

Rainer Flindt

**Amazing Numbers**  
**in** **BIOLOGY**



Springer

# Rainer Flindt · Amazing Numbers in Biology

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Translated by Neil Solomon

 Springer

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## Introduction to the 6<sup>th</sup> German Edition\*

Teaching at schools, colleges, and universities often requires quick recourse to comparative data, whether for working out and presenting certain regularities or for comparing the figures gained from experiment and observation to those of the literature. The tables presented here were compiled to put an end to the time-consuming search for such data.

This compilation is primarily intended for those studying to become teachers and those already teaching at schools, colleges, and universities, for studies have shown pupils' questions are usually morphological in character, involving properties such as body size and weight. This volume aims to give teachers rapid access to such numbers. Much of the data, due to its nature, has long been known and is thus found primarily in older literature, which is not always easy to procure; the most recent of research findings, however, have also been incorporated.

The tables are comparative in character, for only in this way can regularities be recognized. Use of statistical data has been the exception rather than the rule, since they are often subject to change. The tables cannot be complete and were not intended to be. There was conscious effort to select those organisms native to our geographical region and commonly found in biology lessons and practical training. Where possible, the data have been supplemented by extreme values, and these have been marked by an exclamation point (!) in the tables. Furthermore, in this 6<sup>th</sup> German edition\* – taking KUNSCH/KUNSCH: *Der Mensch in Zahlen* [Humans in Numbers], 2001 as its model – several of the sections are prefaced by “Numbers that Amaze” tables in order to attract the reader's attention and to induce him or her to compare and search. Even though these tables, given their specialized topics, are chiefly aimed at biologists, most of them offer the interested lay reader items of interest.

The majority of the tables require little explanation. For this reason, there was a basic decision to forgo the addition of more detailed elucidating texts. Unless there were reasons to organize the data according to size or a specific system, the organisms in the tables are listed alphabetically. This is specifically indicated in all tables where this is not the case.

The fact that this book has now gone into its 6<sup>th</sup> edition and has also appeared in Russian shows that its guiding conception is basically correct. Nevertheless, inconsistencies have been eliminated and data updated for each new edition. The 6<sup>th</sup> edition has once again been thoroughly revised and expanded.

Ludwigsburg, Germany, Spring 2002

Rainer Flindt

\*The basis for the present translation [Translator's note]

## Part 1: Zoology

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As a point of comparison, data on humans have been included in the majority of tables without explicit mention of this in the table legends.



## 1.1 General: Size, Weight, Age ...

### 1.1.0: Numbers that Amaze

This table brings together some interesting data from Sect. 1.1. Subsequent tables provide greater detail and provide a context of comparable data for these figures; references to the literature are also found there.

Largest and heaviest vertebrate that has ever lived (and still does):	Blue whale	Length: 33 m Weight: 136,000 kg
Heaviest extinct terrestrial vertebrate:	<i>Brachiosaurus</i>	Length: 27 m Weight: 50,000 kg
Largest extinct mammal:	Fossil rhinoceros	Length: 8.5 m Weight: 18,000 kg
Smallest mammal:	Etruscan shrew	Length: 4 cm Weight: 2 g
Largest bird:	Ostrich	Weight: 150 kg
Largest extinct bird:	Madagascar's elephant bird	Weight: 400 kg
Bird with the greatest wingspan:	Albatross	Span: 320 cm
Bird with the greatest wing surface area:	Griffon vulture	10,450 cm <sup>2</sup>
Smallest bird:	Little woodstar (hummingbird)	Weight: 1.6 g
Smallest living snake:	<i>Leptotyphlops</i> sp.	Length: 11 cm
Largest living snake:	Reticulated python	Length: up to 10 m
Smallest living reptile:	Lizard-toed gecko	Length: 4 cm Weight: 2 g
Largest living caudate:	Giant salamander	Length: 150 cm
Smallest living caudate:	Pygmy salamander	Length: 4 cm
Largest extinct amphibian:	<i>Palaeosiren</i>	Length: 15 m
Largest living frog:	Goliath frog	Length: 40 cm
Smallest living frog:	Almiqui (Cuban banana frog)	Length: 1 cm
Largest living fish:	Whale shark	Length: 18 m Weight: 10,000 kg
Smallest living fish:	Dwarf goby	Length: 11 mm Weight: 0.2 g
Largest extinct fish:	<i>Carcharodon</i> sp.	Length: 33 m Weight: 125,000 kg
Largest living insect:	Walking stick <i>Pharnacia</i>	Length: 33 cm
Living insect with largest wing surface area:	<i>Coscinocera hercules</i>	Area: 300 cm <sup>2</sup>

**Table 1.1.1: Approximate Numbers of Species in Selected Major Animal Taxa**

For figures on plants, see Tables 2.1.1 and 2.1.2.

In all, 1.4 million animal species have been described.

Figures from BERTELSMANN 1977, *Die Roten Listen* 1997, KÄSTNER 1973, KRAUS and KUBITZKI 1982, *Lexikon der Biologie* 1983-87, MEYER 1964, *Naturschutz aktuell* 1977, RENNER 1984, STORCH and WELSCH 1991

Taxon	on Earth	in Germany
Protozoa	40,000	3,200
Sponges	5,000	28
Cnidaria	10,000	130
Flatworms	16,100	1,100
Roundworms	23,000	1,600
Mollusks	130,000	500
Snails	85,000	380
Clams	25,000	100
Cephalopods	600	15
Segmented worms (annelids)	17,000	1,900
Arthropods	> 1,000,000	32,500
Arachnids	68,000	2,300
Crustaceans	50,000	900
Insects	1,000,000	28,900
Dragonflies	4,700	80
Cockroaches	4,000	12
Locusts, grasshoppers	20,000	80
True bugs	73,000	1,800
Beetles	350,000	5,727
Bees and ants (hymenoptera)	110,000	10,000
Butterflies	120,000	3,000
Flies, gnats	120,000	8,000
Echinoderms	6,500	34
Vertebrates	46,500	476
Fish (incl. lampreys)	20,600	130
Amphibians	3,300	21
Reptiles	6,300	14
Birds	8,600	273
Mammals	3,700	98



Species	Maximum age	Species	Maximum age
Giant salamander	55	Hummingbird	8
Smooth newt	28	Larks	8 r
Tree frog	22	Magpie	25
<b>Reptiles</b>		Ostrich	62
American alligator	66	Owls	60-70
Anaconda	31	Oystercatcher	29
Boa	40	Pelican	50-60
Cobra	28	Penguin	26
European pond turtle	120	Pheasant	27
Galapagos giant tortoise	150	Pigeons/doves	35
Lizards ( <i>Lacerta</i> )	5-8	Red-throated loon or diver	23 r
Rattlesnake	19	Robin	11 r
Slowworm	33 (-54)	Stork	70-100 22r
Tortoise	137	Swallows	16 r
Tuatara	100	Swan	30 (-100)
		Winter wren	5
<b>Birds</b>		<b>Mammals</b>	
Barn owl	14 r	Beaver	20-25
Blackbird	18, 10 r	Baboon	35
Buzzard (or Am.: hawk)	24 r	Bactrian camel	29
Canary	24 (34)	Bison	30
Chaffinch	29	Brown bear	47
Chicken	30	Capuchin monkey	41
Cockatoo	100	Cat	35
Common raven	69	Cattle	20-25 (-49)
Common swift	21 r	Chamois	25-30
Condor	65	Chimpanzee	>50
Crane	62	Common or Harbor seal	26
Crow	118 20r	Deer	30
Cuckoo	40	Dogs	15-20 (-34)
Duck	25 20r	Dolphin	25-30
Eagle	60-80 21r	Domestic pig	27
Eagle owl	68	Donkey	100
European starling	20 r	Dromedary	28
Garden warbler	24	Elephant	70
Goose	31 (50)	European hare	8
Gray heron	60 24.5r	Fallow deer	25
Great cormorant	21 18r	Fat dormouse	9
Great crested grebe	23	Fox	14
Great tit	9	Gibbon	>23
Griffon vulture	118	Giraffe	34
Herring gull	44 32r	Goat	20
House sparrow	23	Golden or Syrian hamster	4

(Cont.) →

Species	Maximum age	Species	Maximum age
Gorilla	60	Orangutan	59
Gray seal	42	Polar bear	41
Guinea pig	9.5 (-15)	Rabbit	18
Hedgehog	14	Rat	3
Hippopotamus	54	Reindeer	16
Horses	40–50 (-61)	Rhinoceros	45
Horseshoe bat	24	Roe deer	16
Human	118	Sea lion	28
Ibex	30	Sheep	20
Kangaroo	30	Shrews	1.5
Lion	30	Squirrel	12
Llama	15	Tiger	30
Long-beaked echidna	49	Whale	100
Mole	3–4	Wild boar	20–30
Moose (in Europe: elk)	25	Wolf	14
Mouse	4	Wood mouse	10 M
Mule	45	Zebra	38
Myotis (bat)	24		

**Table 1.1.3: Largest Representatives of Selected Animal Taxa (Excluding Vertebrates and Insects)**

For data on vertebrates, see Tables 1.1.6 through 1.1.12; for insects, Table 1.1.4.  
L = length, D = diameter, W = width, S = span.

Figures from FRANK 1976, KÄSTNER 1973

Taxon	Species	Dimension
<b>Protozoa</b>	<i>Nummulites</i>	D: 32 cm
<b>Sponges</b>	<i>Spherospongia</i>	D: 2 m
<b>Cnidaria</b>		
Hydrozoa	<i>Brachiocerianthus imperialis</i> , Polyp	L: 2.20 m
	<i>Aequorea</i> sp., jellyfish	D: 40 cm
Scyphozoa	<i>Cyanea arctica</i> , jellyfish	D: 2 m
Sea anemone	<i>Stoichactis</i> sp.	D: 1.50 m
Solitary corals	<i>Fungia</i> sp.	D: 25 cm
Ctenophores	<i>Cestus veneris</i>	L: 1.50 m
<b>Flatworms</b>		
Turbellaria	Terrestrial planarian	L: 60 cm
Trematodes	<i>Nematobothrioides histoidii</i>	L: 6–8 m
Tapeworms	<i>Diphyllobothrium latum</i>	L: 15 m

Taxon	Species	Dimension
<b>Ribbon worms</b>	<i>Lineus longissimus</i>	L: 30 m
<b>Rotifers</b>	<i>Seison</i> sp.	L: 3 mm
<b>Roundworms</b>	<i>Placentonema gigantissima</i> ♂ ♀	L: up to 3.75 m L: up to 8.40 m
<b>Mollusks</b>		
Snails	<i>Semifusus</i> sp.	L: 60 cm (shell)
Clams	<i>Tridacna gigas</i>	L: 1.35 m (shell)
Cephalopods	<i>Architeuthis</i> sp.	L: 6.60 m (without tentacles) 18 m (with tentacles)
<b>Segmented worms (annelids)</b>		
Polychaetes ("many bristled")	<i>Eunice gigantea</i>	L: 3 m
Oligochaetes ("few bristled")	<i>Megascolides australis</i>	L: 3 m
Leeches	<i>Haementeria ghiliani</i>	L: 30 cm
<b>Arthropods</b>		
Scorpions	<i>Pandinus imperator</i>	L: 18 cm
Spiders	<i>Teraphosa leblondi</i> (tarantula)	L: 9 cm (torso)
Crustaceans	<i>Janus hügelii</i> <i>Macrocheira kaempferi</i>	L: 60 cm (without legs) W: 29 cm (carapace) S: 3 m (legs)
Myriapoda	<i>Scolopendra gigantea</i> (centipede) <i>Graphidostreptus gigas</i> (diplopod)	L: 26.5 cm L: 28 cm
<b>Ectoprocta (moss animals)</b> (single animal)		<i>Nolella alta</i> L: 4.6 mm
	<i>Pectinatella gelatinosa</i>	L: 2 m (colony)
<b>Acorn worms</b>	<i>Balanoglossus gigas</i>	L: 2.50 m
<b>Echinoderms</b>		
Crinoids (feather-stars)	<i>Metacrinus superbus</i>	L: 19 cm (arms) 2 m (stem)
	<i>Heliopecten glacialis</i>	L: 35 cm (arms)
Sea cucumbers	<i>Synapta maculata</i> <i>Stichopus variegatus</i>	L: 2 m D: 5 cm L: 1 m
		D: 21 cm
Sea urchin	<i>Sperosoma giganteum</i>	D: 32 cm
Starfish	<i>Freyella remex</i>	L: 45 cm S: 1 m
		L: 70 cm (arms)
Brittle stars	<i>Gorgonocephalus stimpsoni</i>	D: 14.3 cm (disk)
<b>Arrow worms</b>	<i>Sagitta gazellae</i>	L: 10 cm

**Table 1.1.4: The Largest Insects**

L = length, WS = wingspan

Data after KÄSTNER 1973

Taxon	Species	Size
Mayflies	<i>Euthyplocia</i> sp.	L: 5 cm, WS: 8 cm
Dragonflies	<i>Megaloprepus coerulatus</i>	L: 15 cm, WS: 18 cm
Stoneflies	<i>Diamphipnoa helgae</i>	L: 4 cm, WS: 11 cm
Earwigs	<i>Titanolabis colossa</i>	L: 5 cm
Praying mantis	<i>Toxodera</i> sp.	L: 16 cm
Cockroaches	<i>Megaloblatta longipennis</i>	L: 9.5 cm, WS: 17 cm
Termites	<i>Macrotermes goliath</i>	L: 2.2 cm, WS: 8.8 cm
	<i>Bellicositermes natalensis</i> ♂	L: 14 cm
Stick insects (Phasmida)	<i>Pharnacia serratipes</i>	L: 33 cm
Saltatoria		
Katydids (bush crickets)	<i>Saga syriaca</i>	L: 10 cm
	<i>Pseudophyllus colossus</i>	WS: 20 cm
Grasshoppers	<i>Tropidacris latreillei</i>	L: 12 cm, WS: 23 cm
True bugs		
Heteroptera	<i>Belostoma grande</i>	L: 11 cm
Cicadas	<i>Pomponia imperatoria</i>	L: 7 cm, WS: 18 cm
Megaloptera	<i>Sialis flavilatera</i>	WS: 3.8 cm
Snakefly	<i>Acanthocorydalus kolbei</i>	WS: 16 cm
Beetles	<i>Titanus giganteus</i>	L: 15 cm
Bees and ants (hymenoptera)	<i>Pepsis hero</i>	L: 6 cm, WS: 11 cm
Neuroptera	<i>Palpares voeltzkowi</i>	WS: 15.7 cm
Butterflies	<i>Thysania agrippina</i>	WS: 32 cm
	<i>Coscinocera hercules</i>	wing surface: 300 cm <sup>2</sup>
Diptera	<i>Mydas hero</i>	L: 6 cm, WS: 10 cm
Fleas	<i>Histrichopsylla talpae</i>	L: 6 mm

**Table 1.1.5: Size of Populations in Colony-Building Insects**

Listed according to size, in descending order.

Figures from GRZIMEK 1970, JAKOBS and RENNER 1974, KÄSTNER 1973, KEMPER and DÖHRING 1967, MEYER 1964, WEBER 1966

Species	Size of Population
Tropical termites ( <i>Bellicositermes</i> )	3,000,000
Southern wood ant ( <i>Formica rufa</i> )	500,000–800,000
Leafcutter ant ( <i>Atta</i> )	600,000
Driver ants ( <i>Anomma</i> )	100,000
Western subterranean termites ( <i>Reticulitermes</i> )	100,000
Honeybees	40,000–80,000
Yellow meadow ant ( <i>Lasius flavus</i> )	20,000
German yellowjacket wasp ( <i>Paravespula germanica</i> )	5,500
Hornets	700–1,500
Bumblebees	500–2,000
Dolichovespula wasps	200
Paper wasp ( <i>Polistes</i> )	140
Ant ( <i>Promyrmecia aberrans</i> )	12



**Table 1.1.6: Size and Weight of Selected Fish**

The maximum sizes and weights reported here represent, in some cases, one-time record catches. For some species, the world-record sizes and weights for fish caught by angling are given in parentheses. The lengths represent total length.

Data after BLINKER 2001, GOADBY 1996, GRZIMEK 1970, LADIGES and VOGT 1965, MEYER 1964, NORMAN and FRASER 1963, SLIJPER, SPECTOR 1956, WOOD 1982

Species	Normal length	Maximum length (Fishing record)	Weight, up to (Fishing record)
Arapaima	2.5 m	4.5 m	400 kg
Barracuda	1.5–1.8 m	3.0 m (1.68)	50 kg (46.83)
Basking shark		14.0 m	4,000 kg
Beluga	4.0 m	9.0 m	1,600 kg
Black marlin		4.5 m (4.42)	900 kg (707.6)
Blue shark	3.0–4.0 m	6.0 m	800 kg
Carp	0.4–0.5 m	1.2 m (1.07)	30 kg (30.1)
Cod	1.0–1.5 m	1.8 m	95 kg
Dwarf goby ( <i>Pandaka pygmaea</i> ; smallest fish and smallest vertebrate)		11 mm (!)	0.2g (!)
Eel ♀		150 cm	6 kg (6.04)
Eel ♂		50 cm	1 kg
European conger	1.5–1.8 m	3.0 m	70 kg
European perch	0.3 m	0.45 m	2.56 kg
Greenland shark	3.0–4.0 m	7.0 m	
Grouper	2.0–2.2 m	3.5 m	420 kg (248.6)
Halibut	2.0–2.5 m	4.7 m	330 kg
<i>Latimeria</i> (Coelacanth)		1.5 m	52 kg
Lungfish (Australian)	0.6–1.2 m	1.8 m	50 kg
Man-eating shark	5.0–6.0 m	12.0 m (4.60)	3,000 kg (1,075.9)
Manta ray		4.0 m	1,600 kg
		7.0 m (“wing” span)	
Northern bluefin tuna	3.0 m	5.0 m (2.95)	820 kg (443.2)
Ocean sunfish		3.0 m	900 kg
Pike 1.0 m	1.5 m	(1.33) 70 kg	(25)
Salmon	0.9–1.0 m	1.5 m	36 kg (35.89)
Sawfish	6.0 m	10.0 m	2,300 kg
Sea lamprey		1.0 m	1 kg
Swordfish	3.0–4.0 m	6.0 m (4.55)	600 kg (681.8)
Tench	0.4–0.50 m	0.70 m	2 kg (4.97)
Tiger shark	4.0–5.0 m	6.0 m (4.22)	800 kg (626.9)
Trout	0.3 m	0.50 m	16 kg (15.7)
Wels catfish	2.0–2.5 m	5.0 m	300 kg (82)
Whale shark	15.0 m	18.0 m (!)	10,000 kg (!)
Zander		1.2 m	18 kg (18.6)

**Table 1.1.7: Maximum Length of Selected Amphibians**

For the salamanders (caudates) and caecilians, figures refer to total length; for the anura, they refer to crown-rump length (CRL). For figures on extinct amphibians, see Table 1.1.13.

Figures from COCHRAN 1970, GRZIMEK 1970, MERTENS 1947, MEYER 1964

Species	Length
<b>Caecilians and salamanders (caudates)</b>	
Alpine newt ♀	11 cm
Alpine newt ♂	8 cm
Amphiuma ("Congo eel")	100 cm
Axolotl	33 cm
Caecilians	150 cm
Fire salamander	20 cm
Giant salamander	150 cm (!)
Greater siren	100 cm
Mexican pygmy salamander	4 cm (!)
Northern crested newt	14 cm
Palmate newt ♀	9.2 cm
Palmate newt ♂	7.5 cm
Smooth newt ♀	9.5 cm
Smooth newt ♂	11.1 cm
<b>Anura</b>	
Agile frog	8 cm
Almiqui (Cuban banana frog)	1 cm (!)
Colombian giant toad	30 cm
Common frog	10 cm
Common spadefoot toad ♀	8 cm
Common spadefoot toad ♂	6.5 cm
Common toad ♀	13 cm
Common toad ♂	8 cm
Cuban tree frog	13 cm
Giant neotropical toad	20 cm
Goliath frog	40 cm (!)
Green toad	8 cm
Marsh or Lake frog	15 cm
Midwife toad	5 cm
Moor frog	6.5 cm
Natterjack toad	7 cm
Tree frog	5 cm
Yellow-bellied toad	4.5 cm

**Table 1.1.8: Maximum Length and Weight of Selected Reptiles**

The figures for turtles refer to shell length; for all other animals, they refer to total length. Figures for extinct species can be found in Table 1.1.13.

