sprint exercise, stress or excitement (including handling and sampling stress), glucocorticoid therapy, hyperadrenocorticism, excessive administration of glucose/dextrose-containing IV fluids, and diabetes mellitus. Reductions occur due to insulin overdose, insulinoma, islet cell hyperplasia (uncommon), acetonemia/pregnancy toxemia, acute febrile illness, and idiopathically (in certain canine breeds).

β-Hydroxybutyrate levels increase in diabetes mellitus. As a primary component of ketoacidosis, it is also elevated in acetonemia/pregnancy toxemia and severe starvation. Quantification is feasible in both blood and urine specimens.

Bilirubin concentrations are elevated due to fasting (a benign effect in horses and squirrel monkeys, potentially induced by hepatic lipidosis in cats), hemolytic disorders (usually mild increase), hepatic dysfunction, and biliary obstruction (intra- or extra-hepatic). Theoretically, hemolysis is characterised by increased unconjugated (indirect) bilirubin, while hepatic and post-hepatic disorders exhibit elevated conjugated (direct) bilirubin; however, this distinction is often unreliable in practice. Bile acid measurements provide a more accurate assessment of jaundice. Unconjugated hyperbilirubinemia occurs with increased bilirubin production (e.g., hemolytic anemia) or impaired hepatic uptake or conjugation. Despite significant elevations of unconjugated bilirubin in these conditions, the albumin-bound fraction is not filtered by the glomerulus. Consequently, bilirubinuria is atypical in animals with unconjugated hyperbilirubinemia. In hemolytic disorders, hepatic bilirubin excretion and subsequent intestinal delivery may increase substantially, resulting in enhanced urobilinogen formation and urinary excretion.

Conjugated hyperbilirubinemia stems from intrahepatic cholestasis or extrahepatic bile duct obstruction. When bilirubin excretion into bile is compromised, hepatic uptake and conjugation may proceed normally, but conjugated bilirubin is released into the plasma. This elevation in plasma-conjugated bilirubin, which has a lower affinity to albumin, facilitates its glomerulus filtration, resulting in bilirubinuria. In cholestasis conditions, the reduced or absent bilirubin excretion into the intestine significantly diminishes urobilinogen production by intestinal bacteria, typically yielding a negative urinary urobilinogen test in complete extrahepatic obstruction. It should be noted that oral broad-spectrum antibiotic administration may suppress intestinal bacteria activity, potentially leading to a false-negative urobilinogen test in the absence of cholestasis.

Bile acid levels increase with impaired hepatic anion transport, often during liver dysfunction (bile acids being more sensitive to hepatic impairment than bilirubin) and in portosystemic shunts (congenital or acquired). The latter condition is characterised by marked postprandial increases in bile acid concentration, even with normal fasting levels. Bile duct obstruction also elevates bile acids, while feline infectious peritonitis and mild hepatic lipidosis show minimal increases. Interestingly, exceptionally high levels can occur without corresponding structural histologic changes, for reasons that remain unclear.

In liver disease, primary bile acid synthesis may be altered, leading to changes in the proportions of cholic acid and chenodeoxycholic acid, or the production of unusual bile acids. Impaired hepatocellular function or vascular shunts can reduce bile acid removal from the hepatic portal vein diverting portal blood from the liver vasculature to the peripheral circulation. This phenomenon is particularly evident after meals in animals with congenital or acquired hepatoportal shunts. Biliary obstruction results in persistently elevated plasma bile acid concentration and increased urinary bile acid

excretion. Various forms of hepatic disease are associated with increased serum bile acid concentrations.

Cholesterol levels rise due to fatty meals, hepatic or biliary disease, protein-losing nephropathy (and to a lesser extent, other protein-losing syndromes), diabetes mellitus, hyperadrenocorticism, and hypothyroidism. Conversely, severe liver dysfunction and occasionally hyperthyroidism may lead to decreased cholesterol levels.

Lactate dehydrogenase, a ubiquitous enzyme with multiple isoenzymes, requires electrophoretic separation of isoenzymes to identify the source of increased activity, limiting its utility in general clinical practice.

