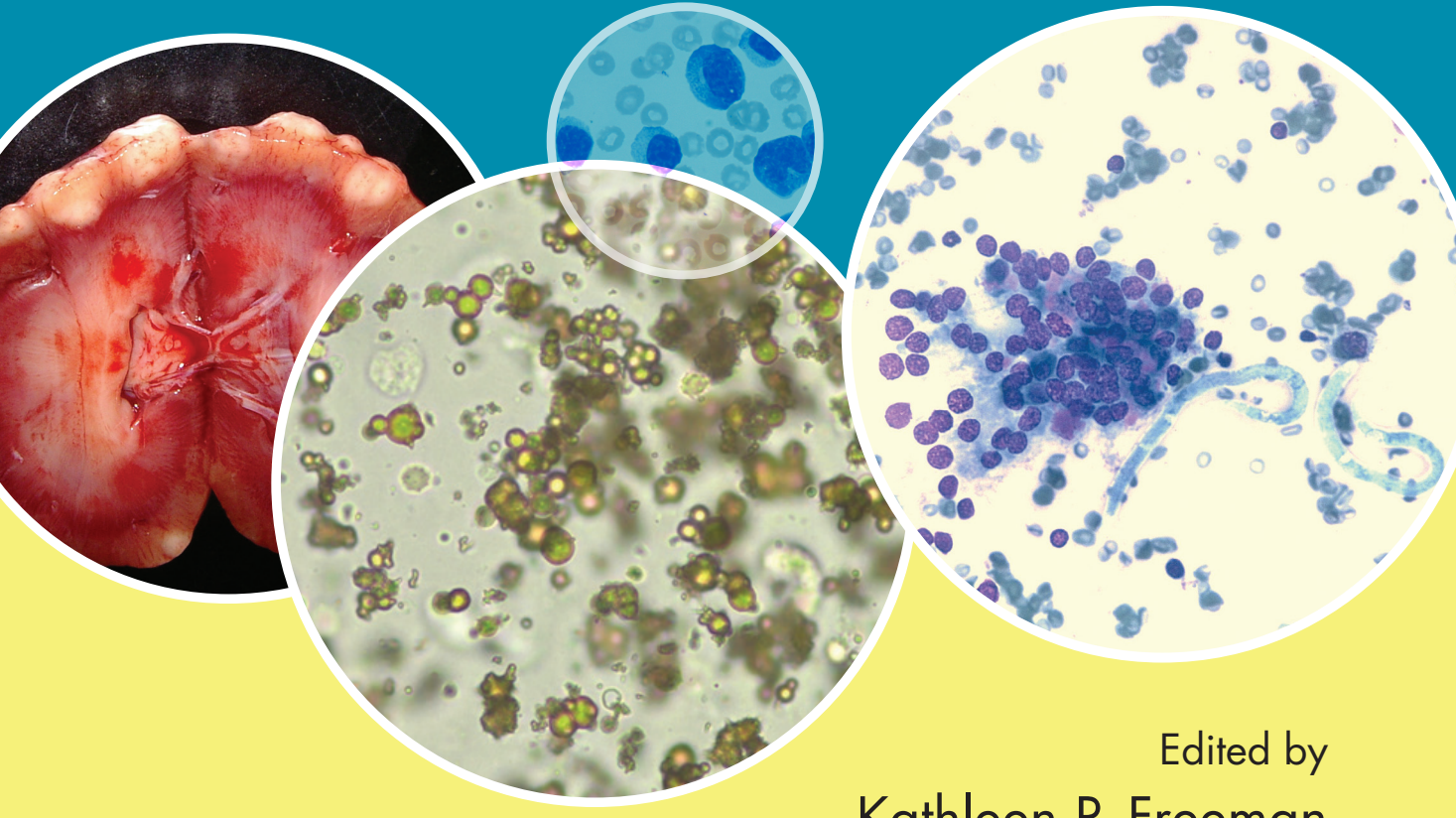
Veterinary Clinical Pathology

A Case-Based Approach



Edited by
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Preface

This book aims to provide a variety of clinical pathology cases covering multiple species and submitted by a selection of clinical pathologists and clinicians. It is not meant to cover all possible clinical pathology diagnoses, but offers a compilation of cases with clinical pathological results encountered by the contributors. The book was inspired by examples provided to the authors by their teachers and mentors when discussing cases and their thought processes in order to encourage the development of their own clinicopathological skills during training. We were further motivated by the need expressed by many veterinary students and trainees in general veterinary medicine, clinical pathology and internal medicine with whom we have interacted to have wider experience of the thought processes of experienced clinical pathologists and clinicians with regard to interpretation of laboratory data.

It was fascinating to see the systematic approaches that each contributor has taken with the cases they have elected to submit. Although the order of consideration and the terminology and phrases used by each contributor may differ slightly, there are many common threads that will be recognised as you read through these cases. You may find that you have 'favourite' contributors whose thought process and approach you admire, and you may seek to incorporate their style, phrases and approach into your own clinical repertoire.

The role of clinicians and clinical pathologists in today's environment lies in providing context, 'telling the story' and giving meaning in order to tie together the clinical presentation and laboratory data and assure the best possible patient care. By providing 'meaning' for ourselves, the owners and our colleagues we are establishing the basis for ongoing learning and a way to approach cases that will help all of us to become better practitioners of the art and science of veterinary medicine and to better communicate with our clients, owners and colleagues.

We hope these cases will provide an opportunity for students, residents, general practitioners and all veterinarians who would like to challenge or improve their skills in veterinary clinical pathology to see various presentations of cases and the ways that the contributors of these cases approach the analysis and interpretation of the data. The format, with general assessment of the laboratory data and questions to be answered regarding its interpretation, pathological mechanisms and clinical significance, should be of benefit in tying together the clinical pathology results, the pathophysiological base for these results, their interpretation, and further testing or information that may be of benefit for diagnosis, monitoring and/or prognosis. When a contributor uses laboratory results to skilfully 'tell the story' of the patient and explain the 'detective work' of the clinician and its interpretation, it is a joy to read!

We therefore present a collection of cases with a wide variety of clinical pathological abnormalities. Topics include haematology, clinical chemistry, endocrinology, acid–base and blood gas analysis, haemostasis, urinalysis, biological variation and quality control. The cases about quality control are unique for such a book and reflect our deep belief that this is an issue of huge importance for all of us. Every laboratory result represents a result with some degree of 'probability' associated with it, since all laboratory results contain some degree of inherent error. Knowledge of the nature of such variation (errors) and how they may influence our laboratory results helps all of us to become better pathologists and clinicians.

The level of difficulty of the various cases is wide, giving beginners the possibility to start improving their clinicopathological skills, providing more complicated cases or cases treating unfamiliar topics (e.g. biological variation) for the more experienced reader and increasing learning opportunities for the less experienced.

We hope that these cases will be of interest to a wide audience and provide a resource for continuing development of expertise in interpretation of laboratory data. We have endeavoured to ensure that the approaches and information are accurate and that recommendations for Further Reading are provided for many of the topics. We hope that you will enjoy these cases and the expertise of the contributors in presenting them for you.