Data after BELLAIRS 1971, GRZIMEK 1970, MANN 1979, MERTENS 1947, SCHMIDT and INGER 1957, WOOD 1982

Species	Length (m)	Weight
<b>Turtles</b>		
Alligator snapping turtle	0.75	100 kg
Green turtle	1.40	200 kg
Leatherback turtle	3.00	800 kg
Seychelles giant tortoise	1.25	250 kg
<b>Crocodilians</b>		
American alligator	5.84	
Gharial	7.11	
Nile crocodile	6.70	1,000 kg
Orinoco crocodile	7.20	
Saltwater or estuarine crocodile	8.50	
<b>Lizards</b>		
Common lizard	0.16	
Common wall lizard	0.19	
Dwarf gecko ( <i>Jaragua sphaero</i> )	0.016 (!)	
Eyed or Jeweled lizard	0.80	
Green iguana	2.20	
Komodo dragon	3.00	165 kg
Lizard-toed gecko	0.04	2 g
Marine iguana	1.75	
Sand lizard	0.32	
Slowworm	0.45	
Tuatara ♂	0.29	1 kg
Western green lizard	0.45	
<b>Snakes</b>		
Aesculapian snake	1.80	
Anaconda	9.60	120 kg
Black mamba	4.00	
Boa constrictor	4.50	60 kg
Bushmaster	3.75	
Crossed viper	0.80	
Dice snake	1.00	
Grass snake	1.50	
King cobra	5.58	

Species	Length (m)	Weight
<i>Leptotyphlops bilineata</i> (smallest snake)	0.11 (!)	
Reticulated python	10.00 (!)	
Smooth snake	0.75	
Western diamondback rattlesnake	2.58	10 kg

### Table 1.1.9: Weight and Wingspan of Selected Birds

For wing surface area and surface loads, see Table 1.2.9. For figures on extinct birds, see Table 1.1.13.

Data after BERNDT and MEISE 1959, GRZIMEK 1970, HEINROTH 1955, HERZOG 1968, STURKIE 1976, ZISWILER 1976

Species	Weight, up to	Wingspan, up to
Albatross	8 kg	320 cm (!)
Barn owl	300 g	95 cm
Black woodpecker	315 g	75 cm
Blue tit	12 g	20 cm
Carrion crow	600 g	100 cm
Common buzzard	1.2 kg	140 cm
Common raven	1,250 g	125 cm
Common swift	43 g	35 cm
Condor	11.3 kg	290 cm
Crest or Kinglet	4 g	16 cm
Eagle owl	3.2 kg	170 cm
Eurasian black vulture (Monk vulture)	14 kg	287 cm
Eurasian curlew	600 g	100 cm
Eurasian jay	195 g	55 cm
Eurasian pygmy owl	60 g	40 cm
Eurasian woodcock	400 g	58 cm
Golden eagle	6 kg	230 cm
Goshawk	2 kg	118 cm
Great black-backed gull	2.2 kg	175 cm
Great bustard ♂	5 kg	
Great bustard ♀	22 kg	240 cm
Great spotted woodpecker	95 g	48 cm
Griffon vulture	8.2 kg	240 cm
Imperial eagle	3.5 kg	215 cm
Little woodstar (smallest hummingbird)	1.6 g (!)	7.5 cm (!)
Marabou stork	5 kg	300 cm
Mute swan	22.5 kg	260 cm
Northern gannet	3 kg	180 cm

(Cont.) →

Species	Weight, up to	Wingspan, up to
Northern lapwing	200 g	70 cm
Ostrich	150 kg (!)	
Painted quail	45 g	
Rock dove or pigeon	300 g	63 cm
Rook	670 g	90 cm
Sparrowhawk	300 g	76 cm
Stork	4.4 kg	220 cm
Tawny owl	500 g	100 cm
White-tailed eagle	6.7 kg	255 cm
Wood grouse or Capercaillie	6 kg	130 cm
Wood pigeon	500 g	75 cm

**Table 1.1.10: Maximum Length and Weight of Selected Mammals**

Figures on length refer to crown-rump length (CRL), except in the case of whales and pin-nipeds, where they refer to total length.

Figures after BRINK 1975, FRÄDRICH and FRÄDRICH 1973, GRZIMEK 1970, KRUMMBIEGEL 1953, SANDERSON 1956, SLIJPER 1967, WOOD 1982

Species	Length, up to (cm)	Weight, up to
Baboon	114	54 kg
Beaver	100	30 kg
Bison	300	1,000 kg
Black rhinoceros	375	2,000 kg
Blue whale	3,300 (!)	136,000 kg (!)
Bowhead whale	2,100	
Brown rat	26	400 g
Camel	345	650 kg
Chamois	130	62 kg
Chimpanzee	170 (standing height)	70 kg
Common eland	345	1,000 kg
Common house mouse	12	30 g
Common or Harbor seal	200	100 kg
Common vole	12	50 g
Dolphin	360	200 kg
Dwarf lemur	13	60 g
Elephant seal	650	3,600 kg
Elephant, African	750	6,000 kg
Elephant, Asian	640	5,000 kg
Ermine	29	450 g
Etruscan shrew	4 (!)	2 g (!)

Species	Length, up to (cm)	Weight, up to
Eurasian badger	85	20 kg
Fat dormouse	19	120 g
Fin whale	2,500	76,000 kg
Fox	90	10 kg
Gibbon	90	22.5 kg
Giraffe	580 (height)	1,200 kg
Golden or Syrian hamster	18	130 g
Gorilla	175 (standing height)	275 kg
Grizzly bear	300	1,200 kg
Guinea pig	33	1,400 g
Hamster	34	500 g
Hazel dormouse	9	40 g
Hedgehog	30	1,200 g
Hippopotamus	450	3,200 kg
Horse (draft horse, "coldblood")		1,000 kg
Horse (warmblood)		500 kg
Ibex	170	150 kg
Indian rhinoceros	420	2,000 kg
Koala	80	16 kg
Least weasel	23	130 g
Leopard	150	80 kg
Lion	190	250 kg
Marmot	73	8 kg
Mole	17	120 g
Moose (in Europe: elk)	310	800 kg
Muskrat	36	1,500 g
Orangutan	150 (standing height)	100 kg
Orca	950	6,350 kg
Polar bear	251	1,000 kg
Pygmy mouse	6.6	6 g
Rabbit	45	2 kg
Red deer (Wapiti)	265	340 kg
Red kangaroo	160	70 kg
Reindeer	220	315 kg
Roe deer	140	50 kg
Sloth	60	5 kg
Sperm whale	2,000	53,000 kg
Square-lipped rhinoceros	400	3,600 kg
Squirrel	25	480 g
Tiger	300	350 kg
Walrus	375	1,500 kg
Water buffalo	300	1,000 kg
Water vole	19	180 g
Wild boar	180	350 kg
Wolf	150	75 kg
Wolverine (Glutton)	87	35 kg

**Table 1.1.11: Size of Selected Breeds of Dog**

Figures give crown–rump length (CRL) and height at withers (= shoulder height), both in centimeters.

Data after HALTENORTH 1958, SMOLIK 1968

Species	CRL	Withers
Wolf	100–140	65–90
Dingo	100	50–55
Affenpinscher	20–25	26
Airedale terrier	55–62	55–62
Appenzeller mountain dog	49–58	48–58
Barzoi	75–80	71–76
Bloodhound	65–72	60–70
Boxer	57–73	53–63
Chihuahua	15–20 (!)	15–23 (!)
Cocker spaniel	35–42	35–42
Collie	56–63	50–60
Dachshund	23–30	23–27
Dalmatian	50–60	50–60
Fox terrier	35–40	35–60
German shepherd	60–65	55–65
Giant schnauzer (Riesenschnauzer)	57–70	60–70
Great Dane	75–90 (!)	72–92 (!)
Greyhound	65	65–70
Italian Greyhound	36	35
Miniature poodle	35	30–35
Newfoundland	63–75	62–75
Pointer	60–65	60–65
Pomeranian	28	28
Poodle	45–60	45–55
Pug	25–32	32
Rottweiler	60–65	55–66
St. Bernard	68–78	65–80

**Table 1.1.12: Height at the Withers (= Shoulder Height) of Horses**

Figures from GRZIMEK 1970, KRUMMBIEGEL 1958, MCGREGOR and EDWARDS 1976

Species	Height at the withers
<b>Wild horses</b>	
Grant's zebra	1.40 m
Grevy's zebra	1.55 m
Hartmann's zebra	1.25 m
Kiang	1.30 m
Kulan	1.70 m (!)
Onager	1.10 m
Przewalski's horse	1.20–1.46 m
Quagga	1.35 m
Somali wild ass	1.40 m
<b>Horse breeds</b>	
Andalusian horse	1.54 m
Anglo-Arabian	1.63–1.65 m
Arabian	1.44–1.50 m
Camargue	1.35–1.45 m
Clydesdale ("coldblood")	1.73 m
Exmoor pony	1.24 m
Fjord horse	1.40 m
Haflinger	1.21–1.48 m
Indian ponies	1.30–1.40 m
Lippizaner	1.55 m
New forest pony	1.22–1.44 m
Norwegian fjord horse	1.40 m
Percheron ("coldblood")	1.73 m
Ponies (greatest height)	1.44 m
Shetland ponies	0.95–1.05 m
Shire horse ("coldblood")	1.82 m (!)
Suffolk ("coldblood")	1.63 m



**Table 1.1.13: Size and Weights of Selected Extinct Vertebrates**

Figures from GRZIMEK 1970, KUHN 1958, KUHN-SCHNYDER 1974, LÜTTSCHWAGER 1961, MEYER 1974, SLIJPER 1967, WOOD 1982

Species	Length (m)	Height (m)	Estimated weight (kg)
<b>Sharks</b>			
<i>Carcharodon megalodon</i>	33		125,000
<b>Fish (placodermi)</b>			
<i>Titanichthys</i>	8		
<b>Amphibians</b>			
<i>Mastodonsaurus</i>	3		
<i>Palaeosiren beinerti</i> (Caecilian)	15		
<i>Prionosuchus plummeri</i>	9		
<b>Reptiles</b>			
<b>Dinosaurs</b>			
<i>Brachiosaurus</i>	27	15	50,000
<i>Brontosaurus</i>	22		40,000
<i>Diplodocus</i>	28		40,000
<i>Iguanodon</i>	11	5	10,000
<i>Stegosaurus</i>	9		1,750
<i>Tyrannosaurus</i>	16	6	
<b>Crocodiles</b>			
<i>Phobosuchus</i>	13.5		
<i>Rhamphosuchus indicus</i>	18.3		
<b>Pterosaurs</b>			
<i>Pteranodon</i>	wingspan 7 m		30
<i>Quetzalcoatlus northropi</i>	wingspan 12 m		86
<b>Ichthyosaurs</b>			
<i>Ichthyosaurus</i>	12		
<b>Snakes</b>			
<i>Pterospheus</i>	11		
<b>Turtles</b>			
<i>Archelon ischirus</i>	6		2,700
<i>Colossochelys atlas</i>	6		
<b>Birds</b>			
<i>Aepyornis</i> (Madagascar's elephant bird)		1.5	400
<i>Archaeopteryx</i>	0.45		
<i>Argentavis magnificens</i> (capable of flying, wingspan 7.6 m)		1.5	120
Dodo		1	25
Giant moa		3.5	250

Species	Length (m)	Height (m)	Estimated weight (kg)
<b>Mammals</b>			
<i>Baluchitherium</i> (fossil rhinoceros)	8.5	5.5	18,000
<i>Dinotherium</i> (fossil elephant)		4	7,500
Cave bear	2.8		
Mammoth	3.5	4	7,500
Aurochs	3	1.8	1,500

**Table 1.1.14: Size of Horns and Teeth**

The figures represent maximum values from individual hunting trophies. Winding horns and teeth measured along their external curvature.

Data after DORST and DANDELLOT 1973, HALTENORTH and TRENSE 1956

Species	Size	
<b>Antlers, horns</b>		
Alpine ibex	147.32 cm	
Aurochs	80.00 cm	
Common eland	112.40 cm	
Impala	92.08 cm	
African buffalo	163.80 cm	
Greater kudu	168.91 cm	
Sable antelope	163.53 cm	
Gemsbok	121.92 cm	
Red deer (Wapiti)	152.40 cm	
Water buffalo	197.49 cm	
Black wildebeest	67.95 cm	
<b>Frontal horn (rhinoceros)</b>		
Square-lipped rhinoceros	158.12 cm	
Indian rhinoceros	60.96 cm	
Black rhinoceros	135.90 cm	
<b>Teeth</b>		
African elephant, tusk	349.25 cm	133.02 kg
Asian elephant, tusk	266.70 cm	72.98 kg
Hippopotamus, lower canine	163.83 cm	
Warthog, tusk	60.96 cm	

**Table 1.1.15: Number of Vertebrae of Selected Vertebrates**

Figures for neck vertebrae alone are found in Table 1.1.16.

After BOGNER and RITTER 1976, GRZIMEK 1970, MEYER 1964, OPPENHEIMER and PINCUSSEN 1930

Species	Vertebrae (n)
Sharks	ca. 400
Rainbow trout	60–69
Herring	ca. 55
Eel	max. 119
Northern crested newt	53
Frog	9
Turtle	34
Slowworm	110
Grass snake	230
Boas	max. 435
<i>Archaeophis</i> (fossil boa)	565 (!)
Songbirds	35
Swan	56
Pets (mammals)	50–60
Human	34

**Table 1.1.16: Number of Cervical (Neck) Vertebrae of Selected Vertebrates**

For overall number of vertebrae, see Table 1.1.15.

Figures from GRZIMEK 1970, KUHN 1958, ZISWILER 1976

Taxon, species	Cervical vertebrae (n)
Amphibians	1
Crocodiles	2
Turtles	8
Monitor lizards	8
Heloderma	9
<i>Elasmosaurus</i> (dinosaur)	76
Birds, normally	14 (-15)
Exceptions:	
Carrion crow	10
Albatross	15
Flamingo	19
Mute swan	26
Mammals	7
Exceptions:	
Three-toed sloth (Genus <i>Bradypus</i> )	9
Hoffmann's two-toed sloth ( <i>Choloepus hoffmanni</i> )	6
Manatees	6

**Table 1.1.17: Relative Skeletal Weight of Selected Vertebrates**

Figures as percentage of body weight. Birds and mammals each listed according to percentage. Larger animals require a much sturdier skeleton than do their smaller counterparts.

Data after HESSE and DOFLEIN 1935, NACHTIGALL 1979, SLIJPER 1967

Species	Skeletal weight (%)
<b>Birds</b>	
Goose	13.3
Chicken	11.7
Sparrow	8.4
Winter wren	7.1
<b>Mammals</b>	
Elephant	25.0
Hippopotamus	20.0
Cattle	20.0
Sheep	20.0
Pig	18.0
Human	15.0
Dog	14.0
Lion	13.0
Cat	11.5
Common or Harbor seal	11.0
Rabbit	9.0
Common house mouse	8.4
Shrew	7.9

**Table 1.1.18: Size of Selected Animal Cells**

Figures for selected species and organs.

Data from DAVID 1977

Species	Organ	Diameter ( $\mu\text{m}$ )	Volume ( $\mu\text{m}^3$ )
Dog	Stomach	15.6	1,988
	Purkinje cells	30.0	14,000
Cat	Pyramidal cells		24,112
	Spinal ganglion		26,767
Horse	Pyramidal cells of Betz		9,348
	Purkinje cells	32.0	16,000

(Cont.) →

Species	Organ	Diameter ( $\mu\text{m}$ )	Volume ( $\mu\text{m}^3$ )
Rabbit	Cerebral cortex		5,000–20,000
	Pyramidal cells of Betz		3,239
	Spinal ganglion		23,995
Mouse	Purkinje cells	19.0	4,000
	Spinal ganglion		4,908
Rat	Purkinje cells	16.0	2,000
	Spinal ganglion		14,440
Cattle	Purkinje cells	32.0	17,000
	Spinal ganglion		125,317
Pig	Purkinje cells	29.0	13,000
Frog	Purkinje cells	7.0	1,500
Chicken	Lymphocytes	8.0–13.0	
Macaque	Spinal ganglion		23,018
Human	Pyramidal cells of Betz		113,400
	Purkinje cells	27.0	10,000
	Muscle (M. psoas)	25.0–90.0	
	Erythrocytes		87
	Spinal ganglion		102,612

**Table 1.1.19: Water Content of Vertebrate Tissue**

See also Table 4.1.11 for more detailed data on human tissue.

From BUDDENBROCK 1956, modified

Species	Smooth muscles	Skeletal muscles	Skin	Kidney	Liver	Bones
Frog	85.0	82.1	81.1	84.4	76.1	58.1
Desert monitor	78.8	78.7	61.8	81.1	75.4	10.6
Rock dove	71.0	77.5	63.0	78.7	74.8	11.2
Gerbil	72.5	74.1	39.3	77.8	70.1	27.1
Lesser Egyptian jerboa	76.6	74.8	48.7	77.7	69.9	26.8
Human	80.0	76.8	70.0	82.5	76.9	30.0

**Table 1.1.20: Amino Acid Composition of the Protein of Vertebrates**

Figures represent percentage of weight.

From BUDDENBROCK 1956, modified

Amino acid	(%)
Glutamic acid	11.2–13.9
Glycine	8.2–10.2
Aspartic acid	8.1–10.4
Leucine	6.1– 7.5
Arginine	5.8– 6.3
Lysine	5.6– 7.9
Valine	4.4– 5.7
Threonine	3.7– 4.3
Isoleucine	3.3– 4.7
Phenylalanine	3.2– 4.2
Methionine	1.7– 2.1
Histidine	1.6– 2.1
Tryptophan	0.6– 1.0

**Table 1.1.21: Effects of Animal Poisons (Not Including Those of Snakes)**

Figures provided represent either the dose that kills half (50%) of the animals tested ( $LD_{50}$ , where LD = lethal dose) or the minimal lethal dose (MLD), calculated in terms of 1 kg body weight of the examined animal species (species in parentheses).

Data on snake poison is found in Table 1.1.22.

Figures from BASSUS 1965, BERTELSMANN 1979, MEBS 1979

Animal species	MLD	$LD_{50}$
<b>Cnidaria</b>		
Congestin (from nematocysts of sea anemone)	5 mg (dog)	
Hypsotoxin (from nematocysts of the siphonophore <i>Physalia</i> )	2.0–2.5 mg (mouse)	
Lophotoxin (from nematocysts of the gorgonian coral <i>Lophogorgia</i> )	8 mg (mouse)	
Palytoxin (from nematocysts of the sea mat <i>Palythoa</i> )		0.01 µg (mouse)
Thalassin (from nematocysts of sea anemone)	2.5–9 mg (dog)	

(Cont.) →

Animal species	MLD	LD <sub>50</sub>
<b>Mollusks</b>		
Murex (poison of murex mollusk)	8.5 mg (mouse)	
<b>Arthropods</b>		
Scorpion ( <i>Buthus acutecarinatus</i> )	0.27 mg (rat)	
Scorpion ( <i>Tityus bahiensis</i> )	0.5–2.0 mg (mouse)	
Spider ( <i>Lycosa raptoria</i> )	0.9 mg (mouse)	
Spider ( <i>Ctenus ferus</i> )		0.34 mg (mouse)
Tarantula ( <i>Atrax robustus</i> )		4.5 mg (mouse)
Cantharidin (from blister beetles)	0.5 mg (human)	
Hornet venom		2.5 mg (mouse)
Bee venom		3.0–4.0 mg (mouse)
Poison of North American harvester ant ( <i>Pogonomyrmex</i> )		0.42 mg (mouse)
<b>Fish</b>		
Poison of stonefish		0.2 mg (mouse)
Poison of pufferfish (Tetrodotoxin)	0.014–0.09 mg (mouse)	
<b>Amphibians</b>		
Salamandrin (from salamanders)	0.1 mg (rabbit)	
Skin poison from newts	0.018–0.02 mg (mouse)	
Bufogenin (from toad skin)		0.13 mg (cat)
Bufotenin (from toad skin)		25 mg (mouse)
Poison from water frog (or pool frog) skin	6–12 mg (rabbit)	
Dart poison (from <i>Phyllobates bicolor</i> )		2.7 mg (mouse)
Batrachotoxin (from <i>P. aurotaenia</i> )		2.0 µg (mouse)
Homobatrachotoxin (from <i>P. aurotaenia</i> )		3.0 µg (mouse)
Pumiliotoxin (from <i>Dendrobates pumilio</i> )		2.0 mg (mouse)
<b>Reptiles (excluding snakes)</b>		
Poison from Heloderma	16 mg (mouse)	

**Table 1.1.22: Effects of Snake Venoms**

Figures provided represent either the dose that kills half (50%) of the mice injected with it ( $LD_{50}$ , where LD = lethal dose) or the minimal lethal dose (MLD), calculated in terms of 1 kg body weight of the examined animal species (species in parentheses).