Sorbitol dehydrogenase levels rise in acute hepatocellular damage in horses but represent a highly labile analyte.

α-Amylase rises in acute pancreatitis but also increases in canine chronic renal dysfunction, limiting its diagnostic value for pancreatitis. Pancreatic lipase immunoreactivity is now preferred for diagnosing pancreatitis in dogs and cats. Amylase is not a reliable indicator of pancreatitis in cats.

Lipase levels increase in acute pancreatitis in dogs, exhibiting longer half-life compared to amylase. This increase may also occur in chronic renal dysfunction. It is worth noting that standard lipase assays are not reliable indicators of pancreatitis in cats.

Immunoreactive trypsin (trypsin-like immunoreactivity) levels decrease in dogs with exocrine pancreatic insufficiency, while showing irregular increases in cases of pancreatitis.

II.3 Tests for Pancreatic Disease

Serum amylase and lipase activities have been used for several decades to diagnose pancreatitis in humans and canines. However, these tests lack the requisite sensitivity and specificity for diagnosing pancreatitis in dogs **(Kaneko et al., 2008)**. Research has shown that significant serum amylase and lipase activities persist following total pancreatectomy, indicating the presence of non-pancreatic sources of these enzymes. Clinical data suggest a mere 50% specificity for pancreatitis using these markers. Various non-pancreatic conditions, including renal, hepatic, intestinal, and neoplastic diseases, can elevate serum amylase and lipase activities. Additionally, steroid administration may increase serum lipase activity and produce variable effects on serum amylase activity. Consequently, measuring serum amylase and lipase activities has a limited diagnostic value for canine pancreatitis. Serum amylase and/or lipase activities 3–5 times the upper reference limit, coupled with consistent clinical signs, suggest pancreatitis. It is crucial, however, to note that approximately 50% of dogs meeting these criteria do not have pancreatitis. In cats, serum amylase and lipase activities are of no clinical utility for pancreatitis diagnosis. Although cats with experimental-induced pancreatitis may show increased serum lipase activity and decreased serum amylase activity, these changes are inconsistent in spontaneous cases. A study examining 12 cats with severe pancreatitis found no instances of serum lipase or amylase activity exceeding the upper reference limit.

Serum trypsin-like immunoreactivity (TLI) concentration primarily measures trypsinogen, the sole form of trypsin circulating in the vascular space of healthy individuals. This assay also detected serum trypsin when present. Species-specific assays have been developed and validated to measure serum TLI concentrations in both

dogs and cats. Healthy animals exhibit low serum TLI. However, during pancreatitis, increased trypsinogen leakage into the vascular space can elevate serum TLI concentration. Prematurely activated trypsin may also contribute to this increase. Yet, both trypsinogen and trypsin are rapidly cleared by the kidneys. Furthermore, proteinase inhibitors, such as α_1-proteinase inhibitor and α_2-macroglobulin, swiftly remove prematurely activated trypsin. Subsequently, α_2-macroglobulin-trypsin complexes are eliminated by the reticuloendothelial system. As a result, the serum half-life of TLI is short, necessitating a significant degree of active inflammation to elevate serum TLI concentration. Serum cTLI and fTLI concentrations are not highly effective for diagnosing pancreatitis in dogs and cats due to their limited sensitivity and the fact that only a limited number of laboratories routinely perform these assays. Consequently, the utility of serum TLI concentration in diagnosing pancreatitis in these animals is restricted **(Meyer & Harvey, 2004; Rebekah, 2023)**.

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Pancreatic lipase immunoreactivity (PLI) concentration is a specific measure of classical pancreatic lipase levels in serum, distinguishing it from serum lipase activity, which evaluates the enzymatic activity of all triglyceridases present, irrespective of their cellular origin. Assays for measuring PLI in canine (cPLI) and feline (fPLI) serum have been developed, validated, and available commercially. Serum PLI is highly specific to exocrine pancreatic function and offers greater sensitivity in diagnosing pancreatitis compared to other diagnostic tests currently available **(Meyer & Harvey, 2004; Rebekah, 2023)**.