Kathleen P. Freeman
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Broad Classification of Cases

Note: There may be considerable overlapping between topics in the various cases. For example, cases concerning general clinical chemistry may also contain information about urinalysis, haemostasis, acid–base and quality control to a higher or lower amount.

Blood gas analysis
4, 17, 30, 50, 69, 89, 106, 156

Clinical chemistry
1, 2, 5, 7, 9, 12, 14, 15, 18, 19, 23, 24, 28, 31, 32, 34, 37, 39, 42, 43, 45, 47, 51, 53, 58, 59, 60, 61, 68, 74, 75, 78, 81, 82, 84, 86, 90, 96, 101, 102, 105, 107, 108, 113, 114, 116, 119, 121, 123, 126, 129, 141, 142, 150, 152, 155, 164, 170, 172, 173, 179, 180, 182, 184, 186, 192, 195, 196, 198, 200

Endocrinology
3, 16, 26, 38, 56, 63, 67, 76, 92, 97, 100, 110, 118, 124, 127, 135, 144, 147, 154, 161, 177, 190

Haematology
8, 21, 27, 40, 41, 46, 49, 54, 66, 70, 71, 79, 83, 87, 88, 94, 99, 115, 130, 136, 138, 139, 153, 158, 162, 167, 169, 176, 181, 187

Haemostasis
10, 35, 57, 91, 103, 133, 134, 143, 194

Infectious disease
6, 20, 25, 36, 52, 55, 65, 73, 85, 95, 104, 112, 120, 125, 131, 137, 145, 149, 151, 159, 166, 171, 188, 174, 185, 193, 197, 199

Protein electrophoresis
13, 33, 48, 80, 109, 122, 165, 191

Quality control
22, 64, 72, 98, 111, 128, 140, 148, 157, 168, 175, 178, 189

Urinalysis
11, 29, 44, 62, 77, 93, 117, 132, 146, 160, 163, 183

Abbreviations

α-1-AGP	alpha-1-acid-glycoprotein
ACTH	adrenocorticotropic hormone
ACVP	American College of Veterinary Pathologists
ADH	antidiuretic hormone
AID	anaemia of inflammatory disease
AKI	acute kidney injury
ALP	alkaline phosphatase
ALT	alanine aminotransferase
ANP	atrial natriuretic peptide
APPs	acute phase proteins
aPTT	activated partial thromboplastin time
AST	aspartate aminotransferase
ASVCP	American Society for Veterinary Clinical Pathology
BCS	body condition score
BJP	Bence-Jones protein
BMBT	buccal mucosal bleeding time
BNP	B-type natriuretic peptide
bpm	beats per minute/breaths per minute
BUN	blood urea nitrogen
C-BNP	carboxy-terminal fragment of BNP, active form
CFU	colony-forming unit
CK	creatine kinase
CLL	chronic lymphocytic leukaemia
CNS	central nervous system
cPLI	canine pancreatic lipase
CRP	C-reactive protein
CRT	capillary refill time
CSF	cerebrospinal fluid
cTLI	canine trypsin-like immunoreactivity
CV_A	analytical coefficient of variation
CV_G	inter-individual coefficient of variation
CV_I	intra-individual coefficient of variation
DHNS	diabetic hyperosmolar non-ketotic syndrome
DIC	disseminated intravascular coagulation
DKA	diabetic ketoacidosis
DM	diabetes mellitus
DSH	domestic shorthair (cat)
ECG	electrocardiogram
ECVCP	European College of Veterinary Clinical Pathologists
EG	ethylene glycol
ELISA	enzyme-linked immunosorbent assay
EMS	equine metabolic syndrome
FBC	full (complete) blood count
FDPs	fibrin/fibrinogen degradation products
FE-K	urinary fractional excretion of potassium
FeLV	feline leukaemia virus
FE-Na	urinary fractional excretion of sodium
FIP	feline infectious peritonitis
FIV	feline immunodeficiency virus
fPLI	feline pancreatic lipase
FT4	free T4
FT4D or FT4ED	free T4 measured by equilibrium dialysis
GFR	glomerular filtration rate
GGT	gamma glutamyl transferase
GI	gastrointestinal
G:I ratio	glucose:insulin ratio
GLDH	glutamate dehydrogenase
GnRH	gonadotropin releasing hormone
HAC	hyperadrenocorticism, Cushing's disease
hCG	human chorionic gonadotropin
HCO_3	bicarbonate concentration
Hct	haematocrit
HDDST	high-dose dexamethasone suppression test
Hgb	haemoglobin
HMWK	high molecular weight kininogen
hpf	high-power field
HR	heart rate
HUS	haemolytic-uraemic syndrome
IFAT	indirect immunofluorescent antibody test
IL	interleukin
IM	intramuscular
IMHA	immune-mediated haemolytic anaemia
IoI	index of individuality
IRIS	International Renal Interest Society
IV	intravenously
IVFT	intravenous fluid therapy

LDDST	low-dose dexamethasone suppression test
LDH	lactate dehydrogenase
LDL	low-density lipoprotein
lpf	low-power field
LUC	large unstained cell
MAA	SAA produced in the mammary gland
MAP	mitogen-activated protein (kinase)
MCH	mean corpuscular haemoglobin
MCHC	mean corpuscular haemoglobin concentration
MCV	mean corpuscular volume
MHC	major histocompatibility complex
MIRG	modified insulin:glucose ratio
n.d.	not done
NPR-A	renal A-type natriuretic peptide receptor
NPR-C	C-type natriuretic peptide receptor
NRBC	nucleated red blood cell
NSAID	non-steroidal anti-inflammatory drug
NT-proBNP	N-terminal of the prohormone brain natriuretic peptide
OspA	outer surface protein A
PA	plasma or serum aldosterone
PCO_2	partial pressure of carbon dioxide
$PaCO_2$	arterial carbon dioxide pressure
PCR	polymerase chain reaction
PCV	packed cell volume
PLE	protein-losing enteropathy
PLN	protein-losing nephropathy
PMSG	pregnant mare serum gonadotropin
PO_2	partial pressure of oxygen
PaO_2	arterial oxygen pressure
PP	psychogenic polydipsia
PPID	pars pituitary intermedia dysfunction
PRA	plasma renin activity
PT	prothrombin time
PTH	parathyroid hormone
PTHrP	parathyroid hormone related protein
PTT	partial thromboplastin time
PU/PD	polyuria/polydipsia
QGI	quality goal index
RAAS	renin–angiotensin–aldosterone system
RBC	red blood cell
RCV	reference change value
RDW	red cell distribution width
RI	reference interval
RIA	radioimmunoassay
RISQI	reciprocal of the square root of insulin
RR	respiratory rate
SAA	serum amyloid A
SG	specific gravity
SIADH	syndrome of inappropriate ADH secretion
SPE	serum protein electrophoresis
SSA	sulphosalicylic acid
T	temperature
T3	tri-iodo-thyronine
T4	thyroxine
TE_a	total allowable error
TEG	thromboelastography, thromboelastogram
TF	tissue factor
TgAA	thyroglobulin autoantibody
TIBC	total iron binding capacity
TLI	trypsin-like immunoreactivity
TNF	tumour necrosis factor
TRH	thyroid-releasing hormone
TSH	thyroid-stimulating hormone (thyrotropin)
TT4	total thyroxine
UPCR	urine protein:creatinine ratio
USG	urine specific gravity
VLDL	very low-density lipoprotein
VlsE	variable major protein-like sequence expression
vWD	von Willebrand's disease
vWF	von Willebrand factor
WBC	white blood cell

Approach to Analysis of Cases

For those readers less experienced in analysis of case data, we thought it may be of benefit to present a bit of the 'thinking' that goes into the approach to case analysis and interpretation. This represents the thoughts of the editors based on their combined experience and their exposure to case data over a number of years and at various institutions and situations.