For the effect of the poison of other animals, see Table 1.1.21.

Data after BASSUS 1965, ZISWILER 1965

Animal species	Dry weight (mg) of poison per bite	$LD_{50}$ (mg/kg) mouse	MLD (mg/kg) mouse/rabbit
Crossed viper			1–1.4 (mouse)
Russell's viper ( <i>Vipera russeli</i> )	130–250	0.82	
Asp viper			1–2 (mouse)
Puff adder ( <i>Bitis arietans</i> )	130–250	3.68	
Rattlesnake ( <i>Crotalus durissus</i> )	35	0.3	
American copperhead ( <i>Agkistrodon contortrix</i> )	52	10.5	
Bushmaster ( <i>Lachesis muta</i> )	280–450	5.93	
Coral snake ( <i>Micrurus fulvius</i> )	2–6	0.97	1.5 (mouse)
Tiger snake ( <i>Notechis scutatus</i> )	70	0.04	0.045 (rabbit)
Indian cobra ( <i>Naja naja</i> )	170–325	0.4	
Krait ( <i>Bungarus caeruleus</i> )	10	0.09	0.04 (rabbit)
Eastern green mamba ( <i>Dendroaspis angusticeps</i> )	80	0.45	
Beaked sea snake ( <i>Enhydrina schistosa</i> )	7–20	0.01	



**Table 1.1.23: Poisonous Effect of Selected Insecticides on Vertebrates**

When the insecticide is orally administered, 50 % of the animals examined die ( $LD_{50}$ ). Figures in milligrams poison per kilogram body weight. The animal species examined are in parentheses. For a comparison, see also Tables 1.1.21 and 1.1.22.

Figures from ALTMANN and DITTMER 1973

Insecticide	$LD_{50}$ (mg/kg)	(Animal species)
Aldicarb	1	(Rat)
Aldrin	44	(Mouse)
	33	(Guinea pig)
Chlordane	430	(Mouse)
DDT	118	(Rat)
	400	(Guinea pig)
	150–400	(Mouse)
DDVP (Dichlorvos)	56– 80	(Rat)
Diazinon	76	(Rat)
Dieldrin	38	(Mouse)
	49	(Guinea pig)
	38– 87	(Rat)
Endrin	16– 36	(Guinea pig)
Heptachlor	68	(Mouse)
	116	(Guinea pig)
Lindane	86	(Mouse)
	100–127	(Guinea pig)
Mevinphos	3.7– 6.1	(Rat)
Parathion (E 605)	3.6	(Rat)
Perthane	9.34	(Rat)
Toxaphene	112	(Mouse)
	69	(Guinea pig)
	69	(Rat)
Zectran (mexacarbate)	15– 63	(Rat)

## 1.2 Movement, Locomotion

**Table 1.2.0: Numbers that Amaze**

This table brings together several interesting figures from Sect. 1.2, which are cited again in the individual tables below, where they are accompanied by references to the literature.

Number of wingbeats per second in insects	Chironomidae ( <i>Forcipomyia</i> )	1,046/s
	Housefly	up to 330/s
Number of wingbeats in birds	Amethyst hummingbird	78/s
	House sparrow	13/s
	Pelican	1.3/s
Wing surface areas in birds	Griffon vulture	10,450 cm <sup>2</sup>
	Ruby-throated hummingbird	10 cm <sup>2</sup>
Greatest surface load in birds	Mute swan	167 N/m <sup>2</sup>
	Albatross	155 N/m <sup>2</sup>
Maximum speed, swimming	Swordfish	90 km/h
	Marlin	80 km/h
	Orca	65 km/h
Maximum speed, running	Cheetah	120 km/h
	Greyhound	110 km/h
	Red kangaroo	80 km/h
Maximum speed, flying	Common swift	180 km/h
	Spine-tailed swift	335 km/h
	Peregrine falcon, in a swoop	290 km/h
Maximum speed, during bird migration	Common swift	150 km/h
Annual migratory flight distance	Arctic tern	40,000 km
	Stork	20,000 km
Maximum jumping distance in animals	Red kangaroo	13.5 m
	Flea	60 cm
		= 9 times its body length
		= 200 times its body length

**Table 1.2.1: Diameter of Muscle Fibers**

Data for selected muscle types and organisms.

Figures from DAVID 1977

Species	Muscle	Diameter ( $\mu\text{m}$ )
Goldfish	Red fibers	36.0
	White fibers	49.4
African clawed frog	Leg muscle	169.0
Rock dove	Breast muscle	26.8
Shrew	Diaphragm	18.0
Mouse	Calf muscle	60.8
Rat	M. extensor digit. long.	85.0
	Diaphragm	34.0
Guinea pig	Diaphragm	25.0
Cat	Diaphragm	30.0
Pig	Diaphragm	60.0
Human	Diaphragm	34.0
	Intercostal muscles	50.4
	M. deltoideus	54.2

**Table 1.2.2: Twitch Times for Muscles**

The twitching of a muscle consists of contraction and relaxation. For contraction times, see Table 1.2.3. Listed in descending order from shortest to longest twitch.

On the physiology of muscles, see also SIEWING 1980.

After BERTELSMANN 1979, HEIDERMANNS 1957

Species	Muscle	Twitch time (s)
Housefly	Wing muscle	0.003
Bumblebee	Wing muscle	0.004
Bee	Wing muscle	0.005
Dragonfly	Wing muscle	0.039
Rock dove	Wing muscle	0.05
Grasshopper	Jumping muscle	0.1
Frog	Calf muscle	0.12
Bat	Wing muscle	0.5
European pond turtle	Biceps	0.9
Human	M. ciliaris	2– 4
Frog	Stomach	100–200
Pond mussel	Adductor muscle	200–600

**Table 1.2.3: Contraction Times of Selected Muscles**

Twitch times of muscles, which include both the contraction time and the relaxation time that follows it, are found in Table 1.2.2.

Figures from PROSSER 1973

Species	Muscle	Contraction time (ms)
Moon jelly		500–1,000
Edible snail	Tentacle retractor	2,500
Earthworm	Longitudinal muscle	70–80
Cockroach	Coxal muscle	4–10
Lobster	Fast remotor muscle	10
Lobster	Slow remotor muscle	50–60
Frog	Twitch fiber	22
Frog	Tonic fiber	46
Frog	Sartorius muscle	75
Toad	Semitendinosus muscle	800
Snake	Costocutaneous muscle	37–54
Turtle	Intestinal muscle	30,000
Finch	Wing muscle	14
Hummingbird	Wing muscle	8
Sloth	Gastrocnemius muscle	174
Guinea pig	Soleus muscle	82
Rat	Soleus muscle	36
Cat	Soleus muscle	70
Cat	Gastrocnemius muscle	40

**Table 1.2.4: Maximum Muscular Strength of Selected Muscles**

Force in N/cm<sup>2</sup> of a muscle cross-section. Compare this also to the so-called load-bearing performance in Table 1.2.5, a figure that combines maximum strength with load-bearing time.

Data after PROSSER 1973

Animal species	Muscle	Force (N/cm <sup>2</sup> )
Cockroach	Coxal muscle	7.8
Oyster	Adductor muscle	117.7
Lobster	Slow remotor muscle	27.5
Lobster	Fast remotor muscle	0.25
Frog	Sartorius muscle	19.6
Rabbit	Uterus	1.3
Dog	Smooth muscle trachea	7.8

(Cont.)→

Animal species	Muscle	Force (N/cm <sup>2</sup> )
Sloth	Gastrocnemius muscle	15.9
Sloth	Diaphragm	20.6
Rat	M. extensor digitorum	29.4
Rat	Gastrocnemius muscle	17.7
Rat	Soleus muscle	2.8
Rat	Cardiac muscle	0.2
Cat	Tenuissimus muscle	13.7
Cat	Duodenal sphincter	4.1

**Table 1.2.5: Load-Bearing Record of Selected Muscles**

The load-bearing performance describes the load in grams that can be borne by 1 cm<sup>2</sup> cross-section of a muscle for 1 h.

Data after HEIDERMANNS 1957

Species	Muscle type	Load-bearing performance
Frog	Calf muscle	4– 6
Toad	Calf muscle	44– 67
Human	Biceps	97–575
Pond mussel	Adductor muscle	1– 2 million

**Table 1.2.6: Number of Wingbeats per Second in Insects**

For the resulting speeds, see Table 1.2.10. For figures for birds, see Table 1.2.8.

For greater detail on insect flight, see SIEWING 1980.

Data after BAUER et al. 1974, BERTELSMANN 1979, FRANZ 1959, HANKE et al. 1977, LAMPEITL 1982, MEYER 1964

Species	Frequency
Bee	
Worker bee	240–250
Soldier bee	285
Queen bee	226–253
Drone	207
Blowfly ( <i>Calliphora</i> )	155
Bumblebee	130–250
Caddis fly	38
Cockchafer (May bug)	46

Species	Frequency
Common blue (butterfly)	11
Crane fly	44–73
Dragonfly ( <i>Aeschna</i> )	22–28
Dragonfly (Broad-bodied chaser)	20
Horsefly	96
Housefly	180–330
Hummingbird hawk-moth	79–85
Ladybug	75–91
Mayfly ( <i>Cloeon</i> )	41–44
Megaloptera ( <i>Eristalis</i> )	177–188
Midge ( <i>Forcipomyia</i> )	1,046
Migratory locust	20
Mosquito	278–307
Silkworm moth	8
Small white (butterfly)	9–12
Soldier beetle	69–87
Wasp	110

**Table 1.2.7: Surface Areas and Surface Loads of Insect Wings**

For data on birds, see Table 1.2.9. Listed according to increasing surface load.

After OPPENHEIMER and PINCUSSEN 1925

Species	Weight (g)	Surface (cm <sup>2</sup> )	Surface load (cN/cm <sup>2</sup> )
Green lacewing	0.008	1.66	0.0047
Small white (butterfly)	0.100	15.80	0.0062
Small tortoiseshell	0.114	8.80	0.0111
Swallowtail butterfly	0.235	16.90	0.0136
Damselfly	0.045	3.05	0.0147
Mayfly ( <i>Ephemera</i> )	0.0308	1.59	0.0190
Midge ( <i>Chironomus</i> )	0.012	0.05	0.0235
Hummingbird hawk-moth	0.16	5.50	0.0284
Ladybug	0.031	0.93	0.0327
Dragonfly ( <i>L. depressa</i> )	0.52	14.90	0.0342
Housefly	0.0115	0.31	0.0364
Wasp, worker	0.0780	1.36	0.0562
Privet hawk-moth	1.740	25.50	0.0669
Honeybee, worker	0.067	0.90	0.0730
Cockchafer (May bug)	0.667	8.15	0.0802

(Cont.) →

Species	Weight (g)	Surface (cm <sup>2</sup> )	Surface load (cN/cm <sup>2</sup> )
Bumblebee	0.118	1.18	0.0981
Earth-boring dung beetle	0.9039	5.90	0.1534
Water scavenger beetle	4.82	19.50	0.1603

### Table 1.2.8: Wingbeat Frequencies in Birds

The speeds reached with these frequencies are found in Table 1.2.10. For figures on insects, see Table 1.2.6.

Data from DORST 1972, HERTEL 1963, HERZOG 1968, ZISWILER 1976

Species	Beats per second
Amethyst hummingbird	78 (!)
Blackbird	5.6
Carrion crow	5
Common buzzard	3
Common swift	12
Eurasian coot	5.8
European starling	5.1
Gray heron	2
Herring gull	3
House sparrow	13
Hummingbirds	30–50
Magpie	3
Mallard	5–10
Mute swan	2.7
Owls	4
Pelican	1.2
Peregrine falcon	4.3
Pheasant	9
Rock dove	8
Stork	2
Turkey	3

**Table 1.2.9: Surface Areas and Surface Loads of Bird Wings**

For corresponding figures for insects, see Table 1.2.7. For the wingspans of birds, see Table 1.1.9. Listed in descending order according to surface area.

As a point of comparison: gliders have a surface load of 25 N/m<sup>2</sup>.

After DORST 1972, HERZOG 1968, OPPENHEIMER and PINCUSSEN 1925

Species	Surface area (cm <sup>2</sup> )	Surface load (N/m <sup>2</sup> )
Griffon vulture	10,450	71
Albatross	6,220	155
Eagle	5,930	69
Mute swan	5,760	167
Great bustard	5,550	74
Stork	5,520	66
Egret	3,590	38
Greylag goose	3,070	112
Great black-backed gull	2,060	77
Crow	2,050	30
Goshawk	2,050	40
Buzzard/Hawk	2,030	41
Herring gull	2,010	41
Peregrine falcon	1,540	37
Barn owl	1,160	24
Mallard	1,150	93
Rock dove	840	24
Northern lapwing	660	30
Magpie	640	32
Common kestrel	490	44
Blackbird	310	28
Great spotted woodpecker	240	30
European starling	190	43
Barn swallow	140	14
Common swift	130	29
Sparrow	120	24
Great tit	100	21
Chaffinch	100	21
Crest or Kinglet	50	11
Ruby-throated hummingbird	10	24



**Table 1.2.10: Maximum Speeds of Selected Animals**

All figures are in kilometers per hour. Some of the speeds given are only achieved for short stretches. The great differences in the data given in the literature on bird flying speeds are based on the fact that no mention is made whether the cited speeds were achieved with or without tailwinds.

Data after BAUER et al. 1974, BERTELSMANN 1979, FRANZ 1959, GRZIMEK 1970, HANKE et al. 1977, HEINROTH 1955, HERTEL 1963, HERZOG 1968, HESSE and DOFLEIN 1935, KÄSTNER 1973, KRUMBIEGEL 1953, LAMPEITL 1982, MANN 1979, MOSSMANN and SARJEANT 1983, NIETHAMMER 1979, SCHWERDTFEGER 1975, SLIJPER 1967, WOOD 1982, WUNDERLICH and GLOEDE 1977, ZISWILER 1976

Species	km/h	Species	km/h
<b>Swimming</b>		Coyote	60
Common eider	35	Deer	67
Dolphin	46	Dromedary	50
Eel	12	Eastern green mamba	11.3
Fin whale	55	Edible snail ( <i>Helix pomatia</i> )	0.00324
Gentoo penguin (under water)	36	Gazelle	75
Giant squid	40	Giant tortoise	0.33
Grass snake	2.9	Giraffe	51
Gray whale	7.5	Gnu	60
Great diving beetle	1.8	Greyhound	110
Human (100 m freestyle)	7	Hare	65
Marlin	80	Herbivorous dinosaurs	6
Orca	65	Hippopotamus	48
Polar bear	10	Horse (gallop)	36
Ringed seal	32	Horse (trot)	13.5
Salmon	39	House cat	48
Sea snakes	3.6	Human (100 m race)	36
Shark	36	Human (flying start)	44.6
Swordfish	90 (!)	Lion	75
Trout	35	Mole	4
Tuna	75	Ostrich	72
<b>Crawling, running</b>		Pill millipede ( <i>Glomeris</i> )	0.013
African elephant	39	Pine moth larva	0.018
Antilopes	70	Planarian	0.009
Bison	55	Polar bear	65
Black mamba	17.6	Racehorse	69
Camel	15	Rat	9.6
Centipede ( <i>Lithobius</i> )	1	Rattlesnake	4
Cheetah	120 (!)	Red deer (Wapiti)	70
Common house mouse	12	Red kangaroo	80
Common vole	8	Rhinoceros	51
		Roadrunner	24
		Shore crab	3.6

Species	km/h	Species	km/h
Sled dogs	23.4	Goshawk	42
Sloth	0.146	Gray partridge	85
Spider ( <i>Tegenaria atrica</i> )	1.3	Great cormorant	70
Starfish	0.000576	Green lacewing	2.2
Theropods (dinosaurs)	16.5	Hawk moth	54
Western green lizard	29	Homing pigeon	80
Wild ass	65	Homing pigeon	177
Wild horse	60	(with a tailwind)	
Wolf	60	Hornets	22
Zebra	65	Horsefly	50
<b>Flying</b>		House sparrow	45
Albatross	70	Housefly	8.2
Bat	50	Hummingbird hawk-moth	18
Bee	29	Mallard	104
Blowfly	11	Mergus	129
Bumblebee	18	Migratory locust	16
Cockchafer (May bug)	11	Mosquito	1.4
Common buzzard	45	Peregrine falcon, in a swoop	290
Common swift	180	Small passerines	up to 61
Crows	59	Small white (butterfly)	14
Dragonfly	30	Sparrowhawk	58
European kingfisher	58	Spine-tailed swift	335 (!)
European starling	81	Stork	45
Falcons	79	Swallow	65
Flyingfish	75	Swan	50
Geese	91	<i>Tabanus bovinus</i> (horsefly)	22
		Tiger beetle	8

**Table 1.2.11: Jumping Distances of Selected Animals**

Listed in ascending order according to jump in relation to body length (BL).

Data after COCHRAN 1970, GRZIMEK 1970, HESSE and DOFLEIN 1935, KRUMBIEGEL 1953

Species	Distance jumped (m)	Relation to body length (BL)
Lion	4–5	2–3 times BL
Tiger	5	2–3 times BL
Fox	2.8	4.3 times BL
Red deer (Wapiti)	11	4.5 times BL
Roadrunner	3	6 times BL
Impala antelope	10	6 times BL
Least weasel	1.2	6 times BL
Kangaroo	6–10 max. 13.5	7 times BL
Wood mouse	0.7	8 times BL
Bullfrog	2	10 times BL
Gibbon	12	13 times BL
Jerboa	2.5	15 times BL
Grasshopper	2	30 times BL
Agile frog	2	33 times BL
Northern cricket frog ( <i>Acris crepitans</i> )	1.25	36 times BL
Sharp-nosed ridged frog ( <i>Rana [Ptychadena] oxyrhynchus</i> )	3.6	45 times BL
Flea	0.6	200 times BL
In comparison: Human, current world record	8.9	5 times BL

**Table 1.2.12: Flight Speeds During Bird Migration**

For maximum speeds, see Table 1.2.10. For annual flight distances, see Table 1.2.13. Listed here in ascending order, according to speed.

After CREUTZ 1965, DORST 1972, SCHÜZ 1971

Species	km/h
Red-backed shrike	40.0
Sparrowhawk	41.4
Barn swallow	44.0
Honey buzzard	45.0
Blue-headed wagtail	46.0–48.0
Wood pigeon, crane, great black-backed gull, hooded crow	50.0
Eurasian siskin	51.0

Species	km/h
Rook	52.2
Chaffinch	52.5
Meadow pipit	53.0
Peregrine falcon	59.2
Crossbill	59.8
Turtle dove	61.0–72.0
Jackdaw	61.6
European starling	74.2
Plover family (Charadriidae)	90.0
Common teal	120.0
Common swift	150.0

**Table 1.2.13: Flight Distances During Bird Migration**

The figures represent an outbound or return flight, which means that the annual distance flown is twice as far. For flight speed during bird migration, see Table 1.2.12. Listed according to distance covered.