A semiquantitative assay for diagnosing canine pancreatitis is available for use at the point of care. A test spot lighter in colour than the reference spot indicates that

pancreatitis can be excluded. Conversely, a darker test spot than the reference spot suggests the potential presence of pancreatitis, necessitating further laboratory measurement of serum cPLI concentration.

Various other diagnostic tests for pancreatitis in dogs and cats have been evaluated, including plasma trypsinogen activation peptide (TAP) concentration, urine TAP concentration, urine TAP: creatinine ratio, serum α_1-proteinase inhibitor trypsin complex concentration, and serum α_2-macroglobulin concentration. However, none of these tests have proven to be clinically useful.

Exocrine Pancreatic Insufficiency: Historically, several faecal tests have been used to diagnose exocrine pancreatic insufficiency (EPI). Microscopic faecal examination for fat and/or undigested starch or muscle fibres may suggest maldigestion but is no longer justified due to the availability of more reliable tests for diagnosing EPI. Faecal proteolytic activity has been used for several decades to diagnose EPI in small animals, but most methods, especially the radiographic film clearance test, are unreliable. One method, involving pre-made tablets to pour a gelatine agar, is considered the most reliable, though false-positive and false-negative results have been reported. The clinical application of faecal proteolytic activity is limited to species lacking more specific assays for pancreatic function and in regions where more accurate and sophisticated tests are unavailable **(Meyer & Harvey, 2004; Rebekah, 2023)**.

Serum TLI concentration is the preferred diagnostic test for EPI in both dogs and cats. TLI assays quantify trypsinogen circulating within the bloodstream. In healthy animals, the serum contains only a trace amount of trypsinogen. However, in dogs and cats suffering from EPI, there is a significant reduction in pancreatic acinar cells, resulting in a significant decrease in serum TLI concentration, which may even become

undetectable. For dogs, the TLI reference range is 5.7–45.2 mcg/L, with a diagnostic threshold set at ≤2.5 mcg/L. Similarly, for cats, the reference range is 12–82 mcg/L, with a diagnostic threshold of ≤8 mcg/L. Rarely, animals with serum TLI concentrations below these thresholds do not exhibit clinical symptoms, likely due to the functional redundancy of the gastrointestinal tract. Conversely, many dogs and cats experiencing chronic diarrhea and weight loss show slight reductions in serum TLI concentration. These cases are often associated with chronic small-intestinal disease and warrant further investigation. However, a subset of these animals may indeed have EPI. In the absence of small-intestinal disease, a trial treatment with pancreatic enzymes followed by a re-evaluation of serum TLI concentration after one month is recommended **(Meyer & Harvey, 2004; Rebekah, 2023)**.

PLI is another specific marker for evaluating exocrine pancreatic function and can be used in diagnosing EPI. However, initial studies showed a slight overlap in serum PLI concentrations between healthy dogs and dogs with EPI, making PLI measurement slightly less reliable than TLI for diagnostic purposes. As a result, PLI assays for both dogs and cats have been adjusted for higher concentrations, rendering them unsuitable for diagnosing EPI in these species.

A **faecal canine elastase concentration** assay has been developed and validated yet it remains inferior to the widely used TLI measurement.

II.4 Point-of-Care Tests

Several biochemical analytes can be estimated in clinical practice without the need for extensive analytical equipment.

Total protein levels can be measured by refractometry, employing the same instrument used for urine-specific gravity measurements, provided it includes a total protein scale. This method is also applicable for measuring protein in ascitic and pleural fluids. The readout may be in g/dL, in which case multiplying the result by 10 will convert it to the SI unit of g/L **(Latimer, 2011)**.

Urea levels can be estimated using chromatographic reaction strips, which correlate well with standard laboratory methods. A rapid whole-blood colour comparison strip is also available, although it reads only up to approximately 20 mmol/L, limiting its utility. A dedicated reflectance meter for urea estimation is not available.