Philosophy

There is always discussion about the use of comprehensive profiles versus profiles selected based on clinical signs and clinical examination findings. At this time, a good general 'comprehensive' minimum database with a complete blood count, urinalysis and multisystem biochemistry profile is considered the standard for laboratory work up of cases in which a clinical diagnosis is not of high certainty based on the clinical examination or other ancillary tests. The benefit of assessing multiple systems lies in determining whether multiple problems are present and whether the findings are compatible with the known aetiopathogenesis and pathophysiology associated with various conditions. Use of the problem-oriented approach helps in the mental organisation and 'sifting' of data with mental designation and documentation of 'highly significant', 'significant', 'lesser significance' or 'unremarkable' findings.

The last few decades have seen a rapid rise in the volume of laboratory testing, with the development of many new technologies. A reliance on laboratory testing and on the clinical pathologist or clinician as the 'story teller' and 'translator of meaning' for laboratory testing appears likely to continue for the foreseeable future.

When reading case write ups written by trainees practicing for learning and for examination preparation, it is a joy to see them develop so that they are able to extract the 'story' from the laboratory data, tie it together in a way that presents good evidence-based conclusions, and point out those items that are part of known patterns and those that are harder or impossible to explain based on the single or multiple problems that have been identified. Such aberrant data may eventually be explained based on further clinical developments, effects of treatment and/or further laboratory testing.

The literature indicates that much laboratory data is likely to be ignored or is not acted upon in a manner that is timely and in keeping with providing the best possible patient care. Some clinicians try to use laboratory testing to confirm their clinical suspicions and some may ignore abnormal data that do not 'fit in' with their clinical findings. The 'best practice' orientation is to determine what findings fit together and to identify those that are unexpected based on the current understanding of disease mechanisms and aetiopathogenesis and pathophysiology, perhaps indicating the presence of additional contributing or causal conditions or a need for further investigation and understanding of the condition.

Other clinicians may claim that they use laboratory testing to identify subclinical conditions or conditions that may be difficult or impossible to identify based on clinical findings alone, but then also claim to dismiss 'abnormal' findings as 'irrelevant' or 'laboratory error' if an explanation for their presence is not apparent or understood. This is the 'clinician laboratory testing paradox' well known to many laboratorians, and it is our mission to be the 'detectives' of the clinical world and an important bridge between the clinics and the world of pathology and anatomy, which are the foundation for veterinary medicine and laboratory medicine.

The clinical pathologist brings unique expertise in knowledge of laboratory instruments, methods and statistical analyses (such as uncertainty associated with the measurements) to the discussion of laboratory findings. As recent discussions with clinicians regarding guideline development for the ASVCP Quality Assurance and Laboratory Standards Committee and the ECVCP Laboratory Standards Committee have shown, clinicians expectations for instrument/method capability (accuracy and precision) may exceed that attainable with current state-of-the-art instruments and methods. In this book some cases are addressing newer applications, such as biological variation and use of the reference change value (critical difference), which provide opportunities for a new understanding of changes in serial data for monitoring the health of veterinary patients and the progression of a disease and its response to treatment.

Purpose

The purpose of case evaluation is to arrive at an interpretation – that is, the synthesis of clinical and laboratory findings in order to reach a clinical diagnosis, with indication of the certainty of such an interpretation and other possible differential diagnoses. Based on the probabilities associated with various findings, further recommendations regarding additional testing, monitoring or prognosis may be possible.

Clinicians, owners and clinical pathologists all desire an 'answer' or a clinical diagnosis from which to proceed. Sometimes this will be based on a highly confident anchor, while other times it will be less firmly based, but still within a 'sea of probability' that has wider boundaries but has a sound basis for its definition. Occasionally, there are challenging cases that resemble 'navigation by starlight across the open ocean' with few or no landmarks. These are the ones that you hope to continue to learn from and, by the journey's end, have clinical or postmortem evidence to unravel the threads and reveal the eventual conclusion to the mystery. That is why dedication to undertaking the 'correct steps' in clinicopathological investigation, whenever possible, and obtaining follow-up information about clinical progress should be instilled in every clinician and clinical pathologist. Only by acquiring continual knowledge about the results and the ongoing clinical and laboratory findings can we know if the interpretations we provide are correct and continue to learn.

Process

Case evaluation is about *pattern recognition*. Patterns of findings help steer you toward or away from various general categories of disease. Then, a good foundation knowledge of diseases and conditions seen in the species of interest and across many species may allow further refinement as to the underlying cause. Finally, expert species knowledge and experience in the laboratory diagnosis of specific conditions may allow a highly specific interpretation and clinical diagnosis to be made.

The order in which individuals look at laboratory tests and their groupings is often remarkably similar amongst experienced pathologists and this has influenced the order in which laboratory data are presented in this book.

Approach

Regardless of your experience with laboratory data, expertise can be obtained by exposure to the thought processes and discussions presented by experienced pathologists. There is a body of literature looking at 'expert thought processes' and how they differ from those of the novice in a variety of vocations, but particularly in medicine, where the development of the synthetic processes needed for interpretation helps separate those with 'more gifted' and 'less gifted' medical expertise. It is our hope that by being exposed to the numerous clinicians who have contributed to this book you will reap the benefits of exposure to multiple expressions, turns of phrase and patterns of 'telling the story' in a way that will help you continue to learn about clinical laboratory medicine and its applications.

Questions

CASE 1

A 6-week-old Clydesdale filly was found collapsed in the field the day after it had been seen galloping round with its mother.

EXAMINATION FINDINGS

The filly was conscious but recumbent, dyspnoeic and poorly responsive to stimuli.

