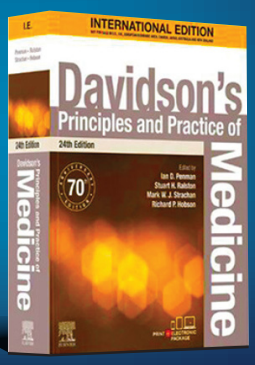
LABORATORY REFERENCE RANGES



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Notes on the international system of units (SI units)

Système International (SI) units are a specific subset of the metre–kilogram–second system of units and were agreed on as the everyday currency for commercial and scientific work in 1960, following a series of international conferences organised by the International Bureau of Weights and Measures. SI units have been adopted widely in clinical laboratories but non-SI units are still used in many countries. For that reason, values in both units are given for common measurements throughout this textbook and commonly used non-SI units are shown in this chapter. The SI unit system is, however, recommended.

Examples of basic SI units

Length	metre (m)
Mass	kilogram (kg)
Amount of substance	mole (mol)
Energy	joule (J)
Pressure	pascal (Pa)
Volume	The basic SI unit of volume is the cubic metre (1000 litres). For convenience, however, the litre (L) is used as the unit of volume in laboratory work.

Examples of decimal multiples and submultiples of SI units

Factor	*Name*	*Prefix*
10^{6}	mega-	M
10^{3}	kilo-	k
10^{-1}	deci-	d
10^{-2}	centi-	c
10^{-3}	milli-	m
10^{-6}	micro-	µ
10^{-9}	nano-	n
10^{-12}	pico-	p
10^{-15}	femto-	f

Exceptions to the use of SI units

By convention, blood pressure is excluded from the SI unit system and is measured in mmHg (millimetres of mercury) rather than pascals.

Mass concentrations such as g/L and µg/L are used in preference to molar concentrations for all protein measurements and for substances that do not have a sufficiently well-defined composition.

Some enzymes and hormones are measured by 'bioassay', in which the activity in the sample is compared with the activity (rather than the mass) of a standard sample that is provided from a central source. For these assays, results are given in standardised 'units' (U/L), or 'international units' (IU/L), which depend on the activity in the standard sample and may not be readily converted to mass units.

Laboratory reference ranges in adults

Reference ranges are largely those used in the Departments of Clinical Biochemistry and Haematology, Lothian Health University Hospitals Division, Edinburgh, UK. Values are shown in both SI units and, where appropriate, non-SI units. Many reference ranges vary between laboratories, depending on the assay method used and on other factors; this is especially the case for enzyme assays. The origin of reference ranges and the interpretation of 'abnormal' results are discussed on page 3. No details are given here of the collection requirements, which may be critical to obtaining a meaningful result. Unless otherwise stated, reference ranges shown apply to adults; values in children may be different.

Many analytes can be measured in either serum (the supernatant of clotted blood) or plasma (the supernatant of anticoagulated blood). A specific requirement for one or the other may depend on a kit manufacturer's recommendations. In other instances, the distinction is critical. An example is fibrinogen, where plasma is required, since fibrinogen is largely absent from serum. In contrast, serum is required for electrophoresis to detect paraproteins because fibrinogen migrates as a discrete band in the zone of interest.

i 1. Urea and electrolytes in venous blood

	Reference range	
Analysis	**SI units**	**Non-SI units**
Sodium	135–145 mmol/L	135–145 mEq/L
Potassium*	3.6–5.0 mmol/L	3.6–5.0 mEq/L
Chloride	95–107 mmol/L	95–107 mEq/L
Urea	2.5–6.6 mmol/L	15–40 mg/dL
Creatinine		
Male	64–111 µmol/L	0.72–1.26 mg/dL
Female	50–98 µmol/L	0.57–1.11 mg/dL

*Serum values are, on average, 0.3 mmol/L higher than plasma values.