Glucose meters intended for whole blood analysis are readily available for home use by diabetic individuals. These devices yield results that are adequately precise for animal blood; however, any unexpected instance of hypoglycemia should be confirmed through a professional laboratory. While fresh whole blood is an option, fluoride blood or plasma is preferred if immediate analysis is not possible.

Ketone levels can be estimated using either urine, which is the preferred sample, or plasma/serum. This evaluation can be performed using the ketone patch on a urine dipstick, providing a qualitative outcome. Furthermore, there are several point-of-care instruments available for the measurement of blood glucose and ketone levels, including specifically β-hydroxybutyrate **(Latimer, 2011)**.

Triglyceride levels may be identified in a plasma or serum sample as lipemia. If the milkiness rises to the top of the tube during storage, chylomicrons are present; otherwise, triglycerides are responsible for milkiness. Although this is a qualitative assessment, it remains valuable, especially in equine patients.

Bilirubin levels can also be visually assessed in most species. Equine and bovine plasma is typically yellow, complicating determination; however, in other species, any yellow colouration is abnormal and suggests elevated bilirubin levels. Visual assessment of the depth and shade of colour may offer additional insights.

Other point-of-care tests include **C-reactive protein** as an indicator of inflammation, and **cardiac troponin** as a marker for cardiac muscle damage.

For emergency in-clinic use, the most critical analytes beyond these simple basic tests are sodium and potassium. A dedicated ion-specific electrode meter is the optimal method for measuring these. Instruments capable of analyzing whole blood are available, though great caution must be exercised to avoid artefacts resulting from unrecognised hemolysis **(Rishniw et al., 2012)**. Critical care meters are also available that can estimate a variety of analytes, including glucose, urea, and electrolytes; however, these have not been extensively validated on nonhuman blood, and results should be interpreted with caution.

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Appendices

Serum Biochemical Analysis Reference Ranges
(Latimer, 2011 ; Kaneko et al., 2008)