BIOCHEMISTRY

Analyte (units)	Result	Reference Interval (adult horses)	Reference Interval (3–6-week-old foals)
Total protein (g/l)	45.2	58–75	42–66
Albumin (g/l)	**17.7**	23–35	26–37
Globulins (g/l)	27.5	30–50	15–33
GGT (U/l)	**263**	13–44	13–30
ALP (U/l)	**365**	84–180	1,195–2,513
GLDH (U/l)	**311**	1–12	8–31
AST (U/l)	**210,000**	258–554	329–337
CK (U/l)	**335,400**	150–385	204–263
Bile acids (µmol/l)	**47.2**	1–15	0–8
Urea (mmol/l)	**57.3**	2.5–8.3	2.8–4.1
Creatinine (µmol/l)	**1,121**	40–150	97–138
Calcium (mmol/l)	**1.8**	2.6–3.3	2.9–3.1
Phosphorus (mmol/l)	**3.4**	0.8–1.8	2.2–2.7
Sodium (mmol/l)	**100**	134–150	135–145
Potassium (mmol/l)	**2.9**	2.7–5.9	4.1–5.0
Chloride (mmol/l)	**69**	98–118	96–102

HAEMATOLOGY

No significant abnormalities.

URINALYSIS

Item	Result	Reference Interval
Appearance	**Red–brown**	Yellow
USG	1.025	>1.025
Sediment analysis		
Erythrocytes	**6/hpf**	<5
Leucocytes	None	<5
Epithelial cells	15/lpf	None to few
Crystals	None	None
Casts	**Many red–brown, finely granular casts**	None
Bacteria	None	None
Dipstick evaluation		
pH	7.3	7.5–8.5
Protein	**4+**	Negative
Bilirubin	**1+**	Negative
Glucose	Negative	Negative
Ketone bodies	Negative	Negative
Blood	**4+**	Negative

QUESTIONS

1 What is your analysis of these results?
2 What are your differential diagnoses?
3 What additional testing would you recommend?

CASE 2

A 1-year-old female Havana cat was referred with a history of recent anaemia (PCV = 14%) documented 2 weeks previously. The cat was living with four other oriental cats, mainly indoors. Vaccination against calicivirus, herpesvirus, panleucopaenia and feline leukaemia virus and deworming was up to date.

EXAMINATION FINDINGS

Unremarkable. T = 39.1°C (102.4°F); HR = 160 bpm; RR = 30 bpm; BCS = 4/9; weight = 3.8 kg (8.3 lb).

HAEMATOLOGY

Measurand (units)	Result	Reference Interval
RBC count (10^9/l)	**4.8**	5.0–10.0
Haemoglobin (g/l)	**79**	80–150
Haematocrit (l/l)	**0.25**	0.30–0.45
MCV (fl)	52	39–55
MCH (pg)	16.4	12.5–17.5
MCHC (g/l)	**316**	320–360
RDW (%)	**24.1**	17.3–22.0
Aggregate reticulocytes (10^9/l)	**177**	0–60
Platelet count (10^9/l)	213	190–400
WBC count (10^9/l)	**26.9**	5.5–19.5
Neutrophils (10^9/l)	**19.9**	2.5–12.5
Band neutrophils (10^9/l)	0	0.0–0.3
Lymphocytes (10^9/l)	3.0	1.5–7.0
Eosinophils (10^9/l)	1.5	0.0–1.5
Monocytes (10^9/l)	**1.0**	0.0–0.85
Basophils (10^9/l)	0	Rare
NRBC (10^9/l)	**0.5**	Rare

No peripheral blood smear examination was done.

COOMBS TEST

Test	Result
Polyvalent Coombs reagent	Negative at 4°C (29.2°F) and 37°C (98.6°F)
Anti-cat IgG	Negative at 4°C (29.2°F) and 37°C (98.6°F)
Anti-cat IgM	Negative at 4°C (29.2°F) and 37°C (98.6°F)
Cold autoagglutination	Negative

BIOCHEMISTRY

Analyte (units)	Result	Reference Interval
Total protein (g/l)	84	57–89
Albumin (g/l)	34	22–40
Globulins (g/l)	49	28–51
ALT (U/l)	**451**	12–130
ALP (U/l)	51	14–111
Glucose (mmol/l)	**9.02**	4.11– 8.83
Cholesterol (mmol/l)	5.56	1.68–5.81
Bilirubin (µmol/l)	<2	0–15
Bile acids (fasting) (µmol/l)	**15**	0–10
Bile acids (post-prandial) (µmol/l)	**35**	0–25
BUN (mmol/l)	10.2	5.7–12.9
Creatinine (µmol/l)	136	71–212
Sodium (mmol/l)	160	144–160
Potassium (mmol/l)	4.3	3.5–5.8
Chloride (mmol/l)	122	109–122
Phosphorus (mmol/l)	1.64	1.00–2.42
Calcium (mmol/l)	2.83	1.95–2.83

URINALYSIS

Item	Result	Reference Interval
Colour	Yellow	Yellow
Turbidity	Clear	Clear
USG	1.034	>1.035
Dipstick evaluation		
pH	6.5	Acidic
Glucose	Negative	Negative
Ketone bodies	Negative	Negative
Bilirubin	Negative	Negative
Protein	Negative	Negative
Blood	Negative	Negative
Sediment analysis		
Erythrocytes	0	<5
Leucocytes	0	<5
Casts	0	None
Crystals	0	None
Epithelial cells	0	None to few

INFECTIOUS DISEASES

Test	Result
FIV antibodies (ELISA)	Negative
FeLV antigen (ELISA)	Negative
FCoV antibodies (IFAT)	**Positive (titre >1,280)**
Mycoplasma haemofelis (PCR)	Negative
Mycoplasma haemominutum (PCR)	Negative
Candidatus mycoplasma turincensis (PCR)	Negative

COAGULATION PROFILE

Analyte (units)	Patient	Reference Interval
PT (seconds)	11.2	8–13
aPTT (seconds)	22.7	10–25
D-dimer (ng/ml)	250	0–250

IMAGING RESULTS

Thoracic radiographs were unremarkable. Abdominal ultrasound revealed abnormal hepatic parenchyma with patchy, mixed echodensity and hyperechoic sparkling areas and hyperechoic foci 1–2 cm in diameter. The hepatic lymph nodes were slightly enlarged (0.5–1 cm in diameter). A small quantity of free peritoneal fluid was detected.

A few attempts to retrieve the abdominal fluid were made but only a small quantity of blood (0.1 ml) was collected. It was thought to be iatrogenic as it clotted.

A fine needle aspirate (FNA) of the liver was performed (**Fig. 2.1**). There were some clusters of hepatocytes with some extracellular purple-staining material. A few non-degenerate neutrophils were also detected.

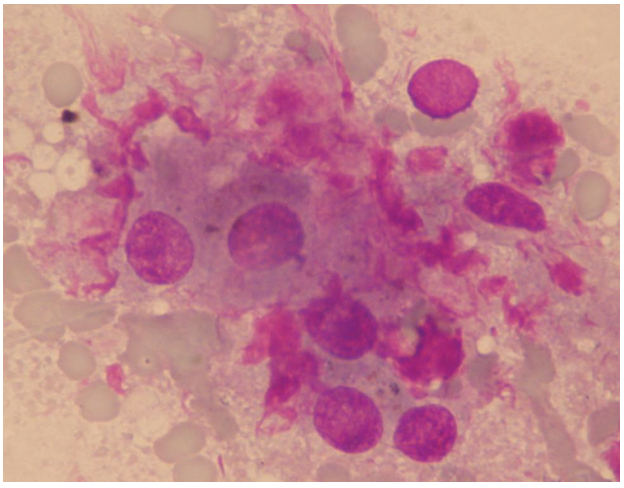

FIG. 2.1 Hepatic aspirate from this Havana cat. Wright–Giemsa, ×100 (oil).