Data after BERNDT and MEISE 1959, CREUTZ 1956, SCHÜZ 1971, ZISWILER 1976

Species	Distance migrated (km)
European starling	1,400
Song thrush	2,600
Northern lapwing	3,000
Common quail	5,000
Greenland wheatear	5,000
Japanese snipe	5,000
Lesser whitethroat	6,000
Crane	6,500
Cuckoo	9,500
Barn swallow	10,000
Stork	10,000
Amur red-footed falcon	10,000
Eurasian dotterel	12,000
American golden plover	15,000
Short-tailed shearwater	17,500
Pectoral sandpiper	20,000
Arctic tern	20,000

**Table 1.2.14: Migratory Times of Selected Birds Native to Germany**

Roman numerals are used to indicate the months. The Arabic numbers 1, 2, and 3 after the slash stand for the first, second, and third “third” of the month.

Figures from FLINDT 1985, SCHÜZ 1971

Species	Spring migration (months)	Autumn migration (months)
Barn swallow	IV/3	IX–X
Black redstart	III/1	X
Blackcap	IV/2–V	IX–X
Chiffchaff	III/2	IX–XI
Common quail	V/3	VIII/2–X
Common redstart	IV/1	X
Common swift	IV/3–V/1	VIII/1
Crane	III/3–IV	XI
Cuckoo	IV	VIII–IX
Eurasian curlew	IV	VIII/3–X
Fieldfare	III–V/1	X–XI
Garden warbler	V	IX
Garganey	III/3–IV	VIII–IX
Golden oriole	IV/3–V/1	IX/1
Gray heron	III–IV	IX–X
Great reed warbler	IV/3	VIII–IX
Greylag goose	III	IX–X
Hoopoe	IV/2	IX–X
Lesser whitethroat	IV/2	IX–X
Nightingale	IV/3	VIII/3–IX
Northern lapwing	III/1	VIII–X
Sedge warbler	IV	IX–X
Snipe	III–IV	IX–XI
Song thrush	II–III	IX–X
Stork	II–IV	VII–VIII
Tree pipit	IV/2, 3	IX
White wagtail	III–V	X
Whitethroat	IV/3–V	IX
Willow warbler	IV/2	IX–X
Wood warbler	IV/3–V/1	VIII/3–IX
Woodlark	II–III	IX–X
Wryneck	IV/2–V/1	VIII/3–IX

## 1.3 Alimentation, Digestion

**Table 1.3.0: Numbers that Amaze**

This table brings together interesting figures from the Sects. 1.3 Alimentation, Digestion, 1.4 Metabolism, and 1.5 Excretion. These numbers are cited again in the individual tables, where they are accompanied by references to the literature. *BL* body length, *BW* body weight.

Daily dietary needs as share of body weight (BW)	Etruscan shrew	200% of BW
	Hummingbird	200% of BW
	Asian elephant	1% of BW
Length of intestine	Sperm whale (absolute)	288 m
	– As compared to BL	24 times
	Minke whale as compared to BL	56 times
Capacity of a cow's stomach		252.5 l
Capacity of a horse's appendix		33.5 l
Capacity of a horse's large intestine		96 l
Body temperature	Shrew	42 °C
	Blackbird	43.6 °C
	Robin	44.6 °C
	Hedgehog during hibernation	6 °C
Length of hibernation	Hazel dormouse, fat dormouse	6–7 months
Number of renal glomeruli	Cattle	8,000,000
Daily urine production	Cattle	up to 20 l
	Horse	up to 10 l
Relative weight of liver (as % of BL)	Kitefin shark ( <i>Scymnorhinus</i> )	22.7%

**Table 1.3.1: Absorption of Nutrients in the Body**

RQ respiratory quotient

For more detail on digestion, see SIEWING 1980.

After PENZLIN 1970

	O <sub>2</sub> consumption in cm <sup>3</sup> per g nutrient	CO <sub>2</sub> released in cm <sup>3</sup> per g nutrient	RQ CO <sub>2</sub> /O <sub>2</sub>	Energy in kcal per g (kJ/g) (kJ/l O <sub>2</sub> )	Caloric equivalent kcal/l O <sub>2</sub>
Carbohydrates	820	820	1	4.1 (17.2)	5.05 (21.1)
Fats	2,020	1,430	0.71	9.4 (39.3)	4.65 (19.5)
Proteins (physiological oxidation)	960	770	0.8	4.3 (18.0)	4.49 (18.8)

**Table 1.3.2: Required Daily Food Intake**

Figures given are percentage of body weight (BW). Listed according to increasing food requirements. Food requirements are related to the basal metabolic rate. See Table 1.4.1.

After HESSE and DOFLEIN 1935, NIETHAMMER 1979, SCHWERDTFEGER 1963, SLIJPER 1967

Species	Food requirements (as % of BW)
Anaconda	0.013
Asian elephant	1.0
Bear	2.0
Tiger	2.8
Lion	2.9
Cattle	3.0
Chicken	3.5
Buzzard/Hawk	4.5
Little owl	6.5
Common kestrel	8.0
Song thrush	10.0
European starling	11.9
Crest or Kinglet	18.0
Least weasel	25.0
Blue tit	30.0
Mouse	40.0
Mole	100.0
Shrews	100.0
Hummingbird	200.0
Pygmy mouse	200.0

**Table 1.3.3: Dental Formulae of Selected Mammals**

The numbers above the fraction bar represent the number of the following distinct types of teeth in the upper jaw: incisors, canines, premolars, and molars, respectively. The numbers below the fraction bar designate the same types of teeth in the lower jaw.

Data after BRINK 1975, BROHMER 1977, GIERSBERG and RIETSCHER 1968, GRZIMEK 1970, KRUMBIEGEL 1953

Species	Dental formula
Apes	$\frac{2 \ 1 \ 2 \ 3}{2 \ 1 \ 2 \ 3}$
Arvicolinae	$\frac{1 \ 0 \ 0 \ 3}{1 \ 0 \ 0 \ 3}$
Bats:	
Horseshoe bats	$\frac{1 \ 1 \ 2 \ 3}{2 \ 1 \ 3 \ 3}$
Mouse-eared bats	$\frac{2 \ 1 \ 3 \ 3}{3 \ 1 \ 3 \ 3}$
Bears	$\frac{3 \ 1 \ 4 \ 2}{3 \ 1 \ 4 \ 3}$
Beaver	$\frac{1 \ 0 \ 1 \ 3}{1 \ 0 \ 1 \ 3}$
Beech marten	$\frac{3 \ 1 \ 4 \ 1}{3 \ 1 \ 4 \ 2}$
Camel	$\frac{1 \ 1 \ 3 \ 3}{3 \ 1 \ 2 \ 3}$
Cat	$\frac{3 \ 1 \ 3 \ 1}{3 \ 1 \ 2 \ 1}$
Cattle	$\frac{0 \ 0 \ 3 \ 3}{3 \ 1 \ 3 \ 3}$
Chamois	Same as cattle
Common or Harbor seal	$\frac{3 \ 1 \ 4 \ 1}{2 \ 1 \ 4 \ 1}$
Deer	Same as cattle
Dog	Same as bears
Dormice	Same as beaver
Elephant	$\frac{1 \ 0 \ 3 \ 3}{0 \ 0 \ 3 \ 3}$

(Cont.) →



Species	Dental formula
Ermine	$\frac{3 \quad 1 \quad 3 \quad 1}{3 \quad 1 \quad 3 \quad 2}$
Eurasian badger	Same as pine marten
Fat dormouse	Same as beaver
Fox	Same as bears
Giraffe	Same as cattle
Goat	Same as cattle
Guinea pig	Same as beaver
Hamster	Same as arvicolinae
Hare	$\frac{2 \quad 0 \quad 3 \quad 3}{1 \quad 0 \quad 2 \quad 3}$
Hazel dormouse	Same as beaver
Hedgehog	$\frac{3 \quad 1 \quad 3 \quad 3}{2 \quad 1 \quad 2 \quad 3}$
Hippopotamus	$\frac{2 \quad 1 \quad 4 \quad 3}{2 \quad 1 \quad 4 \quad 3}$
Horses	$\frac{3 \quad 1 \quad 3 \quad 3}{3 \quad 1 \quad 3 \quad 3}$
Human	Same as apes
Hyena	$\frac{3 \quad 1 \quad 3 \quad 1}{3 \quad 1 \quad 3 \quad 1}$
Ibex	Same as cattle
Least weasel	Same as ermine
Lion	Same as cat
Llama	$\frac{1 \quad 1 \quad 2 \quad 3}{3 \quad 1 \quad 2 \quad 3}$
Lynx	$\frac{3 \quad 1 \quad 2 \quad 1}{3 \quad 1 \quad 2 \quad 1}$
Marmot	Same as squirrel
Mole	$\frac{3 \quad 1 \quad 4 \quad 3}{3 \quad 1 \quad 4 \quad 3}$

Species	Dental formula
Murinae	Same as arvicolinae
New World monkeys	Same as prosimians
Old World monkeys	Same as apes
Old World Porcupine	Same as beaver
Opossum	$\frac{5 \ 1 \ 3 \ 4}{4 \ 1 \ 3 \ 4}$
Pigs	Same as mole
Pine marten	Same as beech marten
Polecat	Same as ermine
Prosimians	$\frac{2 \ 1 \ 3 \ 3}{2 \ 1 \ 3 \ 3}$
Rabbit	Same as hare
Raccoon	$\frac{3 \ 1 \ 4 \ 2}{3 \ 1 \ 4 \ 2}$
Rats	Same as arvicolinae
Rhinoceros	$\frac{0 \ 0 \ 4 \ 3}{0 \ 0 \ 3 \ 3}$
Roe deer	Same as cattle
Sheep	Same as cattle
Shrews	
Genus <i>Sorex</i>	$\frac{3 \ 1 \ 3 \ 3}{1 \ 1 \ 1 \ 3}$
Genus <i>Neomys</i>	$\frac{3 \ 1 \ 2 \ 3}{1 \ 1 \ 1 \ 3}$
Genus <i>Crocidura</i>	$\frac{3 \ 1 \ 1 \ 3}{1 \ 1 \ 1 \ 3}$
Squirrel	$\frac{1 \ 0 \ 2 \ 3}{1 \ 0 \ 1 \ 3}$
Tapir	$\frac{3 \ 1 \ 4 \ 3}{3 \ 1 \ 3 \ 3}$
Tiger	Same as cat
Walrus	$\frac{3 \ 1 \ 3 \ 2}{3 \ 1 \ 3 \ 1}$
Wild cat	Same as cat
Wolf	Same as bears

**Table 1.3.4: Intestinal Length of Selected Vertebrates**

For relative intestinal length (in relation to body length), see Table 1.3.5.

Data after BERTELSMANN 1979, BUDDENBROCK 1956, HALTENORTH 1977, KRUMBIEGEL 1953, MEYER 1964, NIETHAMMER 1979

Species	Length (m)
African elephant	19.0
Bat	0.25
Blue whale	120.0
Brown bear	17.0
Camel	42.0
Cat	2.1
Cattle	51.0
Chicken	1.8
Dog	5.0
Eurasian water shrew	0.26
Goat	32.0
Hedgehog	1.7
Horse	30.0
Human	6.0–8.0
Lion	6.9
Mole	1.2
Mouse	0.5
Pig	22.0
Rabbit	5.6
Rat	1.3
Roe deer	12.0
Sheep	31.0
Siren (“sea cow”)	44.0
Sperm whale	288.0 (!)
Turtle	0.9
Wolf	5.8

**Table 1.3.5: Relative Intestinal Length of Selected Animals**

Numbers indicate relation of intestinal length (*IL*) to body length (*BL*) (how many times longer the intestine is than the body). For absolute lengths, see Table 1.3.4. Among the herbivores (long intestines) and carnivores (short intestines), respectively, the intestines of smaller animals are relatively longer than those of their larger counterparts. The sperm whale represents an exception to this pattern among whales, probably due to its feeding on octopus and squid.

Data after BAUER et al. 1974, BUDDENBROCK 1956, BERTELSMANN 1979, HALTENORTH 1977, HESSE and DOFLEIN 1935, KRUMBIEGEL 1953, *Lexikon der Biologie*, 1964, NIETHAMMER 1979, ZISWILER 1976

Species	Relation of IL to BL (times)	Species	Relation of IL to BL (times)
Bat	1.9	Leguan	0.3
Blue whale	4.5	Lion	3.9
Brown bear	8	Minke whale	56
Camel	12	Mole	8–11
Cat	3–4	Mouse	8
Cattle	22–29	Mudpuppy	3
Chicken	1.8	Nile crocodile	1.8
Cockchafer (May bug)	7	Orangutan	4.5
Common or Harbor seal	28	Pig	14–15
Common shrew	1.3	Pike	1
Dog	5–6	Porpoise	20
Dolphin	15	Python	1.8
Dung beetle ( <i>Scarabaeus</i> )	13	Rabbit	10
Elephant	7	Rat	9–11
Eurasian water shrew	3	Rock dove	7
European pond turtle	9	Roe deer	11
Fox	2.9	Sea lion	37
Great diving beetle	1	Sheep	27
Hedgehog	6.6	Snakes	1
Hippopotamus	12–14	Sperm whale	16–24
Horse	12	Tiger	5
Human	7.5	Turtles	5
Ibex	27	Wolf	4.7

**Table 1.3.6: Proportion of the Total Volume of the Intestinal Tract Made Up by Stomach, Small Intestine, and Appendix in Selected Mammals**

Figures represent percentages (%) of total volume. For absolute numbers, see also Table 1.3.7.

From BUDDENBROCK 1956, modified

Species	Stomach (%)	Small intestine (%)	Appendix (%)
Cattle	70.8	18.5	2.8
Dog	62.3	23.3	1.3
Goat	66.9	20.4	2.3
Guinea pig	19.4	31.1	21.4
Horse	8.5	30.2	15.9
Muskrat	27.2	16.5	37.8
Nutria	19.4	16.7	44.4
Pig	29.2	33.5	5.6
Rabbit	15.1	37.7	31.4
Sheep	66.9	20.4	2.3
Squirrel	42.1	33.4	14.0
White rat	24.2	43.7	16.8

**Table 1.3.7: Capacity of the Digestive Tract and its Parts in Selected Domestic Animals**

From KOLB 1974

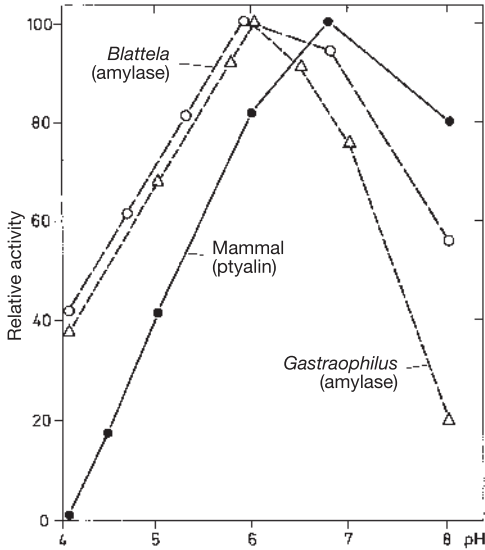
Species	Absolute capacity (l)	Relative capacity (%)
Cat	0.579	
Stomach	0.341	69.5
Small intestine	0.114	14.6
Large intestine	0.124	15.9
Dog	6.95	
Stomach	4.33	62.3
Small intestine	1.62	23.3
Appendix	0.09	1.3
Large intestine and rectum	0.91	13.1
Pig	27.45	
Stomach	8.00	29.2
Small intestine	9.20	33.5
Appendix	1.55	5.6
Large intestine and rectum	8.70	31.7

Species	Absolute capacity (l)	Relative capacity (%)
Horse	211.34	
Stomach	17.96	8.5
Small intestine	63.82	30.2
Appendix	33.54	15.9
Large intestine	96.02	45.4
Sheep	44.20	
Stomach	29.60	66.9
Small intestine	9.00	20.4
Appendix	1.00	3.3
Large intestine and rectum	4.60	10.4
Cattle	356.40	
Stomach	252.50	70.8
Small intestine	66.00	18.5
Appendix	9.90	2.8
Large intestine and rectum	28.00	7.9

**Table 1.3.8: pH Optimum of Selected Digestive Enzymes in Mammals**

Data after BAUER et al. 1974, BUDDENBROCK 1956, *Documenta Geigy* 1975, GANONG 1972, KARLSON 1974

Enzyme	pH value
Aminopeptidase	8.0
Carbohydases	7.0
Cathepsin	4.0–6.0
Chymotrypsin	7.5–8.5
Enteropeptidase	6.0
Gastricin	3.0–3.5
Lipases from carnivores	8.0
Lipases from herbivores	8.4–9.0
Maltase	6.6–7.0
Pancreatic $\alpha$ -amylase	6.9–7.1
Pepsin A	1.5–2.5
Ptyalin	6.7
Trypsin	7.5–8.5



**Fig. 1.3.8:** Dependency of activity of selected amylases on pH value. See also Table 1.3.8.

From PENZLIN 1980, p. 33.

### Table 1.3.9: pH Value of the Saliva of Selected Mammals

From BUDDENBROCK 1956, modified

Species	pH value
Cattle	7.99–8.27
Dog	7.34–7.80
Horse	7.31–7.80
Pig	7.15–7.47
Human	5.93–6.86

### Table 1.3.10: pH Values in the Intestinal Tract of Selected Birds

For figures on mammals, see Table 1.3.11.

Figures from BUDDENBROCK 1956, KOLB 1974

	Crop	Gizzard	Duodenum	Ileum	Large intestine	Appendix
Chicken	4.51	2.6	5.76–6.01	5.78–6.42	6.26	5.71
Rock dove	4.28	2.0	5.23–5.39	5.32–5.89	5.43	
Pheasant	5.78	2.06	6.01–6.19	6.18–6.81	6.61	5.39
Duck	4.92	2.33	6.01–6.19	6.71–6.95	6.37	5.88

**Table 1.3.11: pH Values in the Intestinal Tract of Selected Mammals**

Figures from various authors in BUDDENBROCK 1956, modified

Species	Stomach	Duode- num	Jeju- num	Ileum	Cecum	Colon	Rectum
Horse	4.48	7.5	7.79		7.26	6.95	
Horse	4.45	7.13	7.46		7.23	7.09	6.24
Pig	5.46	6.63	7.44		7.24	6.85	
Rat	6.98		7.32	7.28	7.15		
Rat	3.2–4.6	6.5– 7.2			5.5–7.3	5.6–7.1	
Cattle	4.95 <sup>a</sup>	5.98–7.49		7.54	8.68	7.15	
Cattle	5.53	6.83	8.55	7.93	9.41		
Suckling calf	4.46	6.8–7.1	6.9–7.2	7–7.3	7.2–7.5	7.1–7.5	7.1–7.5

<sup>a</sup>Abomasum**Table 1.3.12: pH Values in the Mid-intestine of Selected Invertebrates**

From BUDDENBROCK 1956, modified

Species	pH value
Bedbug	6.2
Bee	6.3
Butterfly ( <i>Pyrameis</i> )	8.4
Cockroach ( <i>Blatella</i> )	6.2
Cricket	7.6
European rhinoceros beetle	10.0–10.4
Grasshopper ( <i>Tettigonia</i> )	5.9
Greenbottle blowfly ( <i>Lucilia</i> )	7.8–8.0
Louse	7.2
Meal moth	8.4
Paper wasp ( <i>Polistes</i> )	7.3
Primitive insects ( <i>Ctenolepisma</i> )	4.8–7.0
Soft-shell clam ( <i>Mya arenaria</i> )	6.7
Walking stick	6.3



**Table 1.3.13: Duration of Intestinal Passage in Selected Vertebrates**

This table shows the speed of passage of food through the intestine and the start and end of defecation.

Data after BUDDENBROCK 1956, HALTENORTH 1977

Species	Speed of passage (cm/h)	Start of defecation	End of defecation
Bat	3.3	41 min	7 h
Camel	9.7		18 days
Cattle	17.7	25 h	12 days
Dog	7.7	17 h	2.7 days
Horse	35.7	24 h	3.5 days
Mouse	6.4	3 h	8.5 h
Pig	22.9	13 h	4 days
Rabbit	4.7	5 h	5 days
Rat	1.1	6.5 h	5 days
Sheep	8.1	12 h	16 days

**Table 1.3.14: Relative Weight of Liver in Selected Vertebrates**

As percentage of body weight (BW). Figures given are mean values.