Measure	Units	Dog	Cat	Cow	Horse	Sheep	Goat	Rabbit
In Conventional (US) Units								
ALT	U/L	10–109	25–97			26–34	6–19	45–80
Amylase	U/L	226–1,063	550–1,458					200–400
Alk phos	U/L	1–114	0–45			68–387	93–387	12–96
AST	U/L	13–15	7–38	60–125	160–412	60–280	167–513	35–130
CK	U/L	52–368	69–214	0–350	60–330	8.1–12.9	0.8–8.9	140–372
GGT	U/L			6–17.4	6–32	20–52	20–56	0–7
LDH	U/L	0–236	58–120		112–456	238–440	123–392	
SDH	U/L			4.3–15.3	1–8	5.8–27.9	14.0–23.6	
Bicarbonate	mEq/L	17–24	17–24	20–30	24–30	20–25		
Bilirubin	mg/dL	0–0.3	0–0.1	0–1.6	0–3.2	0.1–0.5	0–0.1	0–0.7
Calcium	mg/dL	9.1–11.7	8.7–11.7	8.0–11.4	10.2–13.4	11.5–12.8	8.9–11.7	11–14
Chloride	mEq/L	110–124	115–130	99–107	98–109	95–103	99–110.3	
Cholesterol	mg/dL	135–278	71–156			52–76	80–130	10–80
Creatinine	mg/dL	0.5–1.7	0.9–2.2	0.5–2.2	0.4–2.2	1.2–1.9	1.0–1.8	0.5–2.5
Glucose	mg/dL	76–119	60–120	40–100	62–134	50–80	50–75	75–155
Magnesium	mg/dL	1.6–2.4	1.7–2.6	1.5–2.9	1.4–2.3	2.2–2.8	2.8–3.6	
Phosphorus	mg/dL	2.9–5.3	3.0–6.1	5.6–8.0	1.5–4.7	5.0–7.3	4.2–9.1	4.0–6.5
Potassium	mEq/L	3.9–5.1	3.7–6.1	3.6–4.9	2.9–4.6	3.9–5.4	3.5–6.7	3.5–6.9
Total protein	g/dL	5.4–7.5	6.0–7.9	6.7–7.5	5.6–7.6	6.0–7.9	6.4–7.0	5.4–7.5
Albumin	g/dL	2.3–3.1	2.8–3.9	2.5–3.8	2.6–4.1	2.4–3.0	2.7–3.9	2.7–5.0
Globulin	g/dL	2.7–4.4	2.6–5.1	3.0–3.5	2.6–4.0	3.5–5.7	2.7–4.1	1.5–2.7
Sodium	mEq/L	142–152	146–156	136–144	128–142	139–152	142–155	138–150
Urea nitrogen	mg/dL	8–28	19–34	10–25	11–27	8–20	10–20	20–45
In SI Units								
Bicarbonate	mmol/L	17–24	17–24	20–30	24–30	20–25		
Bilirubin	mcmol/L	0–5.1	0–1.7	0–27.4	0–54.7	1.71–8.55	0–1.71	0–12
Calcium	mmol/L	2.3–2.9	2.2–2.9	2.0–2.8	2.5–3.3	2.88–3.2	2.23–2.93	2.7–3.5
Chloride	mmol/L	110–124	115–130	99–107	98–109	95–103	99–110.3	
Cholesterol	mmol/L	3.5–7.2	1.8–4.0			1.35–1.97	2.07–3.37	0.3–2.1
Creatinine	mcmol/L	44–150	80–194	44–194	35–194	106–168	88.4–159	44.2–221
Glucose	mmol/L	4.2–6.6	3.3–6.7	2.2–5.6	3.4–7.4	2.78–4.44	2.78–4.16	4.1–8.6
Magnesium	mmol/L	0.7–1.0	0.7–1.1	0.6–1.2	0.6–0.9	0.9–1.31	0.31–1.48	
Phosphorus	mmol/L	0.9–1.7	1.0–2.0	1.8–2.6	0.5–1.5	1.62–2.36	1.4–2.9	1.3–2.1
Potassium	mmol/L	3.9–5.1	3.7–6.1	3.6–4.9	2.9–4.6	3.9–5.4	3.5–6.7	3.5–6.9
Protein	g/L	54–75	60–79	67–75	56–76	60–79	64–70	54–75
Albumin	g/L	23–31	28–39	25–38	26–41	24–30	27–39	27–50
Globulin	g/L	27–44	26–51	30–35	26–40	35–57	27–41	15–27
Sodium	mmol/L	142–152	146–156	136–144	128–142	139–152	142–155	138–150
Urea nitrogen	mmol/L	2.9–10.0	6.8–12.1	3.6–8.9	3.9–9.6	2.8–7.1	3.6–7.1	7.1–16.1

Classification of the Dysproteinemias based on the Albumin-to-Globulin Ratio and the Serum Protein Electrophoretic Profile (Kaneko et al., 2008)

A. Normal A:G—normal SPE profi le
1. Hyperproteinemia: dehydration
2. Hypoproteinemia
a. Overhydration
b. Acute blood loss
c. External plasma loss: extravasation from burns, abrasions, exudative lesions, exudative dermatopathies, external parasites;
gastrointestinal disease including parasites
d. Internal plasma loss: vasculitis