QUESTIONS

1. What is your evaluation of the laboratory data?
2. What is your diagnosis/interpretation for this case?
3. What pathophysiology is likely underlying the findings in this case?
4. What other tests would you recommend performing, and why?

CASE 3

A 15-month-old male Border Collie presented with a history of occasional vomiting over the preceding 5 days.

EXAMINATION FINDINGS

No abnormalities were detected on clinical examination and the patient was treated with maropitant citrate monohydrate. The following day the dog was anorexic. On day 2 the dog was dehydrated (7%); T = 35.1°C (95°F); HR = 48 bpm.

HAEMATOLOGY

Measurand (units)	Result (Day 2)	Reference Interval
RBC count (10^{12}/l)	**8.93**	5.4–8.5
Haemoglobin (g/l)	**217**	120–180
Haematocrit (l/l)	**0.63**	0.37–0.56
MCV (fl)	70	67–75
MCHC (g/l)	340	310–350
Platelet count (10^9/l)	304	200–900
WBC count (10^9/l)	10.4	5–18
Neutrophils (10^9/l)	6.34	3.7–13.32
Lymphocytes (10^9/l)	2.7	1.00–3.60
Monocytes (10^9/l)	0.31	0.00–0.72
Eosinophils (10^9/l)	1.04	0.00–1.25
Blood film examination	No abnormalities noted	

BIOCHEMISTRY

Analyte (units)	Result (Day 2)	Reference Interval
Total protein (g/l)	60	55–75
Albumin (g/l)	31	29–35
Globulins (g/l)	29	18–38
ALP (U/l)	73	0–135 (Adult)
ALT (U/l)	**57**	0–40
GGT (U/l)	3	0–14
Total bilirubin (µmol/l)	1.0	0–5.0
Glucose (mmol/l)	3.2	3.0–5.5
Urea (mmol/l)	**41.8**	3.5–7.0
Creatinine (µmol/l)	**389**	0–130
Phosphorus (mmol/l)	**3.1**	0.9–1.6
Calcium (mmol/l)	**3.19**	2.3–3.0
Chloride (mmol/l)	95	95–117
Sodium (mmol/l)	**128**	135–150
Potassium (mmol/l)	**8**	3.5–5.6
Sodium:potassium ratio	**16:1**	>27:1

OTHER INVESTIGATIONS

Item	Result	Reference Interval
USG	**1.021**	>1.030
ECG	No P waves identified	

ACTH STIMULATION TEST

Analyte (units)	Result	Reference Interval
Basal cortisol (nmol/l)	**<28**	28–125
Cortisol post ACTH* (nmol/l)	**<28**	125–520

* Sample collected 60 minutes after an IV injection of 250 µg of tetracosactide, a synthetic analogue of ACTH.

QUESTIONS

1 What is your evaluation of the laboratory data?
2 How might prior therapy affect confirmation of the diagnosis?
3 Briefly outline the pathophysiology underlying these laboratory abnormalities.

CASE 4

A 7-year-old female neutered mixed-breed dog presented because she had diarrhoea for the past several days.

EXAMINATION FINDINGS

There was mild discomfort in the abdomen as well as dry mucous membranes.

ACID–BASE AND BLOOD GAS DATA

Analyte (units)	Result	Reference Interval
Arterial pH	**7.24**	7.36–7.44
$PaCO_2$ (mmHg)	**24**	36–44
PaO_2 (mmHg)	95	85–95
Plasma HCO_3^- (mmol/l)	**10**	18–26
Serum Na^+ (mmol/l)	145	145–155
Serum K^+ (mmol/l)	**6.5**	4–5
Serum Cl^- (mmol/l)	**124**	105–115
Anion gap	?	15–25

QUESTIONS

1 What is the anion gap (AG) in this case?
2 What is your assessment of the arterial pH?
3 What is your assessment of the likely underlying aetiology?
4 Is there appropriate compensation for this condition?
5 Why is the K^+ increased in this case?
6 Why is the Cl^- increased in this case?
7 What is a likely underlying aetiological mechanism for metabolic acidosis?

CASE 5

A 14-year-old female neutered mixed-breed dog presented with vomiting and anorexia of 2 days' duration.

EXAMINATION FINDINGS

The dog was lethargic and demonstrated markedly icteric sclerae (**Fig. 5.1**), mucous membranes and skin. Rectal examination revealed pale mud-coloured faeces.

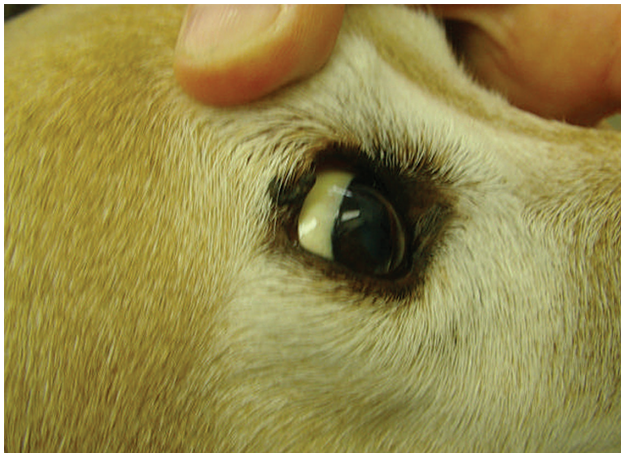

FIG. 5.1 Note the markedly icteric sclera of this dog.

HAEMATOLOGY

Unremarkable.

BIOCHEMISTRY

Analyte (units)	Result	Reference Interval
Total protein (g/l)	69.5	55–70
Albumin (g/l)	31.4	30–37
Globulins (g/l)	**38.1**	23–36
Glucose (mmol/l)	4.66	3.3–6.5
Bilirubin (µmol/l)	**156.82**	<3.6
Cholesterol (mmol/l)	**19.11**	3.3–8.6
Triglycerides (mmol/l)	**1.39**	<0.75
ALP (U/l)	**3,674**	<131
ALT (U/l)	**5,833**	<85
GLDH (U/l)	**1,010**	<10
Urea (mmol/l)	3.3	3.03–9.82
Creatinine (µmol/l)	110	53–123
Sodium (mmol/l)	**144**	147–152
Chloride (mmol/l)	**99**	102–110
Potassium (mmol/l)	3.6	3.35–4.37
Ionised calcium (mmol/l)	1.29	1.23–1.43
Phosphate (mmol/l)	1.56	0.79–2.1

QUESTIONS

1 Describe and discuss the significant biochemistry findings, and give the most likely cause of the icterus.
2 What further examinations are recommended to determine the aetiology of the disease in this dog?