After BUDDENBROCK 1956, HALTENORTH 1977, KOLB 1974

Species	Liver (as % of BW)	Species	Liver (as % of BW)
African elephant	1.6	Human	3.0
Cat	3.6	Kitefin shark	22.7
Cattle	1.2	( <i>Scymnorhinus</i> )	
Chicken	2.7	Lion	3.2
Chimpanzee	2.8	Mouse	7.1
Common vole	4.6	Pig	2.4
Dog	2.9	Rabbit	2.7
Duck	2.4	Rat	3.8
Electric rays	5.7	Rock dove	3.0
Goat	1.3	Sheep	1.3
Golden or Syrian hamster	5.2	Sparrow	5.6
Gorilla	5.1	Squirrel	2.2
Guinea pig	3.9	Stingray	14.9
Hippopotamus	1.8	( <i>Trygon</i> )	
Horse	1.4	Toad	2.8
Houndshark	9.7	Wolf	2.8

**Table 1.3.15: Daily Bile Production in Selected Vertebrates**

Figures express daily bile production in relation to hepatic weight and body weight.

From BUDDENBROCK 1956, modified

Species	cm <sup>3</sup> bile per g liver in 24 h	cm <sup>3</sup> bile per kg body weight in 24 h
Cat	0.45	14.0
Cattle	0.86	15.4
Chicken	0.58	14.2
Dog	0.36	12.0
Duck	0.91	40.1
Goat	0.87	11.8
Guinea pig	6.50	228.0
Hamster	3.03	72.3
Horse	1.46	20.8
Human	0.64	16.0
Mouse	0.63	34.9
Pig	1.04	25.2
Rabbit	4.53	118.0
Rat	1.25	47.1
Rock dove	1.64	40.1
Sheep	0.98	12.1

## 1.4 Metabolism

**Table 1.4.1: Basal Metabolic Rate of Selected Animals**

Figures give oxygen consumption in cubic centimeters of O<sub>2</sub> per gram body weight and per hour. 1 cm<sup>3</sup> O<sub>2</sub> is the equivalent of 1.43 mg. The basal metabolic rate in homoiothermic small animals is, relative to body weight, higher than in comparable large animals, since surface area only increases when squared, but weight (= volume) increases when cubed (see Fig. 1.4.1). Relative to body surface area, the basal metabolic rate is roughly the same. For greater detail, see also STEWING 1980.

Date after FLOREY 1976, HEIDERMANNS 1957, PROSSER 1973, WHITTOU 1970

Species	O <sub>2</sub> consumption (cm <sup>3</sup> O <sub>2</sub> per g BW and per h)	Species	O <sub>2</sub> consumption (cm <sup>3</sup> O <sub>2</sub> per g BW and per h)
<b>Invertebrates</b>		Cattle	0.124
Amoeba	0.2	Chaffinch	3.3
Blowfly	1.7	Chicken	0.43
Blue mussel	0.005–0.076	Common house mouse	1.7
Butterfly ( <i>Vanessa</i> )	0.6	Dog	0.36
Crayfish	0.1	Eel	0.088
Earthworm	0.065	Elephant	0.07–0.11
Freshwater snail	0.011	Frog ( <i>Rana</i> )	0.055
Lobster	0.5	Frog Tadpole ( <i>Rana</i> )	0.065
Lugworm	0.031	Goldfish	0.042–0.07
Mealworm	0.182	Grass snake	0.07
Octopus ( <i>Octopus</i> )	0.09–0.28	Guinea pig	0.6–0.9
Paramecium	1.0–1.3	Hare	0.96
Pond mussel	0.002	Horse	0.03–0.04
Roundworm	0.5	Human	0.21–0.24
Sea anemone	0.013	Hummingbird	4.0
Sea urchin	0.004–0.027	Kangaroo	0.29
Shore crab	0.094	Lizard ( <i>Lacerta</i> )	0.245
Sponge ( <i>Suberitis</i> )	0.24	Pig	0.35
Starfish	0.03–0.4	Python	0.02
Woodlouse	0.096	Rabbit	0.55
<b>Vertebrates</b>		Rat	0.88–0.95
Alligator	0.079	Sheep	0.25
Bat	1.74	Shrew	7.0–10.6
Camel	0.099	Sparrow	3.53
Carp	0.067	Trout	0.205–0.22
Cat	0.45		

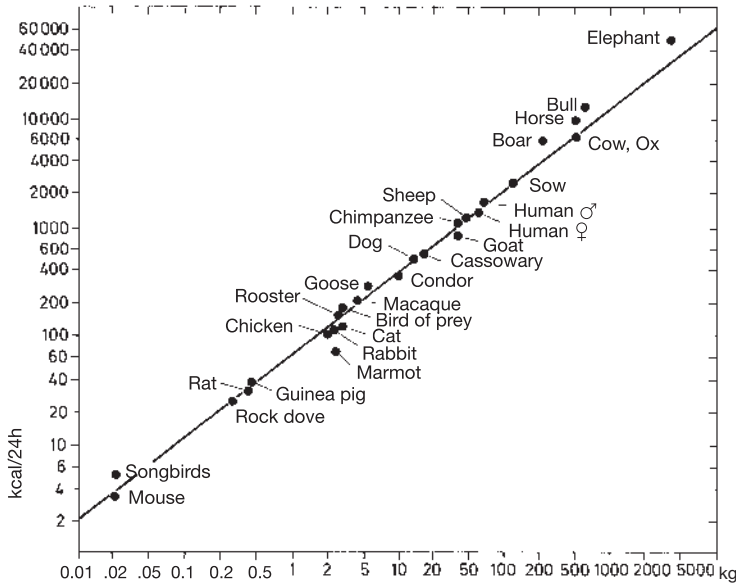


Fig. 1.4.1: Dependency of basal metabolic rates on the body weight of selected homoiothermic animals on a double logarithmic scale. See also Table 1.4.1. From PENZLIN 1980, p. 49

**Table 1.4.2: Body Temperatures of Selected Homoiothermic Animals**

Temperatures given are mean values of rectal readings. For daily variations in body temperature, see Table 1.4.3.

Data after BERTELSMANN 1979, DORST 1972, KOLB 1974, MEYER 1964, NIETHAMMER 1979, PENZLIN 1977, PRECHT et al. 1955, SLIJPER 1967, WITKE 1972, ZISWILER 1976

Species	Body temperature (°C)	Species	Body temperature (°C)
<b>Birds</b>		European starling	41.3
Albatross	40.7	Goose	40.7
Blackbird	43.6	Goshawk	41.9
Black-headed gull	41.4–42.1	Great spotted woodpecker	42.1–43.3
Carrion crow	42.0	King penguin	37.7
Chicken	41.5	Ostrich	37.4
Common buzzard	42.0	Robin	44.6
Common swift	44.0	Rock dove	41.8
Duck	40.5–42.5	Rufous hummingbird	39.0

(Cont.) →

Species	Body temperature (°C)	Species	Body temperature (°C)
Sparrow	41.4	Hazel dormouse	30.0
Sparrowhawk	41.2	Hedgehog, awake	35.0
Stork	40.0	Hedgehog, in hibernation	6.0
Tawny owl	41.0	Hippopotamus	35.4
Winter wren	41.8	Horse	37.6–37.8
		Human	36.2–37.8
<b>Mammals</b>		Kangaroo	36.8
Bat	31.0	Long-beaked echidna	30.0
Capuchin monkey	38.5	Marmot	36.0
Cat	38.8–39.0	Mole	39.4
Cattle	38.5	Mouse	38.0
Chimpanzee	37.0	Pig	39.0
Dog	38.3–39.0	Rabbit	39.2–39.6
Dromedary	38.1	Rat	38.1
Elephant	36.2	Reindeer	37.5–39.8
Fox	38.5	Sheep	39.5
Goat	40.0	Shrew	42.0
Guinea pig	36.0–39.2	Spiny anteater	32.0
		Whale	36.5

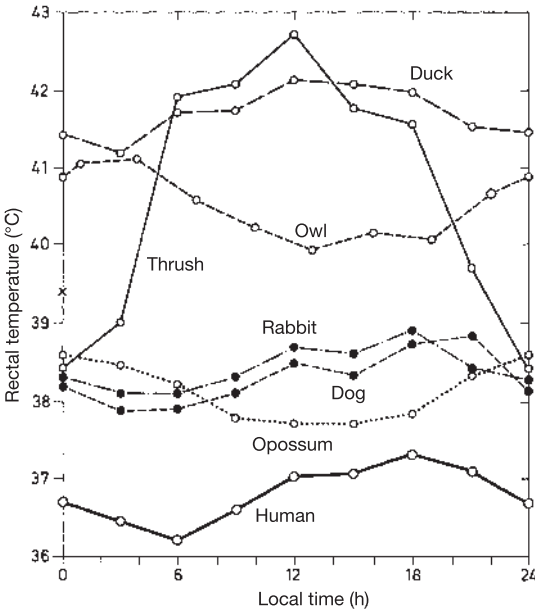


Fig. 1.4.2: Daily movement of body temperature in selected animals. Note the difference between nocturnal animals (owl, opossum) and their diurnal counterparts.

From PRECHT, CHRISTOPHERSEN and HENSEL 1955

**Table 1.4.3: Size of Daily Variations in Body Temperature in Selected Homoiothermic Animals**

For mean temperature values, see Table 1.4.2.

Data after NIETHAMMER 1979, PRECHT et al. 1955

Species	Daily variation (°C)
Camel	3.0
Dog	0.9
Duck	0.9
European starling	3.3
Goshawk	1.8
Guinea pig	0.8
Gull	1.7
Hedgehog	2.0
Human ♀	1.4
Human ♂	1.2
Long-beaked echidna	3.0
Owl	0.9
Rabbit	0.8
Rhesus monkey	3.6
Rock dove	1.4
Thrush	4.0

**Table 1.4.4: Preferred Temperatures of Selected Animals**

Preferred temperatures refer to those temperatures at which an animal most prefers to stay and which it actively seeks.

Data after BELLAIRS 1971, GRZIMEK 1970, HERTER 1962, KÄSTNER 1972, KEMPER and DÖHRING 1967, MEYER 1964

Species	Preferred temperature (°C)
<b>Invertebrates</b>	
Bedbug	33.0
Body louse	32.5
Crayfish ( <i>Cambarus</i> )	25.0
Darkling beetle ( <i>Adesmia metallica</i> )	49.0
Dog flea	38.0
Earwig	32.0
Field cricket	37.0
Great diving beetle	25.0
Ground beetle ( <i>Carabus granulatus</i> )	30.0

(Cont.) →

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Species	Preferred temperature (°C)
Katydid	40.7
Paramecium	23.0–25.0
Snow flea ( <i>Boreus hiemalis</i> )	9.8
Tiger beetle	44.0
Wasp, queen	38.1
Wasp, worker	35.4
Winter moth	6.0
<b>Vertebrates</b>	
American alligator	32.0–35.0
Carp	21.3
Chameleon	45.0
Common house mouse	37.0
Common toad	27.9
Common vole	35.0
Crossed viper	33.0
Gecko ( <i>Tarentola</i> )	38.0
Giant tortoise	28.0–33.0
Goldfish	18.6
Grass snake	34.3
Guinea pig	36.0
Guppy	24.6
Hermann's tortoise	25.0–33.0
Marine iguana	22.0–27.0
Rainbow trout	10.5
Sand lizard	38.8
Slowworm	28.4
Water vole	29.0

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**Table 1.4.5: Duration of Hibernation (Torpor, Winter Rest) of Selected Vertebrates Native to Germany**

Data after BERTELSMANN 1977, FLINDT 1989, MERTENS 1947, MEYER 1964

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Species	Duration (months)
Bats	5–6
Common frog	4–5
Common lizard	5–6
Common toad	4–5
Common wall lizard	5–6
Crossed viper	4–5
Fat dormouse	6–7
Grass snake	4–5
Hamster	2–3.5
Hazel dormouse	6–7
Hedgehog	3–4
Marmot	5–6
Sand lizard	5–6
Slowworm	4–5
Smooth newt	3–4
Squirrel	2–3.5
Tree frog	5–6

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## 1.5 Excretion

**Table 1.5.1: Number of Glomeruli in the Kidneys of Selected Vertebrates**

The absolute number ( $n$ ) is accompanied by a relative measurement, the number of glomeruli per gram of body weight (BW). Listed in ascending order, according to absolute number of glomeruli.

Values from HALTENORTH 1977, OPPENHEIMER and PINCUSSEN 1930, PORTMANN 1959, STURKIE 1976, ZISWILER 1976

Species	Glomeruli ( $n$ )	Glomeruli (per g BW)
Newt	400	80
Frog	2,000	70
Mouse	10,000	670
Bat	34,000	9,675
Rat	52,000	123
Wood mouse	72,000	3,092
Shrew	82,000	12,660
Squirrel	100,000	304
Mole	130,000	1,855
Hare	163,000	87
Hedgehog	186,000	238
Rabbit	285,000	188
Baboon	305,000	156
Cat	460,000	200
Dog	500,000	50
Rock dove	535,000	1,274
Fox	695,000	203
Chicken	840,000	336
Eurasian badger	962,000	80
Roe deer	1,500,000	60
Goose	1,659,000	307
Duck	1,989,000	542
Human	2,000,000	27
Dolphin	3,990,000	139
Deer	4,590,000	32
Common or Harbor seal	4,643,000	268
Cattle	8,000,000	12

**Table 1.5.2: Urine Production of Selected Mammals**

Figures given represent mean values. They are subject to a great degree of fluctuation, given changes in feed or intake of liquids. On the mechanism of urine production, see STEWING 1980. For humans, see also Table 4.5.15.

From BUDDENBROCK 1956, KOLB 1974

Species	Amount in 24 h	Amount in 24 h (cm <sup>3</sup> per kg BW)
Brown bear	2.2 l	21.4
Cat	100–200 cm <sup>3</sup>	80.0
Cattle	12–20 l	24.0
Coyote	560 cm <sup>3</sup>	58.3
Dog (large)	0.5–2 l	40.0
Dog (small)	0.04–0.2 l	40.0
Fox	1.3 l	32.8
Horse	6–10 l	8.4
Human	1–1.6 l	14–23.0
Hyena	545 cm <sup>3</sup>	0.8
Pig	2–4 l	40.0
Sea lion	604 cm <sup>3</sup>	0.9
Sheep	1–1.5 l	10–15.0

**Table 1.5.3: Maximum Urine Concentration in Selected Mammals**

The level of urine concentration is in part dependent upon the length of Henle's loop in nephrons.

Data after PROSSER 1973

Species	Maximum concentration (mOsm)
Camel	2,500–3,170
Cat	2,100–3,250
Common or Harbor seal	2,150–2,420
Dog	2,000–2,660
European ground squirrel (suslik)	3,900
Golden or Syrian hamster	3,000
Harbor porpoise	1,830
Hopping mouse ( <i>Notomys</i> )	5,540–6,400
Human	1,400–1,480
Kangaroo rat ( <i>Dipodomys</i> )	5,500–6,000
Pig	1,100
Rabbit	1,500–1,910

(Cont.) →

Species	Maximum concentration (mOsm)
Rat	2,560–3,000
Rhesus monkey	1,190
Whale	900–1,340

**Table 1.5.4: Composition of the Excrement of Selected Vertebrates**

Figures represent the share of ammonia, urea, uric acid, creatine, and creatinine in excrement, given as a percentage of nitrogenous substances. On the ureic contents of urine, see Table 1.5.5

From BUDDENBROCK 1956, modified

	Ammonia	Urea	Uric acid	Creatine + Creatinine
Shark	2 – 11	81 – 89	0.3– 0.7	
Seawater bony fish	0.3 – 1.3	0.1 – 2.7		24 – 66
Carp	56	6	0.2	6.5
Frog	11 – 21	68 – 78		
Alligator	67 – 81	0.17	up to 20	
Turtle	10 – 22	24 – 48	7 – 28	5.5
Chicken	15 – 20	9 – 11	59 – 70	7 – 9
Goat	3 – 19	29 – 76		4 – 23
Sheep	1.6– 18	51 – 83		3 – 22
Cattle	1.6– 20	27 – 60		6 – 13
Mouse	7.7	64 – 68	0.3	1.7
Primates	1.6– 1.8	54 – 84	0.1– 3.1	3.5– 6.4

**Table 1.5.5: Urea in the Urine of Selected Mammals**

For further figures on the composition of the urine, see Table 1.5.4.

From HALTENORTH 1977, modified

Species	Urea as percentage of urine
Blue whale	1.1
Cattle	1.1 –1.6
Common or Harbor seal	0.3 –3.0
Dog	0.7 –3.5
Elephant	0.18–0.45
Harbor porpoise	1.3 –2.4

Species	Urea as percentage of urine
Horse	0.8 –1.6
Human	1.8
Hyena	2.8 –3.4
Mouse	1.5 –3.2
Rabbit	0.55–0.9
Rat	1.8 –2.7
Sheep	0.6 –0.8
Tiger	2.9 –3.6

**Table 1.5.6: Freezing Point Depression and Osmotic Pressure of Urine in Selected Animals**

In some animals the value is dependent upon that of the external medium (seawater, freshwater); in these cases its freezing point depression is also provided. If this figure is not given, then the given values are independent of the external medium.

After HALTENORTH 1977, HEIDERMANNS 1957

Species	Freezing point depression $\Delta$ °C		Osmotic pressure of urine	
	External medium	Urine	(atm)	([ hPa])
Cat		4.73	52.3	[52,993]
Cattle		1.34	16.2	[16,415]
Crayfish	0.02	0.09	1.1	[1,115]
Dog		3.29	39.8	[40,327]
Elephant		0.34	4.1	[4,154]
Freshwater bony fishes	0.02	0.10	1.2	[1,216]
Freshwater cartilaginous fishes	0.02	0.70	8.5	[8,613]
Frog	0.02	0.17	2.1	[2,128]
Goat		1.25	15.1	[15,300]
Guinea pig		0.91	11.0	[11,146]
Horse		0.32	3.9	[3,952]
Human		1.29	15.6	[15,807]
Lobster	1.85	1.89	22.9	[23,203]
Mitten crab	2.20	2.14	25.9	[26,243]
Mitten crab	0.02	1.23	14.9	[15,097]
Pig		1.70	20.6	[20,873]
Rabbit		0.92	11.1	[11,247]
Seawater cartilaginous fishes	1.85	1.92	23.2	[23,507]
Shore crab	1.00	1.50	18.2	[18,441]
Shore crab ( <i>Carcinus</i> )	1.85	1.90	23.0	[23,305]

**Table 1.5.7: Aquatic Salt Concentration Tolerance Limits of Selected Animals**

Figures for salt given per mille (gram per liter).

Figures from ALTMAN and DITTMER 1966

Animal species	Salt ‰ (g/l)
<b>Fish</b>	
Carp	0– 10
Goldfish	0– 15
Plaice	7– 75
Rainbow trout	0– 35
Sticklebacks ( <i>Gasterosteidae</i> )	0– 55
<b>Invertebrates</b>	
Brine shrimp	35–300
Bristleworm ( <i>Nereis</i> )	0–139
Cockle	22– 60
Mitten crab	0– 47
Moon jelly	8– 35
Octopus ( <i>Octopus</i> )	30– 35
Sand hopper ( <i>Corophium</i> )	17– 72
Shore crab	27– 72
Shrimp ( <i>Crangon</i> )	12– 35
Squid ( <i>Loligo</i> )	31– 36

## 1.6 Heart, Circulation

**Table 1.6.0: Numbers that Amaze**

This table brings together some interesting figures from Sects. 1.6 Heart, Circulation, 1.7 Blood, and 1.8 Respiration. These numbers are cited again in the individual tables of these sections, where they are accompanied by references to the literature.