B. Decreased A:G–abnormal SPE profi le
1. Decreased albumin
a. Selective loss of albumin: glomerulonephritis, nephrosis, nephrotic syndrome, gastrointestinal disease including parasites
b. Decreased synthesis of albumin: chronic liver disease, malnutrition, chronic infl ammatory disease
2. Increased globulins
a. Increased α_1-globulin
i . Acute infl ammatory disease: α_1-antitrypsin, α_1-acid glycoprotein (orosomucoid, seromucoid)
b. Increased α_2-globulin
i . Acute infl ammatory disease: α_2-macroglublin, ceruloplasmin, haptoglobin
ii . Severe active hepatitis: α_2-macroglobulin
iii . Acute nephritis: α_2-macroglobulin
iv . Nephrotic syndrome: α_2-macroglobulin, α_2-lipoprotein (VLDL)
v. Glucocorticoids: haptoglobin in dogs
c. Increased β-globulin
i . Acute hepatitis: transferrin, hemopexin
ii . Nephrotic syndrome: β_2-lipoprotein (LDL), transferrin
iii . Suppurative dermatopathies: IgM, C3
d. Bridging
i . Chronic active hepatitis: IgA, IgM
e. Increased γ-globulin (broad increase)—polyclonal gammopathies: IgG, IgM, IgA
i . Chronic infl ammatory disease, infectious disease, collagen disease
ii . Chronic hepatitis
iii. Hepatic abscess
iv . Suppurative disease: feline infectious dermatitis, suppurative dermatitis, tuberculosis
v . Immune-mediated disease: autoimmune hemolytic anemia, autoimmune thrombocytopenia, Aleutian disease of mink, equine infectious anemia, systemic lupus erythematosus , autoimmune polyarthritis, autoimmune glomerulonephritis, autoimmune dermatitis, allergies
vi . Lymphoid tumors
f. Increased γ-globulin (sharp increase)—monoclonal gammopathies: IgG, IgM, IgA
i . Lymphoid tumors
ii . Plasma cell dyscrasias: multiple myeloma, Aleutian disease of mink
iii. Macroglobulinemia
iv . Canine ehrlichiosis (usually polyclonal)
v . Benign
C. Increased A:G—abnormal profi le
1. Increased albumin: does not occur except in dehydration
2. Decreased globulins
a. Fetal serum
b . Precolostral neonate
c . Combined immunodefi ciency of Arabian foals
d . A gammaglobulinemia

A non-exhaustive summary of the biochemical profile results, listing conditions that alter the biochemical values only
(https://www.uoguelph.ca/ahl/guide-interpretation-ahl-biochemistry-profiles).

Calcium	
Increased values	*Decreased values*
Hyperalbuminemia (dehydration)	Hypoalbuminemia
Hypercalcemia of malignancy e.g., lymphosarcoma	Malabsorption
Primary hyperparathyroidism	Parturient paresis
- parathyroid adenoma or carcinoma	Eclampsia
Excessive vitamin D or Ca	Pancreatic necrosis
Lipemia (artefact)	Renal secondary hyperparathyroidism
Young, growing animals	Artefact
	- EDTA anticoagulant
	- hemolysis
	Massive myopathy
Phosphorus	
Increased values	*Decreased values*
Young, growing animals	Inadequate diet (P, vit D, Ca)
Decreased renal clearance	Parturient paresis (cattle)
- renal disease/failure	Malabsorption
- hypoparathyroidism	Hyperparathyroidism (primary or secondary)
Excessive vitamin D or P intake	Hyperinsulinism (adenoma or administration)
Anorexia, vomiting	Diabetes mellitus (ketoacidosis)
Dehydration/shock	
Tissue trauma, necrosis	
Hemolysis or aging RBCs in sample	
Magnesium	
Increased values	*Decreased values*
Renal failure	Defective GI absorption
Adrenocortical insufficiency	- malabsorption
Hibernation	- primary hypomagnesemia
Diabetes mellitus (coma)	- protein/calorie malnutrition
	Renal magnesium wasting
	- diabetic ketoacidosis
	- diuretic therapy
	Metabolic disease - grass tetany
	Anorexia