CASE 6

An 11-year-old male neutered DSH cat has a history of vaccination against calicivirus, herpesvirus, panleukopaenia and feline leukaemia virus and deworming being up to date. The owner says the cat is acting a little strange and is foaming at the mouth. The owner wants to leave the cat at the clinic for the day for observation. The cat has a previous history of cardiomyopathy and is being treated with diltiazem extended release (30 mg daily).

EXAMINATION FINDINGS

T = 38.3°C (101°F); weight = 4.65 kg (10 lb); HR = 200 bpm; RR = 34 bpm; mucous membranes pale; grade IV/VI heart murmur.

HAEMATOLOGY

Measurand (units)	Result	Reference Interval
RBC count (10^{12}/l)	**1.83**	5–10
Haemoglobin (g/l)	**32.5**	80–150
Haematocrit (l/l)	**0.11**	0.30–0.45
MCV (fl)	**60.6**	39–55
MCH (pg)	**17.7**	12.5–17.5
MCHC (g/l)	**293**	320–360
Aggregated reticulocytes (10^9/l)	**90**	0–60
Platelet count (10^9/l)	**100 (clumped)**	190–400
WBC count (10^9/l)	13.1	5.5–19.5
Neutrophils (10^9/l)	10.03	2.5–12.5
Lymphocytes (10^9/l)	**0.826**	1.5–7.0
Eosinophils (10^9/l)	0	0–1.5
Monocytes (10^9/l)	**0.944**	0.0–0.85
Basophils (10^9/l)	0	Rare
NRBCs (per 100 WBCs)	**3**	Rare

BLOOD SMEAR EVALUATION

3+ polychromasia; 2+ anisocytosis; 1+ autoagglutination.

INFECTIOUS DISEASES TESTS

Test	Result
FIV antibodies (ELISA)	Negative
FeLV antigen (ELISA)	Negative
FCoV antibodies (IFA)	Negative

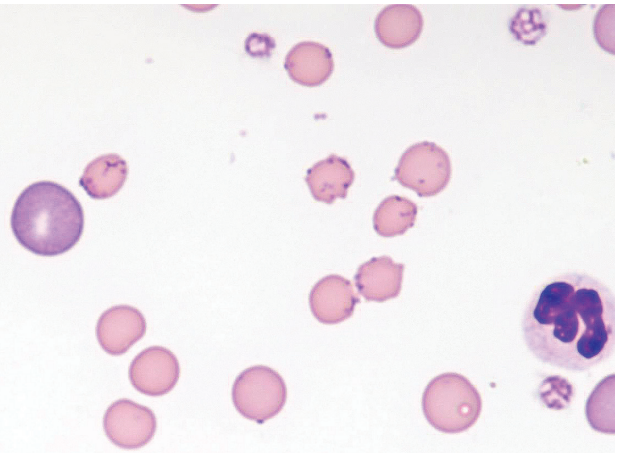

FIG. 6.1 Photomicrograph of the blood smear. Wright–Giemsa, ×100 (oil).

QUESTIONS

1 Does the anaemia appear regenerative?
2 What is the significance of the blood smear picture?

CASE 7

A 9-year-old female cat was recently diagnosed with lymphoma. She is now presented for a regular check before treatment is instituted. A blood smear is prepared from the cat (Fig. 7.1).

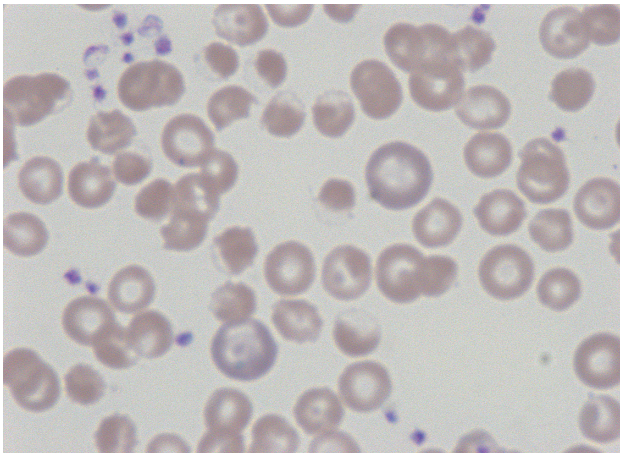

FIG. 7.1 Erythrocytes shown on a blood smear from a cat. May–Grünwald–Giemsa, ×100 (oil).

QUESTIONS

1 Name the abnormality visible in the blood smear.
2 List possible reasons for this finding for dogs, cats, and horses. What is the reason in this case?
3 Describe the underlying pathological mechanism leading to this finding.

CASE 8

A 12-year-old male neutered DSH cat presented for a routine annual health check.

HAEMATOLOGY

Measurand (units)	Result	Reference Interval
RBC count (10^{12}/l)	**4.7**	5–10
Haemoglobin (g/l)	**127**	49–93
Haematocrit (l/l)	**0.18**	0.24–0.45
MCV (fl)	**39.6**	40–55
MCH (pg)	**27.02**	19.5–27.0
MCHC (g/l)	**705**	184–220
Platelet count (10^9/l)	198	180–550
WBC count (10^9/l)	14.8	6–18
Neutrophils (10^9/l)	**13.59**	2.5–12.5
Lymphocytes (10^9/l)	0.84	1.5–7.0
Monocytes (10^9/l)	0.31	0.0–0.9
Eosinophils (10^9/l)	0.07	0.0–1.5
Basophils (10^9/l)	0.01	0.0–0.4

BIOCHEMISTRY

Analyte (units)	Result	Reference Interval
Total protein (g/l)	74.5	54.7–78.0
Albumin (g/l)	29.7	21–33
Globulins (g/l)	49.9	26–51
Glucose (mmol/l)	**31.2**	3.89–6.11
ALP (U/l)	37.3	0–39.7
ALT (U/l)	55	0–70
Urea (mmol/l)	9.65	7.14–10.7
Creatinine (µmol/l)	152	0–168
Sodium (mmol/l)	149	147–156
Chloride (mmol/l)	117	115–130
Potassium (mmol/l)	4.2	3.6–4.8
Ionised calcium (mmol/l)	1.21	1.17–1.32
Phosphate (mmol/l)	**5.1**	0.8–1.9

BLOOD SMEAR EVALUATION

Shows slight anisocytosis of the RBCs. Neutrophils occasionally display small Döhle bodies. Rare platelet clumps are detected in the feathered edge.

QUESTIONS

1. What is the most likely explanation for the laboratory abnormalities?
2. State and explain the causes for an increased MCHC.
3. How do you explain the biochemistry changes in light of the abnormalities discussed in the first two questions?

CASE 9

A 5-year-old male neutered cross-breed dog had accidental access to the psoriasis cream used by his owner. He now has PU/PD.

HAEMATOLOGY

Unremarkable.