Weight of the heart			
	Blue whale	Absolute	598.4 kg
		In relation to BW	4.4 ‰
	Hummingbird	Absolute	0.09 g
		In relation to BW	23.9 ‰
Heart frequencies			
	Fruit fly ( <i>Drosophila</i> )		235/min
	Shrew		1,320/min
	Elephant seal	(On the surface)	60/min
		While diving	4/min
Blood pressure (systolic/diastolic)			
	Giraffe		340/230 mmHg
	Canary		220/154 mmHg
	Mouse		147/106 mmHg
Number and size of red blood cells			
	Goat	18.5 million/mm <sup>3</sup>	3.5 μm × 3.5 μm
	Olm	36,000/mm <sup>3</sup>	58 μm × 34 μm
Coagulation times of blood			
	Lamprey		2–5 s
	Grass snake		27 min
Inner surface of the lung			
	Horse		500 m <sup>2</sup>
	Human		90 m <sup>2</sup>
	Fire salamander		5 cm <sup>2</sup>
Breaths per minute			
	Hummingbird		250
	Mouse		163
	Fin whale		0.5
Maximum diving times and depths of selected animals with lungs			
	Beaked whale	120 min	500 m
	Sperm whale	75 min	1,143 m
	Leatherback turtle		1,200 m

**Table 1.6.1: Heart Weights of Selected Vertebrates (Absolute and Relative)**

The relative weights are given as a per mille of body weight (BW); the absolute weights are in grams. The smaller relative heart weights of larger animals is related to their lower basal metabolic rate. See Table 1.4.1.

Data after BUDDENBROCK 1967, CZICSÁKY 1984, HALTENORTH 1977, DORST 1972, HESSE and DOFLEIN 1935, STURKIE 1976, ZISWILER 1976

Species	Relative heart weight (% of BW)	Absolute heart weight (g)
<b>Fish</b>		
Carp	1.5	1.62
Electric rays	0.6	
Pike	1.9	0.66
Salmon	2.0	10.72
Tiger shark	1.2	41.6
Trout	1.2	0.31
Tuna	3.1	616
<b>Amphibians</b>		
Axolotl	4.5	0.03
Bullfrog	3.2	1.65
Fire salamander	1.86	0.04
Green toad	8.05	
Marsh or Lake frog	1.8	0.14
Northern crested newt	1.96	
Tree frog	5.79	
<b>Reptiles</b>		
Alligator	2.6	137
Boa constrictor	3.1	5.64
Python	3.0	18.5
Western green lizard	3.8	0.91
<b>Birds</b>		
Blackbird	12.9	1.33
Budgerigar	13.2	
Carrion crow	10.7	
Chaffinch	13.2	0.3
Chick (just hatched)	9.0	
Chicken (leghorn)	6.4	
Common buzzard	7.5	4.81
Common kestrel	9.6	
Common raven	9.0	14.29

Species	Relative heart weight (% of BW)	Absolute heart weight (g)
Common swift	16.5	0.71
Domestic pigeon	14.0	
Duck	9.5	
Eagle owl	4.7	
Eurasian jay	9.9	1.52
European starling	16.2	0.93
Goose	8.0	
Great spotted woodpecker	13.4	1.04
Great tit	13.4	0.24
Herring gull	9.8	5.24
House sparrow	15.2	0.42
Hummingbird	23.9 (!)	0.09
Little owl	8.25	
Mallard	8.0	8.75
Northern lapwing	15.1	3.16
Ostrich	9.8	1,205
Pheasant	4.5	5.61
Stork	8.6	28.75
Swallow	14.1	0.32
Swan	10.3	67.6
Winter wren	16.2	0.14
Wood pigeon	10.63	5.32
<b>Mammals</b>		
African elephant	3.9	19,500
Bison	6.6	6,600
Blue whale	4.4	598,400
Capuchin monkey	8.0	
Common house mouse	6.45	0.19
Dog	6.8	135
European rabbit	3.21	
Fin whale	5.0	380,000
Fox	9.0	63
Greyhound	12.9	
Guinea pig	4.0	4.8
Hare	9.42	
Harvest mouse	12.9	0.07
Hedgehog	4.0	4.8
Horse	9.0	4,000
Human	4.3	300
Jaguar	5.4	
Lion	3.0	750

(Cont.) →



Species	Relative heart weight (% of BW)	Absolute heart weight (g)
Mole	5.8	0.23
Myotis (bat)	10.45	0.22
Polar bear	5.8	2,900
Rat	3.62	1.45
Rhinoceros	6.3	
Roe deer	8.0	400
Shrew	14.0	0.11
Sperm whale	3.2	116,000
Squirrel	6.7	3.22
Weasel	16.7	0.75
Wood mouse	7.0	0.13

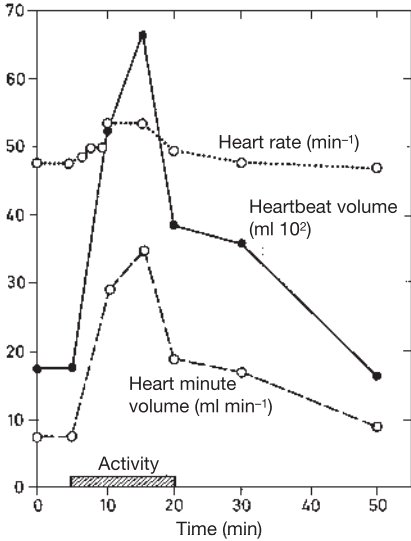
**Table 1.6.2: Heart Rates of Selected Animals**

Values given are only directly comparable with one another in birds and mammals. In poikilothermic animals they are strongly dependent on temperature. Heart rates in small homoiothermic animals reflect basal metabolic rates that are higher than in their larger counterparts. See also Table 1.4.1

After BUDDENBROCK 1967, HALTENORTH 1977, KOLB 1974, OPPENHEIMER and PINCUSSEN 1925, ZISWILER 1976

Species	Heartbeats per minute	Species	Heartbeats per minute
<b>Invertebrates</b>			
Amber snail	26	Pond mussel	4–6
Anopheles mosquito	110	Primitive insect ( <i>Machilis</i> )	150–160
Aquatic sowbug	310	Privet hawk-moth (caterpillar)	39–82
Blue mussel	10–15	Privet hawk-moth (imago)	40–50
Cockroach	60–80	Shrimp	146
Cross spider ( <i>Araneus</i> )	130–134	Small white (butterfly)	29
Dragonfly ( <i>Anax</i> )	60	Stag beetle	16
Edible crab	90–120	Tunicate ( <i>Ciona</i> )	17
Edible snail ( <i>Helix pomatia</i> )	40–50	Woodlouse	180–200
Fruit fly	235		
Lobster	50		
Lugworm	13–22		
Migratory locust	80–130		
Octopus ( <i>Octopus</i> )	33–40		

Species	Heartbeats per minute	Species	Heartbeats per minute
<b>Vertebrates</b>		Goat	70–80
Bat ( <i>P. pipistrellus</i> )	660	Golden or Syrian hamster	350–500
Brown rat	260–450	Goldfish	36–40
Caiman	36–50	Goose	80
Capuchin monkey	160	Grass snake	23–40
Carp	40–80	Guinea pig	200–312
Cat	110–130	Hedgehog (hibernating)	18
Cat shark	65	Hedgehog (nonhibernating)	280–320
Cattle	45–50	Horse	32–44
Chicken	330–375	Human	60–90
Common buzzard	206–351	Lion	40
Common frog	35–40	Mouse	450–550
Common pipistrelle	972	Ostrich	60–70
Common swift	700	Panther	60
Common toad	40–50	Pig	60–80
Crossed viper	40	Pike	30–42
Crow	380	Rabbit	150–280
Crow	300–352	Rattlesnake	44–47
Dog	60–180	Rock dove	150–250
Dolphin	84–140	Sand lizard	60–70
Duck	229–420	Sheep	60–80
Eel	10–15	Shrew	500–1,320 (!)
Electric rays	16–50	Slowworm	64
Elephant	22–28	Sparrow	745–850
Elephant seal		Stork	270
on the water surface	60	Turkey	93
while diving	4	Western green lizard	60–66
Fox	100	Whale	15–16
Giant tortoise	30–40		
Giraffe	66		



**Fig. 1.6.2:** Dependency of cardiac activity (heart minute volume, heartbeat volume, and heart rate) on temperature and activity in rainbow trout. See also Tables 1.6.2 and 1.6.3. From PENZLIN 1980, p. 251

### Table 1.6.3: Heart Minute Volumes of Selected Animals

The heart minute volume (HMV) given refers to the amount of blood in cubic centimeters moved by the heart of the given animal in 1 min. Strong physical exertion can raise this figure considerably, in humans up to 30 l. It is calculated by multiplying the heart rate (Table 1.6.2) by the heartbeat volume.

Figures from BUDDENBROCK 1967

Species	HMV (cm <sup>3</sup> /min)
Cattle	45,800
Chicken	400
Dog	2,000– 3,000
Frog	20– 30
Horse	18,000–24,000
Human	5,500– 6,000
Migratory locust	0.015
Octopus ( <i>Octopus</i> )	57– 81
Pig	4,500
Turtle	148

**Table 1.6.4: Blood Pressure of Selected Animals**

Figures represent systolic and diastolic blood pressure, respectively, separated by a slash. Single numbers represent mean values.

After ALTMAN and DITTMER 1974, BUDDENBROCK 1967, HALTENORTH 1977, KOLB 1962

Species	Blood pressure (mmHg)	(in hPa)
Canary	220/154	(293/205)
Cat	155/100	(207/133)
Cattle	134/88	(179/117)
Chicken	150/120	(200/160)
Chimpanzee	136/80 (!)	(181/107)
Common or Harbor seal	150/105	(200/140)
Crocodile	50	(67)
Cuttlefish	44/22	(59/29)
Dog	156/100	(208/133)
Duck	180/134	(240/179)
Eel	35– 40	(47–53)
Electric rays	16/14	(21/19)
European starling	180/130	(240/173)
Frog	32/19	(43/25)
Giraffe	340/230	(453/307)
Goat	120/84	(160/112)
Golden or Syrian hamster	170/120	(227/160)
Grass snake	89	(119)
Guinea pig	77/47	(103/63)
Horse	190/120	(253/160)
Human	120/80	(160/107)
Kangaroo	122/79	(163/105)
Lobster	8	(11)
Mouse	147/106	(196/141)
Pig	169/108	(225/144)
Pike	35.5	(47)
Rabbit	110/80	(147/107)
Rat	145/105	(193/140)
Rock dove	187/138	(249/184)
Salamander	22/12	(29/16)
Salmon	75	(100)
Shark	32/16	(43/21)
Sheep	103/85	(137/113)
Slider turtle	30/26	(40/35)
Sparrow	180/140	(240/187)
Trout	39/34	(52/45)

## 1.7 Blood

**Table 1.7.1: Blood Volumes of Vertebrates**

Data given as percentage of body weight (BW). Considerable variations are possible in some cases.

Data after BERTELSMANN 1979, OPPENHEIMER and PINCUSSEN 1925, PROSSER 1973

Species	Blood volume as percentage of BW	
	Mean value	Limits
Bat ( <i>Myotis</i> )	13.0	
Blue whale	6.5	
Cat	5.6	
Cattle		5.2– 5.7
Chicken	7.0	
Common frog	5.6	4.7– 6.3
Crocodile	15.4	
Dog	8.6	2.3– 8.7
Duck	10.2	
Eel	2.9	
Fat dormouse	5.8	5.3– 6.0
Goat	7.3	
Grass snake	7.7	
Guinea pig	7.5	
Hare	7.5	6.4– 8.1
Hedgehog	8.0	
Horse	7.6	
Human ♂		6.5– 7.1
Human ♀		7.1– 7.8
Lizard	5.8	4.7– 7.0
Mouse	5.8	4.6– 7.0
Mudpuppy	2.9	
Pig	4.6	2.3– 8.7
Rat	7.5	
Rock dove	7.8	
Rooster	9.0	
Salamander	6.1	5.5– 6.8
Salmon	2.8	
Sea lamprey	4.9	
Sharks	7.0	
Sheep	8.1	6.6– 10.4
Slowworm	5.2	3.8– 7.6
Turtle	9.1	

**Table 1.7.2: Number and Size of Red Blood Cells in Selected Vertebrates**

The number is in millions per cubic millimeter; size is given in micrometers.

After BUDDENBROCK 1967, HALTENORTH 1977, HEIDERMANNS 1957, HESSE and DOFLEIN 1935, KOLB 1974, *Kosmos-Lexikon* 1953, PORTMANN 1959, STURKIE 1976

Species	Size ( $\mu\text{m}$ )	Number (1,000,000/ $\text{mm}^3$ )
Carp	11.0 $\times$ 8.2	1.40
Carrion crow	12.0 $\times$ 7.0	2.49
Cat	4.5 $\times$ 4.5	8.22
Chaffinch	12.4 $\times$ 7.5	3.66
Chimpanzee	7.4 $\times$ 7.4	5.10
Common frog	23.0 $\times$ 16.0	0.49
Common toad	20.5 $\times$ 13.3	0.38
Dog	7.0 $\times$ 7.0	6.65
Edible frog	23.0 $\times$ 16.0	0.60
Eel	15.0 $\times$ 12.0	1.1
Electric rays	27.0 $\times$ 20.0	0.14
Elephant	9.0 $\times$ 9.0	2.02
Fire salamander	43.0 $\times$ 25.0	0.09
Goat	3.5 $\times$ 3.5	18.50 (!)
Golden or Syrian hamster	5.6 $\times$ 5.6	6.90
Grass snake	18.0 $\times$ 11.0	0.97
Guinea pig	7.4 $\times$ 7.4	5.60
Horse ("coldblood")		6.90
Horse (thoroughbred)		8.90
Human ♀	7.5 $\times$ 7.5	4.50
Human ♂	7.5 $\times$ 7.5	5.00
Lamprey	15.0 $\times$ 15.0	0.13
Llama	7.6 $\times$ 4.4	13.19
Mouse	6.0 $\times$ 6.0	9.50
Mudpuppy	58.0 $\times$ 34.0 (!)	0.036
Musk deer	2.5 $\times$ 2.5 (!)	
Natterjack toad	20.7 $\times$ 14.4	0.65
Northern crested newt	31.0 $\times$ 22.0	0.164
Ostrich	14.0 $\times$ 9.0	1.62
Pig	6.0 $\times$ 6.0	6.96
Rat	7.5 $\times$ 7.5	9.00
Rock dove	14.0 $\times$ 7.0	3.00
Sand lizard	16.0 $\times$ 10.0	1.42
Slowworm	18.0 $\times$ 9.0	1.52
Sole	12.0 $\times$ 9.0	2.00
Walrus	9.2 $\times$ 9.2	

**Table 1.7.3: Number of Platelets of Selected Animals**

Figures given in thousands per cubic centimeter. For the number of red blood cells, see Table 1.7.2; for the lifespan of platelets, see Table 1.7.5.

After HALTENORTH 1977, STURKIE 1976

Species	Number of platelets (1,000s per mm <sup>3</sup> )
Cat	164– 500
Cattle	542– 975
Chicken	30.4
Dog	188– 960
Golden or Syrian hamster	160– 516
Guinea pig	525– 900
Horse	249– 461
Human	200– 500
Mouse	246– 339
Ostrich	10.5
Pig	296– 616
Rabbit	170–1.120
Rat	702– 796
Rhesus monkey	155– 424
Rock dove	13.0
Sheep	284– 659

**Table 1.7.4: Coagulation Times of Blood in Vertebrates**

Figures from BERTELSMANN 1979. HEIDERMANNS 1957. KOLB 1974. MEYER 1964

Species	Coagulation time
Cat	1.0– 3.0 min
Cattle	6.5 min
Chicken	4.5 min
Cod (Baltic Sea)	3.0 min
Dog	4.5 min
Edible frog	5.0 min
Goat	2.5 min
Grass snake	27.0 min
Horse	11.5 min
Human	5.0– 6.0 min
Lamprey	2.0– 5.0 s
Perch	20.0 s
Pig	3.5 min
Rabbit	4.0 min
Rock dove	1.5 min
Sheep	2.5 min

**Table 1.7.5: Lifespan of Blood Cells**

In white blood cells, both granulocytes and lymphocytes, there is great variation among the individual forms

Figures from ALTMANN and DITTMER 1972, BUDDENBROCK 1967, PLATT 1976

Species	Lifespan
<b>Erythrocytes</b>	
Cat	68– 77 days
Chicken	35 days
Dog	90–135 days
Duck	42 days
Goat	106–125 days
Guinea pig	80– 90 days
Horse	140–150 days
Human	108–150 days
Mouse	20– 45 days
Pig	62– 71 days
Rabbit	45– 68 days
Rat	45– 68 days
Rock dove	105 days
Sheep	70–153 days
Turtle	500 days
<b>Granulocytes</b>	
Human	30– 40 days
<b>Lymphocytes</b>	
Human	
Effector cells	10 days
Memory cells	>10 years
Rat	14 days – 9 months
<b>Platelets</b>	
Cat	2– 4 days
Cattle	10 days
Dog	7– 9 days
Guinea pig	5 days
Human	8– 14 days
Mouse	4 days
Rabbit	6 days
Rat	4– 5 days



**Table 1.7.6: Hematocrit Levels of Selected Vertebrates**

The hematocrit is the percentage of total blood volume occupied by red blood cells.

After BUDDENBROCK 1967, HALTENORTH 1977, KOLB 1974, STURKIE 1970

Alligator	30.0–31.0	Goose	44.0
Bonito (fish)	37.1	Guinea pig	42.0
Carrion crow	53.8	Horse (“coldblood”)	35.0
Cat	40.0	Horse (thoroughbred)	42.0
Cattle	40.0	Human	45.0
Chicken	34.5–37.5	Mouse	41.5
Chimpanzee	41.5	Opossum	35.3
Colubrid [snake] ( <i>Natrix</i> )	21.9	Pig	41.5
Common frog	41.8	Rabbit	41.5
Common or Harbor seal	48.0	Rat	46.0
Dog	45.5	Rock dove	58.5
Dolphin	51.7	Sheep	32.0
Duck	39.5	Slider turtle	31.9
Goat	34.0	Sparrow	37.0–52.0
Golden or Syrian hamster	46.0		

**Table 1.7.7: Hemoglobin Levels in the Blood of Selected Animals**

Data in grams hemoglobin (Hb) per 100 cm<sup>3</sup> blood. For more detailed figures on humans, see Table 4.3.11.

Data after BUDDENBROCK 1967, HALTENORTH 1977, KOLB 1974, MEYER 1964, STURKIE 1976, WIT-  
TKE 1972

Bat	15.0	Great ramshorn snail	1.5
Carp	12.2	Guinea pig	15.9
Carrion crow	16.4	Horse	12.6
Cat	10.2	Human ♂	12.0–16.0
Cat shark	4.8	Human ♀	14.0–18.0
Cattle	16.0	Hummingbird	18.0
Chaffinch	13.9	Long-beaked echidna	16.7
Chicken	11.2	Mouse	12.5
Common frog	13.0	Pheasant	18.9
Dog	16.8	Pig	13.3
Earthworm	3.8	Rabbit	11.8
Eel	10.9	Reptiles	6.9
Fox	11.0	Rock dove	13.7–16.0
Goat	10.6	Sheep	12.5
Golden or Syrian hamster	15.0	Sparrow	14.0
Goose	12.7	Thornback ray	2.3

**Table 1.7.8: Molecular Weight of the Hemoglobin of Selected Animals**

In the case of the hemoglobin of invertebrates, which is not stored in the blood corpuscles, just a relatively small number of larger molecules allow for a high level of oxygen capacity (see also Table 1.7.9) without a marked increase in the osmotic pressure of the blood or hemolymph. On this, cf. also Table 5.3.

From HEIDERMANNS 1957

Species	Molecular weight
Earthworm	3,000,000
Great ramshorn snail ( <i>Planorbis</i> )	1,540,000
Lamprey	19,100
Lugworm ( <i>Arenicola</i> )	3,000,000
Midge larvae ( <i>Chironomus</i> )	31,500
Mussel ( <i>Arca</i> )	33,000
Vertebrates	68,000
Water flea	400,000

**Table 1.7.9: Oxygen Capacity of the Blood (or Hemolymph) of Selected Animals**

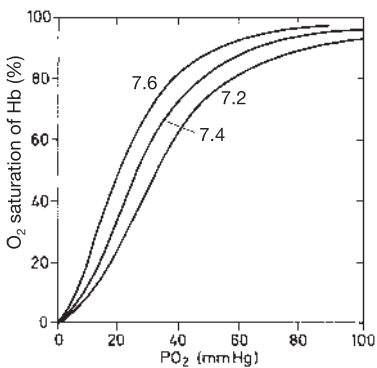
All figures are given in cubic centimeters oxygen per hundred cubic centimeters blood.