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i 2. Analytes in arterial blood

	Reference range	
Analysis	**SI units**	**Non-SI units**
Bicarbonate	21–29 mmol/L	21–29 mEq/L
Hydrogen ion	37–45 nmol/L	pH 7.35–7.43
***Pa*CO_2**	4.5–6.0 kPa	34–45 mmHg
***Pa*O_2**	12–15 kPa	90–113 mmHg
Oxygen saturation	>97%	

3. Hormones in venous blood

Hormone	Reference range	
	SI units	Non-SI units
Adrenocorticotrophic hormone (ACTH) (plasma)	1.5–13.9 pmol/L (0700–1000 hrs)	63 ng/L
Aldosterone		
Supine (at least 30 mins)	30–440 pmol/L	1.09–15.9 ng/dL
Erect (at least 1 hr)	110–860 pmol/L	3.97–31.0 ng/dL
Cortisol	Dynamic tests are required – see Box 18.53, p. 680	
Follicle-stimulating hormone (FSH)		
Male	1.0–10.0 IU/L	–
Female	3.0–10.0 IU/L (early follicular)	–
	>30 IU/L (post-menopausal)	–
Gastrin (plasma, fasting)	<40 pmol/L	<83 pg/mL
Growth hormone (GH)	Dynamic tests are usually required – see Box 18.55, p. 682	
	<0.5 μg/L excludes acromegaly (if insulin-like growth factor 1 (IGF-1) in reference range)	<2 mIU/L
	>6 μg/L excludes GH deficiency	>18 mIU/L
Insulin	Highly variable and interpretable only in relation to plasma glucose and body habitus	
Luteinising hormone (LH)		
Male	1.0–9.0 IU/L	–
Female	2.0–9.0 IU/L (early follicular)	–
	>20 IU/L (post-menopausal)	–
17β-Oestradiol		
Male	<160 pmol/L	<43 pg/mL
Female: early follicular	75–140 pmol/L	20–38 pg/mL
post-menopausal	<150 pmol/L	<41 pg/mL
Parathyroid hormone (PTH)	1.6–6.9 pmol/L	16–69 pg/mL
Progesterone (in luteal phase in women)		
Consistent with ovulation	>30 nmol/L	>9.3 ng/mL
Probable ovulatory cycle	15–30 nmol/L	4.7–9.3 ng/mL
Anovulatory cycle	<10 nmol/L	<3 ng/mL
Prolactin (PRL)	60–500 mIU/L	2.8–23.5 ng/mL
Renin concentration		
Supine (at least 30 mins)	5–40 mIU/L	–
Sitting (at least 15 mins)	5–45 mIU/L	–
Erect (at least 1 hr)	16–63 mIU/L	–
Testosterone		
Male	10–38 nmol/L	290–1090 ng/dL
Female	0.3–1.9 nmol/L	10–90 ng/dL
Thyroid-stimulating hormone (TSH)	0.2–4.5 mIU/L	–
Thyroxine (free), (free T_4)	9–21 pmol/L	0.7–1.63 ng/dL
Triiodothyronine (free), (free T_3)	2.6–6.2 pmol/L	0.16–0.4 ng/dL

Notes

1. A number of hormones are unstable and collection details are critical to obtaining a meaningful result. Refer to local laboratory handbook.
2. Values in the table are only a guideline; hormone levels can often be meaningfully understood only in relation to factors such as gender, age, time of day, pubertal status, stage of the menstrual cycle, pregnancy and menopausal status.
3. Reference ranges are usually dependent on the method used for analysis and frequently differ between laboratories. Non-SI units also differ; those shown here are amongst those most widely used. Readers are encouraged to consult their local laboratory for non-SI units for individual analytes and their respective reference ranges.