Sodium	
Increased values	*Decreased values*
Dehydration	Hemolysis (in dogs)
Hemolysis (except dogs)	Excessive loss
Sodium excess (fluid therapy)	- hypoadrenocorticism
Adrenocortical hyperfunction	- vomiting, diarrhea
Excessive water loss	- diuretic therapy
- sweating	- advanced renal failure
Osmotic diuresis	Excessive secretion of ADH
Salt poisoning	- tumor
	Water intoxication
	Excessive fluids - therapy of acute renal disease
Potassium	
Increased values	*Decreased values*
Hypoadrenocorticism	Without total body K^+ deficit
-(Addison's disease)	- respiratory alkalosis
Normal in Akitas	With total body K^+ deficit
Marked increase in WBC, platelets	- gastrointestinal loss
Acidosis - shift out of cells	- urinary loss
Decreased excretion	- hyperaldosteronism
- renal failure	- excessive steroids
- diuretics, K+ sparing	- excessive ACTH
Increased input	- renal tubular acidosis
- rhabdomyolysis	Diuretics
- diet	Improper sample handling (birds)
Improper sample collection	
handling (hemolysis in some species)	
Na:K ratio	
Increased values	*Decreased values*
clinically insignificant	Addison's disease
	<23:1 – suspicious
	<20:1 – highly suggestive, in the absence of GI disease, renal disease, or body cavity effusions

Chloride	
Increased values	*Decreased values*
All causes of increased sodium	All causes of decreased sodium
Metabolic acidosis	Metabolic alkalosis
Respiratory alkalosis	Respiratory acidosis
Decreased excretion	Upper GI loss – vomiting
Excessive salt intake	Chronic renal disease
Water deprivation (dehydration)	Adrenocortical hypofunction
Adrenocortical hypofunction	Excess circulating organic acids (lactate, ketoacids, etc.)
Total Protein	
Increased values	*Decreased values*
Dehydration, shock	Young animals
Increased production	Failure of passive transfer; Malabsorption
- monoclonal gammopathies	Increased loss - blood loss
- multiple myeloma	- protein-losing enteropathy
- some lymphomas	- draining wounds
- polyclonal gammopathy	- nephrosis
- infections	- amyloidosis, glomerulonephritis
- hepatic disease	Decreased production
Artefact	- immunosuppression, e.g., cyclosporine
- lipemia	- chronic hepatic disease
- hemolysis	
Albumin	
Increased values	*Decreased values*
Dehydration	Increased loss – glomerulonephritis
Shock	- amyloidosis, nephrotic syndrome
Lipemia (interference)	- severe enteritis; protein-losing enteropathy
	- hemorrhage
	- third space effusion
	- exudative skin disease, vasculitis, inflammation
	Decreased production - chronic hepatic disease
	- chronic infections
	- malnutrition
	Over-hydration

Globulin	
Increased values Polyclonal gammopathy - many infections - many parasites Rheumatoid arthritis, lupus Monoclonal gammopathy - multiple myeloma - lymphoproliferative disease Hepatopathy Dehydration, shock	*Decreased values* Failure of passive transfer Decreased production - malabsorption - hepatic disease - immunodeficiency Increased loss - hemorrhage - protein-losing enteropathy - serum loss (burns)
A:G ratio	
Increased values Hyperalbuminemia, with normal or low globulins	*Decreased values* Hyperglobulinemia, with normal or low albumin
Urea (best interpreted in combination with creatinine)	
Increased values Pre-renal azotemia - dehydration, shock - hypoadrenocorticism - high protein intake (slight effect) - hypercatabolism, e.g., fever - drugs - steroids, aminoglycosides - upper GI hemorrhage Renal azotemia - many causes Post-renal azotemia - obstruction, rupture	*Decreased values* Decreased production - severe hepatic disease - portosystemic shunts - malnutrition - malabsorption Fluid therapy
Creatinine	
Increased values Decreased renal perfusion - dehydration, shock - hypoadrenocorticism - heart failure	*Decreased values* Usually clinically insignificant Young animals Cachexia