Figures from BUDDENBROCK 1967, FLOREY 1970, HALTENORTH 1977, KOLB 1974

Species	Oxygen capacity (cm <sup>3</sup> O <sub>2</sub> /100 cm <sup>3</sup> blood)
<b>Invertebrates</b>	
Blue mussel	0.32
Earthworm	5.10– 5.40
Edible crab	3.44
Edible snail ( <i>Helix pomatia</i> )	1.10– 2.20
Great ramshorn snail	1.20– 2.80
Lobster	1.30
Lugworm	5.00
Midge larva	5.40–11.60
Octopus ( <i>Octopus</i> )	3.10
Roundworm	3.00
Scorpion	1.80
Shore crab	1.14– 1.16
Starfish	0.46

(Cont.) →

Species	Oxygen capacity ( $\text{cm}^3 \text{O}_2 / 100 \text{cm}^3 \text{blood}$ )
<b>Vertebrates</b>	
Adelie penguin	22.40
Carp	12.50
Cat	13.10–14.30
Cattle	16.80
Chicken	10.00
Chimpanzee	17.40
Crocodile	8.00–10.00
Dog	19.80
Edible frog	9.80–13.30
Electric eel	19.70
Goat	14.20
Golden or Syrian hamster	20.80
Goldfish	10.70
Guinea pig	21.30
Harbor porpoise	18.20
Hedgehog	15.30
Horse	16.70
Human	21.30
Lamprey	1.20
Lungfish	6.80
Mackerel	15.70
Mouse	17.30
Orca	21.50
Pig	17.80
Rabbit	16.00
Rock dove	20.00
Shark	4.50
Sperm whale	29.90
Turtle	6.60–10.80



**Fig. 1.7.9:** Influence of the pH value of blood on oxygen saturation of hemoglobin. See also Table 1.7.9  
From REMANE, STORCH and WELSCH 1985

**Table 1.7.10: Blood Sugar Levels in Selected Vertebrates**

Figures in milligrams sugar per 100 cm<sup>3</sup> blood.

Figures from BUDDENBROCK 1956, KOLB 1974

Species	Blood sugar level (mg/100 cm <sup>3</sup> )
Alligator	59– 97
Black redstart	347
Canary	236
Cat shark	27– 39
Cattle	40– 70
Chicken	130–260
Common swift	305
Devil anglerfish (bony fish)	5– 25
Dog	60– 90
Duck	148
Electric rays	13– 77
Frog ( <i>Rana</i> )	30– 75
Goat	45– 60
Horse	55– 95
Houndshark	65–137
Human	60–100
Ostrich	164
Pig	45– 75
Rabbit	97–109
Rat	92–106
Rock dove	190
Sheep	30– 50
Sparrow	288
Turtle ( <i>Emys</i> )	58– 99

**Table 1.7.11: Protein Levels of Bodily Fluids (Blood, Hemolymph, Coelom Fluid) of Selected Animals**

Figures in milligrams protein per cubic centimeter.  $10 \text{ mg/cm}^3 = 1 \%$ . The figures represent mean values.

Figures from BUDDENBROCK 1967, PROSSER 1973

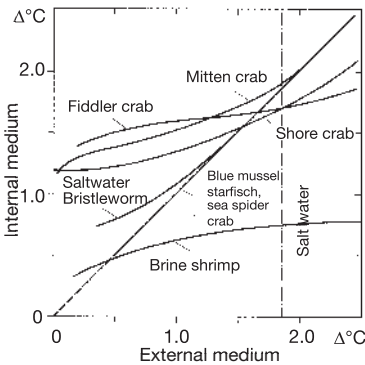
Species	Protein level (mg/cm <sup>3</sup> )
Alligator	51.7
Blue mussel	1.5
Bony fish (common whitefish)	41.9
Bumblebee	50.0
Cattle	50.2
Chicken	31.8
Cuttlefish ( <i>Sepia</i> )	49.8
Dog	58.0–70.0
Dolphin	75.0
Edible snail ( <i>Helix pomatia</i> )	24.0–33.0
Frog ( <i>Rana</i> )	24.0
Goose	30.0
Horse	75.0
Human	75.0
Jellyfish	0.4
Lamprey	36.0
Lizard	45.7
Lobster	40.0
Lugworm ( <i>Arenicola</i> )	0.2
Pond mussel	3.0
Rabbit	54.4
Rat	59.0
Ray	41.2
Salamander	21.6
Sea cucumber	0.7
Sea mouse (bristleworm)	0.9
Shark	30.0
Shore crab	40.0–60.0
Silkworm, caterpillar	10.0
Silkworm, imago	60.0
Slowworm	40.3
Starfish	0.6
Walking stick	10.0

**Table 1.7.12: Freezing Point Depression and Osmolarity of the Blood of Selected Animals**

Osmolarity can be calculated from the easily measurable extent of freezing point depression of a liquid, since a molar solution exhibits a freezing point depression of 1.85 °C and an osmotic pressure of 22.4 atm (22,697 hPa). See also Table 1.7.13.

Data after HALTENORTH 1977, HANKE et al. 1977, HEIDERMANNS 1957

Species	Freezing point depression ( $\Delta^\circ\text{C}$ )	Osmolarity (mOsm)	Osmotic pressure (Atm)	Osmotic pressure ([hPa])
Blue mussel	2.26	1,216	27.3	[27,662]
Carp	0.50	270	6.0	[6,080]
Cat	0.63	339	7.6	[7,701]
Cat shark	2.22	1,195	26.8	[27,155]
Cattle	0.59	318	7.2	[7,295]
Cod (Baltic Sea)	0.76	409	9.2	[9,222]
Crayfish	0.80	431	9.7	[9,829]
Dog	0.60	323	7.3	[7,397]
Earthworm	0.45	242	5.4	[5,472]
Edible frog	0.40	215	4.8	[4,864]
Eel	0.62	334	7.5	[7,599]
Horse	0.56	302	6.8	[6,890]
Human	0.56	301	6.8	[6,890]
Lobster	1.89	1,017	22.8	[23,102]
Pig	0.61	329	7.4	[7,498]
Pinniped	0.70	377	8.4	[8,511]
Plaice	0.79	425	9.5	[9,626]
Pond mussel	0.09	48	1.1	[1,115]
Praying mantis	0.89	479	10.7	[10,842]
Rabbit	0.64	345	7.8	[7,903]
Sheep	0.62	334	7.5	[7,599]
Shore crab	1.97	1,060	23.8	[24,115]



**Fig. 1.7.12: Dependency of freezing point depression in blood upon that in external medium.**  
See also Table 1.7.12.  
From PENZLIN 1980, p. 311

**Table 1.7.13: Freezing Point Depression und Osmotic Pressure of Hemolymphs of Arthropods**

A molar solution has a freezing point depression of 1.85 °C and an osmotic pressure of 22.4 atm (22,697 hPa). See also Table 1.7.12.

After BUDDENBROCK 1967

Species	Freezing point depression ( $\Delta$ °C)	Osmotic pressure (atm)	Osmotic pressure ([hPa])
<i>Drosophila</i> larva	0.700	8.5	[8,613]
Ground beetle ( <i>Carabus</i> )	0.940	11.4	[11,551]
House cricket	0.720	8.7	[8,815]
Meal moth larva	1.120	13.6	[13,780]
Mosquito larva	0.650	7.9	[8,005]
Praying mantis	0.885	10.7	[10,842]
Scorpion	1.125	13.6	[13,780]
Spider	0.894	10.8	[10,943]

**Table 1.7.14: Physiological Salt Solutions (Ringer's, Tyrode's, Locke's Solutions) for Selected Animals**

Figures in grams per liter distilled water. Possible shares of water of crystallization of the substances was not taken into account.

After BAUER et al. 1974, HEIDERMANNS 1957

Solution	NaCl	KCl	CaCl <sub>2</sub>	MgCl <sub>2</sub>	NaH <sub>2</sub> PO <sub>4</sub>	NaHCO <sub>3</sub>	Glucose
Ringer's earthworm	6.00	0.12	0.20	–	0.10	–	–
Ringer's insect	10.93	1.57	0.83	0.17	–	–	–
Ringer's insect	7.60	0.75	0.22	0.19	0.37	0.48	–
Ringer's isopod	14.70	0.70	1.67	0.95	–	–	–
Ringer's frog (summer)	6.00	0.05	0.29	–	–	0.30	–
Ringer's frog (winter)	6.00	0.10	0.15	–	–	0.30	–
Locke's frog	6.00	0.30	0.20	–	–	0.20	–
Ringer's mammal	8.70	0.20	0.20	–	–	0.1–1.0	–
Tyrode's mammal	8.00	0.20	0.20	0.10	0.05	1.0	1.0
Locke's mammal	9.20	0.42	0.24	–	–	0.15	–

## 1.8 Respiration

**Table 1.8.0: Numbers that Amaze**

This table brings together some interesting numbers on respiration in animals, which are cited again in the individual tables below.

Interior lung surface	in humans	90 m <sup>2</sup>
	in horses	500 m <sup>2</sup>
Breaths per minute	in hummingbirds	250
	in mice	163
	in Eurasian siskins	114
Air volume inhaled and exhaled in one breath		
	in orcas	46,200 cm <sup>3</sup>
	in horses	7,500 cm <sup>3</sup>
	by comparison: in humans	500 cm <sup>3</sup>
Maximum diving time	in beaked whales	120 min
	in leatherback turtles	120 min
	in bowhead whales	80 min
Maximum diving depth	in sperm whales	1,143 m
	in leatherback turtles	1,200 m
Oxygen consumption during exertion per kilogram body weight		
	in mice	28 g
	in humans	5.6 g



**Table 1.8.1: Relative Lung Weight in Selected Vertebrates**

Values vary greatly. For this reason, a range is given for humans. The figures given for animals are mean values. Figures represent percentage of body weight.

Data after CSICSÁKY 1984, HALTENORTH 1977

Species	%
<b>Mammals</b>	
African elephant	2.08
Beluga whale	2.70
Cat	1.04
Cattle	0.72
Chimpanzee	1.36
Common vole	1.70
Dog	0.94
Golden or Syrian hamster	0.46
Guinea pig	1.18
Hippopotamus	0.84
Horse	0.70
Human	0.73–3.13
Lion	2.12
Rat	0.79
Rhesus monkey	1.89
Walrus	1.36
Wolf	3.56
<b>Birds</b>	
Budgerigar	0.73
Carrion crow	1.19
Common buzzard	0.64
House sparrow	1.35
Hummingbird	1.37
Mallard	0.83
Ostrich	2.36
Pheasant	0.34
Rock dove	1.06
Stork	0.81
Swan	0.65

**Table 1.8.2: Interior Lung Surface of Selected Animals**

Figures represent mean values. Within a given class of vertebrates and among animals of the same size, those animals that move quickly are equipped with a larger lung surface.

Values after ALTMAN and DITTMER 1974, HALTENORTH 1977, KRUMBIEGEL 1953, ZISWILER 1976

Species	Interior lung surface (m <sup>2</sup> )
Alligator	2.0
Bat (myotis)	0.5
Cat	20.0
Common or Harbor seal	65.0
Common toad	0.008
Dog	90.0
Dolphin	43.0
Fire salamander	0.0005
Horse	500.0
Human	90.0
Lungfish	0.016
Mouse	0.12
Rabbit	5.9
Rat	0.56
Sloth	5.0

**Table 1.8.3: Breathing Rate and Single-Breath Air Volume of Selected Vertebrates**

Data after BERTELSMANN 1979, Enzyklopädie 1979, KRUMBIEGEL 1953, MEYER 1964, OPPENHEIMER and PINCUSSEN 1925, PENZLIN 1977, ZISWILER 1976

Species	Breaths/min	Volume (cm <sup>3</sup> )
Bat	50	
Buzzard/Hawk	20	
Capuchin monkey	46	
Carrion crow	25	
Cat	30	34
Cat shark	52	
Cattle	30	3,400
Chicken	27	31
Chimpanzee	19	
Common swift	90	
Dog	18	320
Duck	42	30
Electric rays	60	
Elephant	6	

(Cont.) →

Species	Breaths/min	Volume (cm <sup>3</sup> )
Eurasian siskin	114	
European conger	48	
Fin whale	0.5	
Fox	24	
Giraffe	9	3,400
Golden or Syrian hamster	74	0.83
Gorilla	19	
Greater weever fish	26	
Guinea pig	90	1.75
Harbor porpoise	1.1	9,000
Hedgehog, awake	20	
Hedgehog, hibernating	5	
Horse	10	7,500
Human	11	500
Hummingbird	250 (!)	
Lion	10	
Lungfish ( <i>Neoceratodus</i> )	28	15
Moray eel	26	
Mouse	163	0.15
Orca	1.1	46,200
Ostrich	3	
Painted comber (fish)	56	
Rabbit	37	21
Rat	85	0.86
Rock dove	30	4.7
Sheep	20	362
Shrew	120	
Sparrow	90	
Stork	8	
Wolf	14	

**Table 1.8.4: Oxygen Consumption of Selected Animals**

Figures in grams oxygen per kilogram body weight and hour. One gram of oxygen ( $O_2$ ) corresponds to approx. 700  $cm^3$ . See also Table 1.4 and the comments found there on the relationship between oxygen consumption and body size.

Listed in systematic order.

Figures from SCHLIEPER 1952, VANGEROW 1975

Taxon, species	Body weight	Oxygen consumption (g $O_2$ per kg and h)
Paramecium	0.001 mg	0.7
Radiolaria (Protozoa)	0.1 mg	0.1
Cnidaria	10–100 g	0.004–0.02
Mussels	25–250 g	0.002–0.03
Snails	20–50 g	0.01–0.1
Cephalopods	10 g	0.6–0.32
Segmented worms (annelids)	1–20 g	0.03–0.7
Crustaceans	5–500 g	0.04–0.28
Echinoderms	10–600 g	0.018–0.04
Carp	200 g	0.08–0.3
Pike	200 g	0.49
Frog	30 g	0.03–0.09
		max. 0.63
Reptiles	30 g	0.02–0.03
Chicken	2 kg	0.79–1.1
Mouse (resting)	20 g	3.5
(running)		28
Rat (resting)	110 g	2.4
Dog (resting)	9 kg	0.72
Horse	400 kg	0.3
Human (resting)	70 kg	0.28
(working)		5.6

**Table 1.8.5: Oxygen Consumption During Hibernation of Selected European Mammals**

Figures represent oxygen consumption in cubic centimeters oxygen ( $O_2$ ) per kilogram body weight (BW) and hour. For figures for nonhibernating animals, see Table 1.8.4. On hibernation, see also Table 1.4.5.

Data after ALTMAN and DITTMER 1972

Species	Oxygen consumption ( $cm^3 O_2$ per kg BW and per hour)
Common pipistrelle	53
European ground squirrel (suslik)	15

(Cont.) →

Species	Oxygen consumption (cm <sup>3</sup> O <sub>2</sub> per kg BW and per hour)
Fat dormouse	17–29
Giant noctule	30
Hamster	32
Hazel dormouse	40
Hedgehog	28
Long-eared bat	69
Marmot	18
Myotis (bat)	20

**Table 1.8.6: Maximum Diving Depth and Diving Time of Air-Breathing Vertebrates**

Figures from BRINK 1975, FRÄDRICH and FRÄDRICH 1973, GRZIMEK 1970, KRUMBIEGEL 1953, *Nat. Rdsch.*, NIETHAMMER 1979, PENZLIN 1970, SCHÄFER 1968, WOOD 1982, ZISWILER 1976

Species	Maximum diving time	Maximum depth
Alligator	120 min	
Beaked whale	120 min (!)	500 m
Beaver	15 min	
Blue whale	30 min	200 m
Bowhead whale	80 min	1,000 m
Common or Harbor seal	15 min	
Duck	15 min	
Elephant seal	30 min	100 m
Gray seal	18 min	146 m
Great cormorant	5 min	40 m
Great crested grebe	56 s	40 m
Guillemot	12 min	
Harbor porpoise		170 m
Hippopotamus	19 min	
Human	2 min	72 m
Leatherback turtle		1,200 m (!)
Loon	15 min	75 m
Muskrat	12 min	
Northern gannet		10 m
Penguins		60 m
Platypus	12 min	
Polar bear	2 min	
Sea otter		50 m
Sirenia (“sea cows”)	10 min	
Sperm whale	75 min	1,143 m
Walrus	10 min	30 m
Weddell seal	43 min	600 m

## 1.9 Reproduction, Development

**Table 1.9.0: Numbers that Amaze**

This table brings together some interesting numbers from this section, which are also cited in individual tables, where they are accompanied by references to the literature.

Egg size and weight	Hummingbird	13 × 8 mm/0.2 g
	Ostrich	150 × 130 mm/1,500 g
	Foss. Madagascar's elephant bird	340 × 250 mm/10,000 g
	Python	120 × 60 mm
	Sea or shark catfish	22 × 22 mm
Sexual maturity begins	in Norway lemming ♀	at the age of 19 days
	in tuatara	at the age of 20 years
	in rhinoceros	at the age of 20 years
Incubation and nesting time lasts, respectively,	in royal albatross	80 days, 243 days
	in nightingale	13 days, 12 days
Pregnancy lasts	in opossum	13 days
	in elephant	up to 660 days
Relative birth weight (as a proportion of that of the mother)	in kangaroo	0.0003 %
	in bats	up to 40 %
Maximum number of eggs per clutch	in turbot	9,000,000
	in green toad	12,000
	in leatherback turtle	100
	in gray partridge	18
Diploid chromosome number	in lamprey	174
	in roundworm	2

**Table 1.9.1: Size of Egg Cells in Selected Animals (Excluding Birds)**

No figures for birds; for these, see Table 1.9.13. For fish, see Table 1.9.9. For insect eggs, the length is given

Data after *Lexikon der Biologie*, OPPENHEIMER and PINCUSSEN 1927, SLIJPER 1967, STARCK 1975, SPECTOR 1956

Species	Maximum egg diameter
African clawed frog	1.5 mm
Alligator	50 mm
Bee	1.75 mm
Cat	130 $\mu\text{m}$
Cattle	150 $\mu\text{m}$
Coelacanth	100 mm
Colorado potato beetle	1.75 mm
Common vole	60 $\mu\text{m}$
Dog	140 $\mu\text{m}$
Frog	500 $\mu\text{m}$
Fruit fly	500 $\mu\text{m}$
Guinea pig	100 $\mu\text{m}$
Horse	140 $\mu\text{m}$
House cricket	2.5 mm
Human	100 $\mu\text{m}$
Lamprey	2 mm
Lancelet	110 $\mu\text{m}$
Lungfish	3.75 mm
Moon jelly	190 $\mu\text{m}$
Pig	140 $\mu\text{m}$
Pike	1 mm
Platypus	4 mm
Python	60 $\times$ 120 mm
Quoll	240 $\mu\text{m}$
Rabbit	130 $\mu\text{m}$
Rat	70 $\mu\text{m}$
Rhesus monkey	120 $\mu\text{m}$
Roundworm	45 $\mu\text{m}$
Sea urchin	70 $\mu\text{m}$
Sheep	180 $\mu\text{m}$
Whale	130 $\mu\text{m}$

**Table 1.9.2: Dimensions of Sperm of Selected Animals**

Figures from DAVID 1977

Species	Overall length ( $\mu\text{m}$ )	Length of head ( $\mu\text{m}$ )
Cat	54.0	4.0
Cattle	73.2	8.8
Guinea pig	93.0	13.0
Hedgehog	85.0	5.0
Human	58.0– 67.0	4.5– 5.5
Mouse	100.0	7.0
Rat	170.0–200.0	10.0

**Table 1.9.3: Chromosome Sets of Selected Animals**Diploid values, numbers of chromosomes ( $n$ ). For plants, see Table 2.2.9.After ALTMANN and DITTMER 1972, BRESCH and HAUSMANN 1972, DAUMER 1977, Kosmos 1953, *Lexikon der Biologie*, NAGL 1976, NIGON and LUEKEN 1976, SPECTOR 1956, STARCK 1974

Species	Chromosomes ( $n$ )	Species	Chromosomes ( $n$ )
<b>Invertebrates</b>		Liver fluke	12
Bee	32	Migratory locust ♂	23
Cockroach ♂	47	Moon jelly	20
Cuttlefish ( <i>Sepia</i> )	12	Mosquito ( <i>Culex</i> )	6
Cyclops (water flea)	14	Praying mantis ♂	27
Dragonfly ( <i>Aeschna</i> )	26	Roundworm	2
Earthworm	32	Scorpion ( <i>Buthus</i> )	14
Edible snail ( <i>Helix pomatia</i> )	54	Sea urchin ( <i>Paracentrotus</i> )	36
Firebug	24	Silkworm	20
Fruit fly ( <i>Drosophila</i> )	8	Silverfish	34
Great diving beetle	38	Small white (butterfly)	30
Head louse	12	Spider ( <i>Aranea</i> )	14
Heliozoa	44	Sponge ( <i>Sycon</i> )	26
House spider ♂	43	Starfish	36
Housefly	12	Stentor protozoan	28
Hydra	32	Water flea	20
Ixodes ricinus tick	28	White-lipped banded snail	48
Lancelet	24	Woodlouse	56
Leech ( <i>Glossosiphonia</i> )	26	Yellow mealworm beetle	20

(Cont.) →



Species	Chromosomes ( <i>n</i> )	Species	Chromosomes ( <i>n</i> )
<b>Vertebrates</b>		Chicken	78
<b>Fish</b>		Duck	80
Carp	104	Egret	68
Cat shark	24	Greylag goose	80
Goldfish	94	House sparrow	76
Guppy	48	Rock dove	80
Lamprey	174		
Pike	18		
Swordtail	48		
<b>Amphibians</b>		<b>Mammals</b>	
Axolotl	28	Baboon	42
Common Eurasian spadefoot toad	26	Bat ( <i>Myotis</i> )	44
Common frog	26	Capuchin monkey	54
Common toad	22	Cattle	60
Edible frog	26	Chimpanzee	48
Fire salamander	24	Common house mouse	40
Green toad	22	Dog	78
Midwife toad	36	Gibbon	52
Natterjack toad	22	Golden or Syrian hamster	44
Northern crested newt	24	Gorilla	48
Tree frog	24	Guinea pig	64
		Hare	48
<b>Reptiles</b>		Hedgehog	48
Alligator	32	Horse	64
Asp viper	42	House cat	38
Crossed viper	36	Human	46
European pond turtle	50	Kangaroo	22
Hawksbill turtle	58	Macaque	44
Sand lizard	38	Mole	34
Slowworm	44	Orangutan	44
		Pig	38
<b>Birds</b>		Rabbit	44
Blackbird	80	Rat	42
Canary	80	Rhesus monkey	42
		Sheep	54
		Tarsier	80

**Table 1.9.4: Age of Sexual Maturity in Selected Animals**

For a comparison of time of sexual maturity with lifespan in mammals, see Table 1.9.19.