i 4. Other common analytes in venous blood

Analyte	Reference range	
	SI units	Non-SI units
α_1-antitrypsin	1.1–2.1 g/L	110–210 mg/dL
Alanine aminotransferase (ALT)	10–50 U/L	–
Albumin	35–50 g/L	3.5–5.0 g/dL
Alkaline phosphatase (ALP)	40–125 U/L	–
Amylase	<100 U/L	–
Aspartate aminotransferase (AST)	10–45 U/L	–
Bile acids (fasting)	<14 µmol/L	–
Bilirubin (total)	3–16 µmol/L	0.18–0.94 mg/dL
Calcium (total)	2.1–2.6 mmol/L	4.2–5.2 mEq/L or 8.5–10.5 mg/dL
Carboxyhaemoglobin	0.1–3.0% Levels of up to 8% may be found in heavy smokers	–
Caeruloplasmin	0.16–0.47 g/L	16–47 mg/dL
Cholesterol (total)	Ideal level varies according to cardiovascular risk (see cardiovascular risk chart, p. 511)	
HDL-cholesterol	Ideal level varies according to cardiovascular risk, so reference ranges can be misleading. According to the National Cholesterol Education Programme Adult Treatment Panel III (ATPIII), a low HDL-cholesterol is <1.0 mmol/L (<40 mg/dL)	
Complement		
C3	0.81–1.57 g/L	–
C4	0.13–1.39 g/L	–
Total haemolytic complement	0.086–0.410 g/L	–
Copper	10–22 µmol/L	64–140 µg/dL
C-reactive protein (CRP)	<5 mg/L Highly sensitive CRP assays also exist that measure lower values and may be useful in estimating cardiovascular risk	
Creatine kinase (CK; total)		
Male	55–170 U/L	–
Female	30–135 U/L	–
Creatine kinase MB isoenzyme	<6% of total CK	–
Ethanol	Not normally detectable	
Marked intoxication	65–87 mmol/L	300–400 mg/dL
Stupor	87–109 mmol/L	400–500 mg/dL
Coma	>109 mmol/L	>500 mg/dL

Analyte	Reference range	
	SI units	Non-SI units
γ-glutamyl transferase (GGT)	Male 10–55 U/L Female 5–35 U/L	–
Glucose (fasting)	3.6–5.8 mmol/L See page 722 for definitions of impaired glucose tolerance and diabetes mellitus, and page 738 for definition of hypoglycaemia	65–104 mg/dL
Glycated haemoglobin (HbA_{1c})	4.0–6.0% 20–42 mmol/mol Hb See page 722 for diagnosis of diabetes mellitus	–
Immunoglobulins (Ig)		
IgA	0.8–4.5 g/L	–
IgE	0–250 kU/L	–
IgG	6.0–15.0 g/L	–
IgM	0.35–2.90 g/L	–
Lactate	0.6–2.4 mmol/L	5.4–21.6 mg/dL
Lactate dehydrogenase (LDH; total)	125–220 U/L	–
Lead	<0.5 µmol/L	<10 µg/dL
Magnesium	0.75–1.0 mmol/L	1.5–2.0 mEq/L or 1.82–2.43 mg/dL
Osmolality	280–296 mOsmol/kg	–
Osmolarity	280–296 mOsmol/L	–
Phosphate (fasting)	0.8–1.4 mmol/L	2.48–4.34 mg/dL
Protein (total)	60–80 g/L	6–8 g/dL
Triglycerides (fasting)	0.6–1.7 mmol/L	53–150 mg/dL
Troponins	Values consistent with myocardial infarction are crucially dependent on which troponin is measured (I or T) and on the method employed. Interpret in context of clinical presentation. See page 450	
Tryptase	0–135 mg/L	–
Urate		
Male	0.12–0.42 mmol/L	2.0–7.0 mg/dL
Female	0.12–0.36 mmol/L	2.0–6.0 mg/dL
Vitamin D (25(OH)D)		
Normal	>50 nmol/L	>20 ng/mL
Insufficiency	25–50 nmol/L	10–20 ng/ml
Deficiency	<25 nmol/L	<10 ng/mL
Zinc	10–18 µmol/L	65–118 µg/dL