BIOCHEMISTRY

Analyte (units)	Result	Reference Interval
Total protein (g/l)	**77**	55–75
Albumin (g/l)	**45**	25–40
Globulins (g/l)	32	23–35
Glucose (mmol/l)	6	3.3–6.5
ALP (U/l)	112	0–130
ALT (U/l)	69	0–85
Urea (mmol/l)	**12.2**	3.3–8.0

Analyte (units)	Result	Reference Interval
Creatinine (µmol/l)	**158**	45–150
Sodium (mmol/l)	148	135–155
Chloride (mmol/l)	113	105–120
Potassium (mmol/l)	4	3.35–4.37
Total calcium (mmol/l)	**3.55**	2.30–2.80
Ionised calcium (mmol/l)	**1.86**	1.18–1.40
Phosphate (mmol/l)	**1.52**	0.78–1.41

URINALYSIS

Item	Result	Reference Interval
Colour	Straw colour	Yellow
Turbidity	Slightly cloudy	Clear
USG	**1.006**	>1.030
Dipstick evaluation		
pH	5.5	
Protein	Trace	Negative to trace
Glucose	Negative	Negative
Ketone bodies	Negative	Negative
Bilirubin	Negative	Negative
Blood	Negative	Negative

QUESTIONS

1 Is this azotaemia likely to be pre-renal, renal or post-renal? Why?
2 How would you explain the low USG?
3 Explain the possible cause of the reported hypercalcaemia.
4 What is your diagnosis?

CASE 10

A 3-year-old male West Highland White Terrier was admitted to the hospital 2 days ago.

EXAMINATION FINDINGS

At admission the dog was lethargic, with clinical signs of systemic inflammatory response (febrile, increased HR and RR). Pancreatitis was diagnosed and treatment initiated. Forty-eight hours later dog had not clinically improved significantly, he was bleeding from venipuncture sites and development of a consumptive coagulopathy (DIC) was suspected.

SELECTED LABORATORY TEST RESULTS

At admission

Measurand (units)	Result	Reference Interval
RBC count (10^{12}/l)	**4.2**	4.6–8.4
Haemoglobin (l/l)	120	119–190
Haematocrit (l/l)	**0.35**	0.39–0.59
Platelet count (10^9/l)	**105**	200–500
WBC count (10^9/l)	**27.2**	6.5–18.1
Neutrophils (10^9/l)	**20.5**	3.2–12.1
Band neutrophils (10^9/l)	**1.0**	<0.3
Lymphocytes (10^9/l)	4.5	1–4.8
Monocytes (10^9/l)	0.6	0–1.2
Eosinophils (10^9/l)	0.6	0–1.2
Basophils (10^9/l)	0	0–0.05
C-reactive protein (mg/l)	**135**	<35
Fibrinogen (g/l)	1.2	1–4

Present (48 hours)

Measurand (units)	Result	Reference Interval
RBC count (10^{12}/l)	**4.4**	4.6–8.4
Haemoglobin (l/l)	**101**	119–190
Haematocrit (l/l)	**0.34**	0.39–0.59
Platelet count (10^9/l)	**87**	200–500
WBC count (10^9/l)	**25.2**	6.5–18.1
Neutrophils (10^9/l)	**18.4**	3.2–12.1
Band neutrophils (10^9/l)	**1.2**	<0.3
Lymphocytes (10^9/l)	4.1	1–4.8
Monocytes (10^9/l)	0.6	0–1.2
Eosinophils (10^9/l)	0.9	0–1.2
Basophils (10^9/l)	0	0–0.05
C-reactive protein (mg/l)	**140**	<35
Fibrinogen (g/l)	**0.8**	1–4
aPTT (seconds)	**14**	10–13
PT (seconds)	**10**	7–9
D-dimer (mg/l)	**4.2**	<0.5

To confirm suspicion of DIC, the presence of (a) activation of coagulation, (b) inhibitor consumption and (c) increased fibrinolytic activity has to be demonstrated along with an obvious clinical cause.

QUESTION

1 Are all these aspects demonstrated in the clinical history and laboratory tests to confirm suspicion of DIC?

CASE 11

A 5-year-old male neutered DSH cat presented because of a few episodes of feline lower urinary tract disease (FLUTD).

URINALYSIS

Item	Result	Reference Interval
Colour	Light yellow	Variable
Transparency	**Turbid**	Clear
USG	1.035	1.020–1.060
Dipstick evaluation		
pH	6.5	Acidic
Protein	Negative	Traces
Ketone bodies	Negative	Negative
Bilirubin	Negative	Negative
Blood	+	Negative

Urine sediment analysis
See **Fig. 11.1**.

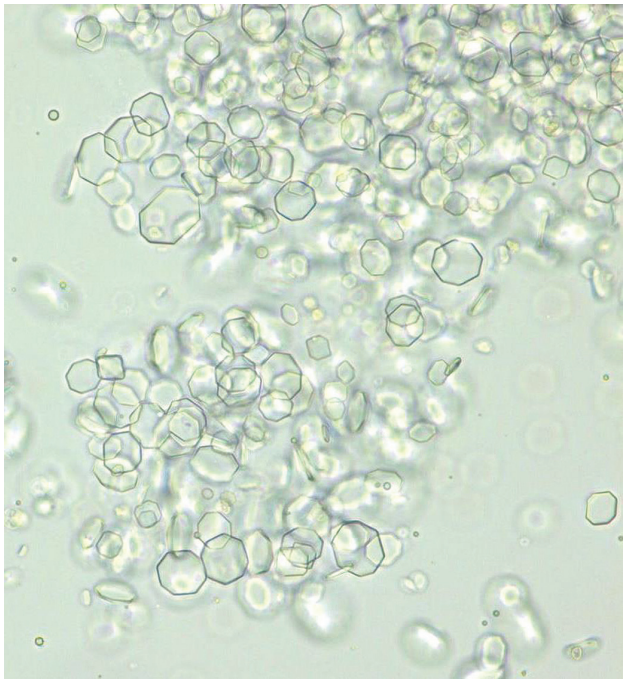

FIG. 11.1 Unstained urine sediment. ×40. (Courtesy Dr Judith Leidinger)

QUESTIONS

1 What crystals can be seen on the picture?
2 What is the most important differential diagnosis?
3 How can you differentiate between these two types of crystals?
4 What do the crystals shown indicate?

CASE 12

A 1-year-old male Cocker Spaniel presents for lethargy and anorexia.

HAEMATOLOGY

The MCV, MCH, MCHC and platelet count are within normal limits.