(not affected by the other pre-renal changes that increase urea) Renal azotemia (as for urea) Post-renal azotemia (as for urea)	
Glucose	
Increased values Transitory (excitement, stress) Diabetes mellitus Pancreatitis Hyperadrenocorticism Therapy - steroids, glucagon, epinephrine, glucose solution Pituitary neoplasms Pheochromocytoma Hyperthyroidism	*Decreased values* Decreased glucose production Adrenal insufficiency Hyperinsulinism (insulinoma) Hepatic disease Malabsorption/starvation Pregnancy toxemia, ketosis Fulminating infections Idiopathic in toy breeds *** delayed separation of serum from RBCs** **(glucose decreases at 5% per h in presence of RBCs)**
Cholesterol	
Increased values Hypothyroidism Increased fat mobilization - diabetes mellitus - anorexia in ponies - hyperadrenocorticism - starvation - steatitis in cats Decreased lipoprotein lipase activity (Min. Schnauzers) - pancreatitis Cholestatic diseases Nephrotic syndrome Nutritional myopathy Recently fed; high fat diet (usually only mild increase)	*Decreased values* Decreased uptake - low fat diet, malabsorption Decreased production - advanced hepatic disease Increased loss or catabolism - protein-losing enteropathy - hyperthyroidism
Bilirubin, total and conjugated	
Increased values	*Decreased values*

Hemolysis, blood loss into body cavity Hepatic disease - cholestasis - hepatocellular injury - bile duct rupture - hepatic failure Fasting (unusual; occasionally seen in anorexic cats)	Exposure of serum to sunlight Decreased RBC turnover (significant)
Free bilirubin	
Increased values Intravascular hemolysis Anorexia in horses	*Decreased values* Clinically insignificant
Alkaline phosphatase (ALP)	
Increased values Steroids - endogenous, exogenous Young growing animals As for ALT, but especially cholestatic disorders Acute pancreatitis Metastatic neoplasms of bone, osteosarcoma Diabetes mellitus Drugs (anticonvulsants) Hyperthyroidism (cats)	*Decreased values* Clinically insignificant Anticoagulants - EDTA
***g*-glutamyltransferase (GGT, gamma GT)**	
Increased values Hepatic disease, generally parallels alkphos in hepatobiliary disease Cholestasis Hepatic fibrosis Administration of glucocorticoids (dogs only) Newborn (colostrum – dogs, cattle, sheep)	*Decreased values* Clinically insignificant
Alanine aminotransferase (ALT)	
Increased values	*Decreased values*

Hepatitis, hypoxia Hepatic necrosis Cholestasis Hepatic neoplasms Diabetes mellitus (slight) Induced by drugs – anticonvulsants, steroids (dogs), thiacetarsamide	Clinically insignificant
Aspartate aminotransferase (AST)	
Increased values Hepatitis, hypoxia Hepatic necrosis Skeletal muscle damage Myocardial necrosis Acute pancreatitis Diabetes mellitus (slight) Hemolysis (artefact)	*Decreased values* Clinically insignificant
Creatine kinase (CK)	
Increased values Seizures Myocardial necrosis Necrosis of skeletal muscle - intramuscular injections - downer animals - recent severe exercise Cerebrocortical necrosis Hemolysis (artefact) Obstructive urolithiasis, cat	*Decreased values* Clinically insignificant Lack of refrigeration of serum
Amylase	
Increased values Pancreatic diseases Renal disease (occasional) Intestinal mucosal disease Corticosteroids (mild)	*Decreased values* Usually, clinically insignificant
Lipase	
Increased values Pancreatic diseases	*Decreased values* Clinically insignificant

Renal disease (occasional) Corticosteroids (mild) Liver tumors	
β-hydroxybutyrate (BHBA)	
Increased values Hepatic disease - fatty liver - subclinical ketosis	*Decreased values* Clinically insignificant
Non-esterified fatty acids (NEFA)	
Increased values Negative energy balance	*Decreased values* Clinically insignificant
Haptoglobin	
Increased values Acute inflammation or infection	*Decreased values* Clinically insignificant
Glutamate dehydrogenase (GLDH)	
Increased values Hepatic necrosis/inflammation, esp. sheep, goats, cattle Bile duct obstruction Steroid induction	*Decreased values* Clinically insignificant
Uric acid (used mostly in birds)	
Increased values Visceral gout (birds) Dalmatian breed Advanced hepatic disease	*Decreased values* Clinically insignificant
Serum amyloid A (SAA)	
Increased values Acute inflammation or infection (horses)	*Decreased values* Clinically insignificant