5. Common analytes in urine

Analyte	Reference range	
	SI units	Non-SI units
Albumin	Definitions of microalbuminuria are given on page 394 Proteinuria is defined below	
Calcium (normal diet)	Up to 7.5 mmol/24 hrs	Up to 15 mEq/24 hrs or 300 mg/24 hrs
Copper	<0.6 µmol/24 hrs	<38 µg/24 hrs
Cortisol	20–180 nmol/24 hrs	7.2–65 µg/24 hrs
Creatinine Male Female	 6.3–23 mmol/24 hrs 4.1–15 mmol/24 hrs	 712–2600 mg/24 hrs 463–1695 mg/24 hrs
5-Hydroxyindole-3-acetic acid (5-HIAA)	10–42 µmol/24 hrs	1.9–8.1 mg/24 hrs
Metadrenalines Normetadrenaline Metadrenaline	 0.4–3.4 µmol/24 hrs 0.3–1.7 µmol/24 hrs	 73–620 µg/24 hrs 59–335 µg/24 hrs
Oxalate	0.04–0.49 mmol/24 hrs	3.6–44 mg/24 hrs
Phosphate	15–50 mmol/24 hrs	465–1548 mg/24 hrs
Potassium*	25–100 mmol/24 hrs	25–100 mEq/24 hrs
Protein	<0.3 g/L	<0.03 g/dL
Sodium*	100–200 mmol/24 hrs	100–200 mEq/24 hrs
Urate	1.2–3.0 mmol/24 hrs	202–504 mg/24 hrs
Urea	170–600 mmol/24 hrs	10.2–36.0 g/24 hrs
Zinc	3–21 µmol/24 hrs	195–1365 µg/24 hrs

*The urinary output of electrolytes such as sodium and potassium is normally a reflection of dietary intake. This can vary widely. The values quoted are appropriate to a 'Western' diet.

6. Analytes in cerebrospinal fluid

Analysis	Reference range	
	SI units	Non–SI units
Cells	$<5\times10^6$ cells/L (all mononuclear)	<5 cells/mm^3
Glucose[1]	2.3–4.5 mmol/L	41–81 mg/dL
IgG index[2]	<0.65	–
Total protein	0.14–0.45 g/L	0.014–0.045 g/dL

[1]Interpret in relation to plasma glucose. Values in CSF are typically approximately two-thirds of plasma levels. [2]A crude index of increase in IgG attributable to intrathecal synthesis.

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7. Analytes in faeces

Analyte	Reference range	
	SI units	Non-SI units
Calprotectin	<50 µg/g	–
Elastase	>200 µg/g	–