Measurand (units)	Result	Reference Interval
RBC count (10^{12}/l)	**4.62**	5.5–8.5
Haemoglobin (g/l)	**94**	130–195
Haematocrit (l/l)	**0.31**	0.37–0.55
WBC count (10^9/l)	**28.5**	6–17
Neutrophils (10^9/l)	**21.38**	3.0–11.5
Band neutrophils (10^9/l)	**0.57**	0–0.5
Lymphocytes (10^9/l)	**4.28**	1.0–3.6
Monocytes (10^9/l)	0.86	0.04–1.35
Basophils (10^9/l)	0	0.0–0.4
Eosinophils (10^9/l)	**1.43**	0.0–1.25

BIOCHEMISTRY

Analyte (units)	Result	Reference Interval
Total protein (g/l)	**51.3**	54–71
Albumin (g/l)	**20.8**	26–33
Globulins (g/l)	30.4	27–44
Glucose (mmol/l)	6.29	3.66–6.31
Total bilirubin (µmol/l)	0.5	0–3.4
Cholesterol (mmol/l)	**7.98**	3.5–7.0
Triglycerides (mmol/l)	0.56	0.29–3.88
ALP (U/l)	27	0–97
ALT (U/l)	33	0–55
GLDH (U/l)	8	0–12
Urea (mmol/l)	**14.97**	3.57–8.57
Creatinine (µmol/l)	**177**	35–106
Sodium (mmol/l)	150	141–152

Analyte (units)	Result	Reference Interval
Chloride (mmol/l)	113	100–120
Potassium (mmol/l)	4.2	3.6–5.35
Ionised calcium (mmol/l)	1.3	1.16–1.31
Phosphate (mmol/l)	**3.7**	0.7–1.6

URINALYSIS

Item	Result	Reference Interval
USG	**1.010**	>1.030
Urine protein (mg/l)	**2,164**	0–1,000
Dipstick evaluation		
pH	6.5	Acidic
Bilirubin	Negative	Negative to trace
Blood	Negative	Negative
Glucose	Negative	Negative
Ketone bodies	Negative	Negative
Protein	**3+**	Negative
Protein:creatinine ratio	**9.8**	<0.2
Sediment analysis		
Erythrocytes	<5	0–5/hpf
Leucocytes	<5	0–5/hpf
Epithelial cells	None	Rare/lpf
Crystals	None	Variable/lpf
Casts	None	Variable/lpf
Bacteria	None	None

QUESTIONS

1 Describe and discuss the laboratory abnormalities. What is the most likely diagnosis?
2 How is this diagnosis defined?

CASE 13

A 10-year-old male neutered cross-breed dog presented for lethargy and weight loss.

EXAMINATION FINDINGS

No abnormalities other than a thin body condition were identified.

BIOCHEMISTRY

Analyte (units)	Result	Reference Interval
Total protein (g/l)	84	56–72
Albumin (g/l)	23	27–38
Globulins (g/l)	61	22–36

OTHER TESTS

Agarose gel serum protein electrophoresis was performed (**Figs. 13.1, 13.2**).

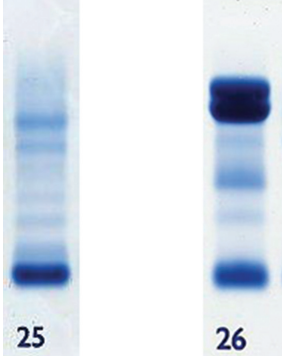

FIG. 13.1 Stained agarose gel electrophoresis. Albumin band is at the bottom of the gel. Left gel (25) is from a dog that is within normal limits. Right gel (26) is from this patient.

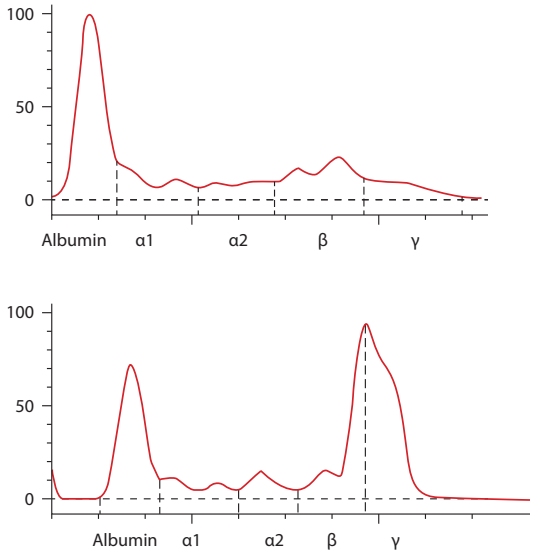

FIG. 13.2 Densitometry tracing of agarose gel. Top tracing is from a dog that is within normal limits. Bottom tracing is from this patient.

QUESTIONS

1 What is your interpretation of the agarose gel serum protein electrophoresis?
2 What are the differential diagnoses in this case?
3 What other type of serum protein electrophoresis may be helpful in confirming the finding suggested by the agarose gel electrophoresis?

CASE 14

A 10-year-old female neutered Siamese cat had been lethargic for several weeks and had a decreased appetite. Additionally, the owners noted mild weight loss.

EXAMINATION FINDINGS

Examination revealed a mild discomfort in the cranial abdominal region. A parasitological faecal examination was unremarkable.

HAEMATOLOGY

Unremarkable.

BIOCHEMISTRY

Analyte (units)	Result	Reference Interval
Total protein (g/l)	**52.4**	54.7–78.0
Albumin (g/l)	**20.9**	21–33
Globulins (g/l)	31.5	26–51
Glucose (mmol/l)	**15.4**	3.89–6.11
Total bilirubin (µmol/l)	**8**	<3.4
ALP (U/l)	**42.3**	0–39.7
ALT (U/l)	**95**	0–70
Urea (mmol/l)	**12.3**	7.14–10.7
Creatinine (µmol/l)	**192**	0–168
Sodium (mmol/l)	155	147–156
Chloride (mmol/l)	124	115–130
Potassium (mmol/l)	4.7	3.6–4.8
Ionised calcium (mmol/l)	1.22	1.17–1.32
Phosphate (mmol/l)	**2.1**	0.8–1.9
fPLI (µg/l)	**249**	2.0–6.1

QUESTIONS

1 What is the most likely explanation for the laboratory abnormalities? Describe the pathomechanism.
2 What further analyses would you recommend, and why?

CASE 15

The owner of a 17-year-old Cob gelding asked for a health check on his horse because it was losing weight and had an oculonasal discharge.

EXAMINATION FINDINGS

The rectal temperature was 40°C (104°F) and the submandibular and prescapular lymph nodes were moderately enlarged.

HAEMATOLOGY

Measurand (units)	Result	Reference Interval
RBC count (10^{12}/l)	**4.61**	5.5–9.5
Haemoglobin (g/l)	83	80–140
Haematocrit (l/l)	**0.23**	0.24–0.45
MCV (fl)	50	40–56
MCHC (g/l)	363	340–380
WBC count (10^9/l)	**21.2**	6–12
Neutrophils (10^9/l)	**12.29**	3.0–6.3
Band neutrophils (10^9/l)	0	0–0.17
Lymphocytes (10^9/l)	**7.21**	1.3–4.3
Monocytes (10^9/l)	**1.7**	0–1.0
Eosinophils (10^9/l)	0	0–1.0
Basophils (10^9/l)	0	0–0.3
Fibrinogen (g/l) (heat precipitation method)	**4.2**	2–4