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8. Haematological values

Analysis	Reference range	
	SI units	Non-SI units
Bleeding time (Ivy)	<8 mins	–
Blood volume		
Male	65–85 mL/kg	–
Female	60–80 mL/kg	–
Coagulation screen		
Prothrombin time (PT)	10.5–13.5 secs	–
Activated partial thromboplastin time (APTT)	26–36 secs	–
D-dimers		
Interpret in relation to clinical presentation	<200 ng/mL	–
Erythrocyte sedimentation rate (ESR)	Higher values in older patients are not necessarily abnormal	
Adult male	0–10 mm/hr	–
Adult female	3–15 mm/hr	–
Ferritin		
Male (and post-menopausal female)	20–300 µg/L	20–300 ng/mL
Female (pre-menopausal)	15–200 µg/L	15–200 ng/mL
Fibrinogen	1.5–4.0 g/L	0.15–0.4 g/dL
Folate		
Serum	2.8–20 µg/L	2.8–20 ng/mL
Red cell	120–500 µg/L	120–500 ng/mL
Haemoglobin		
Male	130–180 g/L	13–18 g/dL
Female	115–165 g/L	11.5–16.5 g/dL
Haptoglobin	0.4–2.4 g/L	0.04–0.24 g/dL
Iron		
Male	14–32 µmol/L	78–178 µg/dL
Female	10–28 µmol/L	56–157 µg/dL
Leucocytes (adults)	$4.0–11.0\times10^9$/L	$4.0–11.0\times10^3$/mm^3
Differential white cell count		
Neutrophil granulocytes	$2.0–7.5\times10^9$/L	$2.0–7.5\times10^3$/mm^3
Lymphocytes	$1.5–4.0\times10^9$/L	$1.5–4.0\times10^3$/mm^3
Monocytes	$0.2–0.8\times10^9$/L	$0.2–0.8\times10^3$/mm^3
Eosinophil granulocytes	$0.04–0.4\times10^9$/L	$0.04–0.4\times10^3$/mm^3
Basophil granulocytes	$0.01–0.1\times10^9$/L	$0.01–0.1\times10^3$/mm^3
Mean cell haemoglobin (MCH)	27–32 pg	–
Mean cell volume (MCV)	78–98 fl	–
Packed cell volume (PCV) or haematocrit		
Male	0.40–0.54	–
Female	0.37–0.47	–
Platelets	$150–350\times10^9$/L	$150–350\times10^3$/mm^3
Red cell count		
Male	$4.5–6.5\times10^{12}$/L	$4.5–6.5\times10^6$/mm^3
Female	$3.8–5.8\times10^{12}$/L	$3.8–5.8\times10^6$/mm^3
Red cell lifespan		
Mean	120 days	–
Half-life (^{51}Cr)	25–35 days	–
Reticulocytes (adults)	$25–85\times10^9$/L	$25–85\times10^3$/mm^3
Transferrin	2.0–4.0 g/L	0.2–0.4 g/dL
Transferrin saturation		
Male	25–50%	–
Female	14–50%	–
Vitamin B_{12}		
Normal	>210 ng/L	–
Intermediate	180–200 ng/L	–
Low	<180 ng/L	–

Laboratory reference ranges in childhood and adolescence

The levels of many analytes in blood vary due to the physiological changes that occur during growth and adolescence. Hospital laboratories may provide reference ranges that are age-adjusted or based on pubertal stage but this is not always the case. It is therefore important for the doctor requesting these tests to understand the impact of age and puberty on interpretation of the results. For example, a creatinine of 70 µmol/L (0.79 mg/dL) is perfectly normal for the majority of adults but may indicate significant renal impairment in a child. Reference ranges for hormone results are described according to the Tanner stages of puberty (p. 1290).

9. Analytes that may be significantly affected by growth and puberty

Analyte	Age/Pubertal stage	Gender	Reference range
Alkaline phosphatase (ALP)	<1 year	M, F	80–580 U/L
	1–16 years	M, F	100–400 U/L
	16–20 years	M	50–250 U/L
		F	40–200 U/L
Creatinine	<1 year	M, F	12–39 µmol/L (0.14–0.44 mg/dL)
	1–4 years	M, F	13–42 µmol/L (0.15–0.48 mg/dL)
	4–12 years	M, F	20–57 µmol/L (0.23–0.64 mg/dL)
	12–15 years	M, F	31–67 µmol/L (0.35–0.76 mg/dL)
	15–18 years	M	39–92 µmol/L (0.44–1.04 mg/dL)
		F	34–72 µmol/L (0.38–0.81 mg/dL)
Follicle-stimulating hormone (FSH)	Prepubertal	M	<3.0 IU/L (<0.6 µg/L)
		F	<3.2 IU/L (<0.64 µg/L)
	Pubertal stage 2	M	<6.6 IU/L (<1.32 µg/L)
		F	<4.1 IU/L (<0.82 µg/L)
	Pubertal stage 3	M	0.7–5.0 IU/L (0.14–1 µg/L)
	Pubertal stages 4–5	M	1.5–6.0 IU/L (0.3–1.2 µg/L)
	Pubertal stages 3–5	F	2.5–13.5 IU/L (0.5–2.7 µg/L)
Insulin-like growth factor 1	<7 years	M	15–349 µg/L
		F	17–272 µg/L
	8–16 years	M	67–510 µg/L
		F	59–502 µg/L
Luteinising hormone (LH)	Prepubertal	M	<1.0 IU/L (<0.1 µg/L)
	Pubertal stage 2	M	<3.0 IU/L (<0.3 µg/L)
	Prepubertal and pubertal stage 2	F	<1.0 IU/L (<0.1 µg/L)
	Pubertal stage 3	M	1.0–4.0 IU/L (0.1–0.4 µg/L)
	Pubertal stages 4–5	M	1.0–5.0 IU/L (0.1–0.6 µg/L)
	Pubertal stages 3–5	F	1.0–8.0 IU/L (0.1–0.9 µg/L)
17β-Oestradiol	Prepubertal and pubertal stages 2–3	M	<75 pmol/L (<20 pg/mL)
	Prepubertal and pubertal stage 2	F	<100 pmol/L (<27 pg/mL)
	Pubertal stages 4–5	M	<130 pmol/L (<35 pg/mL)
	Pubertal stages 3–5	F	<150 pmol/L (<41 pg/mL)
Testosterone	Prepubertal	M	<0.5 nmol/L (<10 ng/dL)
		F	<0.6 nmol/L (<20 ng/dL)
	Pubertal stage 2	M	<10.6 nmol/L (<310 ng/dL)
		F	<1.4 nmol/L (<40 ng/dL)
	Pubertal stage 3	M	0.4–30 nmol/L (10–870 ng/dL)
	Pubertal stage 4	M	5.6–30 nmol/L (160–870 ng/dL)
	Pubertal stage 5	M	10–30 nmol/L (290–870 ng/dL)
	Pubertal stages 3–5	F	0.4–1.9 nmol/L (10–50 ng/dL)

*Non-SI equivalents are given in brackets where appropriate.

Laboratory reference ranges in pregnancy

The levels of many analytes in blood vary during pregnancy, when many hormonal and metabolic changes occur. The standard adult reference ranges may therefore not be appropriate and it is important for the clinician reviewing the results to be aware of this to enable appropriate interpretation and patient management.

10. Analytes that may be significantly affected by pregnancy

	Reference range		
Analyte	First trimester	Second trimester	Third trimester
Alkaline phosphatase (ALP)	17–88 U/L	25–126 U/L	38–229 U/L
Packed cell volume (PCV) or haematocrit	0.31–0.41	0.30–0.39	0.28–0.40
Haemoglobin	116–139 g/L	97–148 g/L	95–150 g/L
Human chorionic gonadotrophin	4 weeks: 16–156 IU/L 4–9 weeks: 101–233 000 IU/L 9–13 weeks: 20 900–291 000 IU/L	4270–103 000 IU/L	2700–78 300 IU/L
17β-Oestradiol	690–9166 pmol/L (188–2497 pg/mL)	4691–26 401 pmol/L (1278–7192 pg/mL)	12 701–22 528 pmol/L (3460–6137 pg/mL)
Progesterone	25–153 nmol/L (8–48 ng/mL)	Not available	314–1088 nmol/L (99–342 ng/mL)
Prolactin	765–4532 mIU/L (36–213 ng/mL)	2340–7021 mIU/L (110–330 ng/mL)	2914–7914 mIU/L (137–372 ng/mL)
Thyroid-stimulating hormone (TSH)	0.60–3.40 mIU/L	0.37–3.60 mIU/L	0.38–4.04 mIU/L
Thyroxine (free), (free T_4)	10–18 pmol/L 0.77–1.40 ng/dL	9–16 pmol/L 0.70–1.24 ng/dL	8–14 pmol/L 0.62–1.09 ng/dL

*Non-SI equivalents are given in brackets where appropriate.

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