Data after ALTMAN and DITTMER 1972, BOGNER and RITTER 1976, FRÄDRICH and FRÄDRICH 1973, GRZIMEK 1970, KRUMBIEGEL 1953, MEYER 1964, MICHEL 1986, SPECTOR 1956, ZISWILER 1976

Species	Age of sexual maturity	Species	Age of sexual maturity
Anura	3–4 years	Guinea pig	55–70 days
Baboon	4– 8 years	Hare	6 months
Bat	1 year	Hedgehog	2 years
Beaver	2 years	Herring	3– 7 months
Beech marten	2 years	Hippopotamus	2.5 years
Birds of prey	3– 6 years	Horse	3– 4 years
Bison	3 years	Human	12–18 years
Blue whale	4 years	Lion	3–5 years
Brown bear	5 years	Lizards	2– 3 years
Camel	4 years	Lobster	5 years
Carp	4– 5 years	Macaque	2 years
Cat	1 year	Mole	2 years
Cattle	1.5– 2 years	Mouse	2– 6 months
Chickens	1– 2 years	Norway lemming ♀	19 days (!)
Chimpanzee	8–10 years	Opossum	8 months
Common frog	3 years	Orangutan	10 years
Common or Harbor seal	4 years	Ostrich	3– 4 years
Crocodile	3–6 years	Platypus	2 years
Deer	1.5 years	Polar bear	2– 3 years
Dog	1 year	Rabbit	5– 9 months
Domestic pig	7 months	Rat	2– 3 months
Ducks	1– 2 years	Rhinoceros	20 years (!)
Edible snail ( <i>Helix pomatia</i> )	2– 3 years	Roe deer	14 months
Elephants	12–15 years	Salamander	3– 4 years
European pond turtle	12 years	Sheep	1– 2 years
Fox	10 months	Shrew ( <i>Sorex</i> )	1– 2 years
Gibbon	8–10 years	Songbirds	1 year
Giraffe	6– 7 years	Tiger	4– 5 years
Goat	1– 2 years	Trout	2– 4 years
Golden or Syrian hamster	2 months	Tuatara	20 years (!)
Gorilla ♂	6– 7 years	Wild boar	1.5 years
Gorilla ♀	9–10 years	Wolf	3 years

**Table 1.9.5: Cell Division Time in Protozoa**

For figures on cell division in higher organisms, see Table 5.7.

Data after OPPENHEIMER and PINCUSSEN 1930

Species	Cell division time
<i>Amoebacristalligera</i>	3 min
<i>Amoeba vespertilio</i>	1 h
<i>Opalina ranarum</i>	40–50 min
<i>Paramecium aurelia</i>	ca. 2 h
<i>Paramecium caudatum</i>	ca. 1 h
<i>Pelomyxia binucleata</i>	7.5 h
<i>Stentor polymorphus</i>	ca. 2 h
<i>Stylonychia mytilus</i>	1–2 h
<i>Vorticella</i>	30 min

**Table 1.9.6: Reproduction and Development of Selected Insects**

Figures from ALTMAN and DITTMER 1972, SPECTOR 1956

Species	Eggs per female	Duration of developmental stage (days)				Generations
		Egg	Larva	Pupa	Imago	
Black bean aphid		90–120	10	–	7–20	
Blowfly	100–500	1–2	4–15	3–13	10–40	2–4
Cockroach ( <i>Blatella germanica</i> )	218–267	17	40–42	–	80–232	1–4
Cockroach ( <i>Periplaneta americana</i> )	200–1,000	32–58	285–616	–	102–558	£ 1
Fruit fly ( <i>Drosophila</i> )	100	<1	3–11	2–8	14	5–6
Grasshopper	300–400	90–120	6–40	–	>30	1
Green-veined white	200–500	7	14	7–14		3–6
Honeybee		3	8	9	35–40	
House cricket	728	56–84	210–231	–	50–90	1
Housefly	75–720	1–3	4–10	4–18	10–50	4–18
Louse	50–300	5–21	7–10	–	10–30	10–12
Meal moth	116–700	>3	40	5–7	3–4	>6
Mosquito ( <i>Aedes</i> )	75–750	2–365	6	2–3	15–60	2–12
Silkworm	300–500	9–12	21–25	14–21	2–3	1–2
Walking stick	200	90	110	–	180	1
Yellow mealworm beetle	276	12–16	120–150	18–20	60–90	1

**Table 1.9.7: Reproductive and Developmental Data of Selected Butterflies Native to Germany Over the Course of the Year**

For the length of individual stages of selected insects, see Table 1.9.6. Monthly data separated by semicolons (;) indicate the appearance of several generations.

Figures from AMANN 1976, FLINDT 1985, HIGGINS and RILEY 1971

	Imago	Egg	Caterpillar	Pupa
Admiral	V-VI; VII-VIII IX-X	IV-VII	VI-X	IX-X
Brimstone	VII-VI	VI	VI-VII	VII
Comma	VI-VII; VIII-V	V; VII VII-VIII	V-VI;	VI; VIII
Eyed hawk moth	VI-VII	VI	VI-IX	IX-VI
Garden tiger	VII-VIII	VII-VIII	VIII-V	VI-VII
Gypsy moth	VII-IX	IX-V	V-VI	VI-VII
Hummingbird hawk moth	VII-X		VI-VIII	VII-VIII
Large yellow underwing	VI-VII; VIII-IX	VIII	IX-V	V-VI
Map butterfly	IV-VI; VII-VIII	V; VII VIII-IX	VI-VII;	VII; IX-V
Mourning cloak	VII-VI	V-VI	VI-VII	VII
Oak processionary	VIII-IX	IX-V	V-VII	VIII
Orange tip	IV-VI	V	V-VII	VIII-IV
Peacock	VII-V	V-VI	V-VII	VII
Pine hawk moth	V-VII	V-VI	VI-X	X-V
Pine moth	VI-VII	VII	VIII-VI	VI-VII
Privet hawk moth	V-VII	VI	VI-IX	IX-VI
Red underwing	VII-IX	VIII-V	V-VI	VI-VII
Silver-washed fritillary	VI-IX	IX-IV	IV-VI	VI
Small tortoiseshell	VI-VII; VIII-VI	V; VII VII-VIII	V-VI; VIII	VI-VII;
Small white (butterfly)	IV-VI; VII-VIII; IX-X		VI-VII; VIII-X	VII-VIII; X-V
Summer fruit tortrix moth	VIII	IV	V-VI o. V-IV	VII
Swallowtail butterfly	IV-VI; VII-VIII	V-VI; VIII	V-VI; VIII-IX	VI-VII; VIII-IV
Winter moth	X-XII	XI-III	III-VI	VI-X

**Table 1.9.8: Spawning Data of Selected Fish Native to Germany**

Data after LADIGES and VOGT 1965

Species	Months	Species	Months
Barbel	V-VII	Gudgeon	V-VI
Bitterling	IV-VI	Loach	III-IV
(Carp) Bream	V-VI	Pike	II-IV
Brook lamprey	II-V	Rainbow trout	XII-V
Brown trout	I-III	Roach	IV-V
Bullhead	III-V	Rudd	IV-V
Carp	V-VII	Salmon	IX-II
Chub	IV-VI	Sea lamprey	V-VII
Crucian carp	V-VI	Sticklebacks (gasterosteidae)	III-VII
Eurasian minnow	IV-VI	Sturgeon	VI-VII
European perch	III-VI	Wels catfish	V-VII
Grayling	III-VI	Whitefishes	IX-XII

**Table 1.9.9: Number and Size of Eggs per Clutch in Selected Fish**

The size of the clutch is given as the number of eggs per kilogram body weight (BW). For absolute numbers, see Table 1.9.10. For figures for birds, see Tables 1.9.12 and 1.9.13. Listed according to relative size of clutch.

From BOGNER and RITTER 1976, ZISWILER 1976

Species	Egg diameter (mm)	Clutch size (number of eggs per kg BW)
Turbot	0.9- 1.2	1,200,000
Burbot	1.0- 1.5	1,000,000
Mackerel	0.9- 1.4	800,000
Cod	1.2- 1.8	500,000
Plaice	1.6- 2.2	150,000
European perch	2.0- 2.5	100,000
Carp	1.2- 1.5	100,000
Herring	1.2- 1.5	100,000
European smelt	0.9- 1.0	50,000
Pike	2.5- 3.0	30,000
Sturgeon	2.0- 3.0	25,000
Grayling	3.2- 4.0	8,000
Trout	3.5- 5.5	2,500
Salmon	5.5- 6.0	2,000
Sea or shark catfish	19.0-22.0	50

**Table 1.9.10: Number of Annual Offspring (Eggs, Larvae, Young) in Fish, Amphibians, and Reptiles**

For egg sizes and clutch sizes relative to body weight, see Table 1.9.9.

Figures from GRZIMEK 1970, *Kosmos-Lexikon* 1953, ZISWILER 1976

Species	Number of progeny
<b>Fish</b>	
Bitterling	50 eggs
Blue shark	30–50 young
Brown trout	up to 1,500 eggs
Carp	up to 700,000 eggs
Cat shark	18–20 eggs
Cod	6,500,000 eggs
Electric rays	10–14 eggs
Herring	30,000 eggs
Manta ray	1 young
Salmon	up to 40,000 eggs
Sandtiger shark	2 eggs
Sticklebacks (gasterosteidae)	60–120 eggs
Sturgeon	6,000,000 eggs
Turbot	9,000,000 eggs
Zander	up to 500,000 eggs
<b>Amphibians</b>	
Alpine salamander	1–2 young
Common frog	1,000–4,000 eggs
Common toad	5,000–8,000 eggs
Edible frog	10,000 eggs
Fire salamander	20–40 larvae
Fire-bellied toads	50–80 eggs
Green toad	10,000–12,000 eggs
Midwife toad	60–80 eggs
Northern crested newt	100–200 eggs
Tree frog	800–1,000 eggs
<b>Reptiles</b>	
African pancake tortoise	1 egg
American alligator	20–70 eggs
Anaconda	30–40 young
Common lizard	3–10 young
Common wall lizard (2–3 clutches)	2–8 eggs
Crossed viper	5–18 young
European pond turtle	3–16 eggs
Galapagos giant tortoise	10–14 eggs
Grass snake	up to 40 eggs

(Cont.) →

Species	Number of progeny
Hermann's tortoise	5- 8 eggs
Leatherback turtle	80-100 eggs
Nile crocodile	30-50 eggs
Nile monitor	40-60 eggs
Python	100 eggs
Rattlesnake	10- 20 young
Sand lizard	5-14 eggs
Slowworm	5- 15 eggs
Smooth snake	3- 15 young

**Table 1.9.11: Reproductive Data of Amphibians and Reptiles Native to Germany**

Months are given in which eggs are laid or youth are born. For number of offspring, see Table 1.9.10.

Data after FLINDT 1985, MERTENS 1947

Art	Months
<b>Amphibians</b>	
Agile frog	III-IV
Common frog	II-IV
Common spadefoot toad	III-V
Common toad	II-IV
Edible frog	V-VI
European fire-bellied toad	V
Fire salamander	III-X
Green toad	IV-VI
Midwife toad	V-VI
Moor frog	III-IV
Natterjack toad	IV-VI
Newts	III-V
Tree frog	IV-V
Yellow-bellied toad	IV-IX
<b>Reptiles</b>	
Aesculapian snake	VI-VII
Common lizard	VI-VIII
Common wall lizard	V-VI
Crossed viper	VIII-IX
Dice snake	VI
Grass snake	VII-VIII
Sand lizard	V-VII
Slowworm	VIII-IX
Smooth snake	VIII-IX

**Table 1.9.12: Number of Eggs per Clutch in Selected Bird Species**

Figures for cuckoo are per breeding period. As a point of comparison: battery farm hens lay on average 265 eggs a year (data from 1985).

For egg size, see Table 1.9.13.

Data after BERNDT and MEISE 1959, HARRISON 1975, HOEHER 1972, MICHAELIS 1974

Species	Clutch size	Species	Clutch size
Albatross	1	Gray heron	3–5
Barn owl	4–6	Gray partridge	8–18
Barn swallow	4–5	Great cormorant	3–4
Black grouse	6–12	Great crested grebe	4
Black woodpecker	4–5	Great spotted woodpecker	4–8
Blackbird	4–6	Great tit	8–10
Blackcap	5	Greylag goose	5–6
Black-headed gull	3	Griffon vulture	1
Blue tit	10–13	Herring gull	2–3
Budgerigar	4–6	House sparrow	5–6
Carriion crow	5	Hummingbird ( <i>Mellisuga</i> )	2
Chaffinch	4–6	Jackdaw	5
Chiffchaff	5–6	King penguin	1
Common buzzard	2–3	Magpie	6–7
Common raven	4–6	Mallard	7–11
Common swift	2	Mute swan	5–8
Cuckoo	15–16	Nightingale	4–6
Eagle owl	2–3	Northern lapwing	4
Eurasian coot	5–9	Ostrich	15
Eurasian jay	5–6	Pheasant	8–12
Eurasian nuthatch	6–8	Robin	5–6
Eurasian reed warbler	4	Skylark	3–5
European kingfisher	6–7	Stork	3–5
European starling	5–7	Turkey	8–12
Flamingo	1	White wagtail	5–6
Goldcrest	8–11	Winter wren	6–7
Golden eagle	2	Wood grouse or Capercaillie	6–10
Golden oriole	3–4	Wood pigeon	2–3
Goshawk	3–4	Yellowhammer	3–5



**Table 1.9.13: Egg Size and Weight in Selected Bird Species**

For egg sizes of other groups of animals, see Table 1.9.1. For bird clutch size, see Table 1.9.12. As a point of comparison: a chicken egg weighs on average 50 g.

Data after BERNDT and MEISE 1959, GRZIMEK 1970, HARRISON 1957, HOEHER 1972, STARCK 1975, ZISWILER 1976

Species	Egg size (mm)	Egg weight (g)
<i>Aepyornis</i> (Madagascar's extinct elephant bird)	340 × 250	10,000.0
Barn swallow	20 × 13	2.0
Black redstart	19 × 15	2.0
Blackbird	29 × 22	6.0– 9.0
Black-headed gull	52 × 37	38.0
Budgerigar	19 × 16	2.0
Carrion crow	40 × 30	19.0
Chaffinch	19 × 15	2.1
Chiffchaff	15 × 12	1.4
Common buzzard	56 × 45	60.0
Common raven	50 × 34	30.0
Common swift	25 × 16	3.6
Eagle owl	60 × 50	75.0
Emperor penguin	131 × 86	450.0
Eurasian coot	52 × 36	38.0
European kingfisher	23 × 19	4.5
European starling	30 × 21	6.5
Goldcrest	14 × 10	0.7
Golden eagle	76 × 58	140.0
Gray heron	61 × 43	60.0
Great crested grebe	53 × 36	40.0
Great spotted woodpecker	26 × 19	5.2
Great tit	18 × 13	1.6
Greylag goose	86 × 57	176.0
Griffon vulture	92 × 70	252.0
House sparrow	22 × 16	3.0
Hummingbird ( <i>Mellisuga</i> )	13 × 8 (!)	0.2 (!)
Jackdaw	35 × 25	12.0
Long-eared owl	40 × 32	23.0
Magpie	34 × 24	10.0
Mallard	58 × 41	50.0
Mute swan	114 × 74	350.0
Nightingale	21 × 16	2.7
Northern lapwing	46 × 33	25.0
Ostrich	150 × 130 (!)	1,500.0 (!)
Peregrine falcon	52 × 41	48.0
Pheasant	45 × 36	30.0
Skylark	23 × 17	3.4

Species	Egg size (mm)	Egg weight (g)
Stork	77 × 53	118.0
Winter wren	16 × 12	1.3
Wood pigeon	40 × 29	19.0

**Table 1.9.14: Length of Time of Incubation and Nesting (in Nidicolous Members) of Selected Bird Species**

Lengths given in days. *NF* nidifugous species.

As a point of comparison: incubation time for a domestic chicken is 21 days.

Figures from BERNDT and MEISE 1959, HARRISON 1975, HEINROTH 1955, HOEHER 1972, MICHAELIS 1974, PFLUGFELDER 1962, SPECTOR 1956, ZISWILER 1976

Species	Incubation time (days)	Nesting time (days)
Barn swallow	14–16	21
Black redstart	13	13–16
Blackbird	13–14	13–16
Black-headed gull	22–24	NF
Budgerigar	18	30
Canary	12–14	16–20
Carrion crow	18–20	30–32
Chaffinch	12–13	13–14
Chiffchaff	13–14	13–16
Common buzzard	33–35	42–49
Common raven	20–21	40–50
Common swift	18–20	38–54
Cuckoo	12	22–23
Eagle owl	31–37	70
Eurasian coot	21–24	NF
European kingfisher	19–21	26–28
European starling	14–15	21
Golden eagle	43–45	75–80
Great crested grebe	25–29	NF
Great spotted woodpecker	12–13	21
Great tit	13–14	15–18
Griffon vulture	48–50	90
House sparrow	12–14	15–16
Hummingbirds	14–17	19–29
Jackdaw	17–18	30–35
King penguin	52	NF
Long-eared owl	27–28	21–24
Magpie	17–18	25–27

(Cont.) →

Species	Incubation time (days)	Nesting time (days)
Mallard	26–29	NF
Mute swan	34–38	NF
Nightingale	13	11–12
Northern lapwing	24–29	NF
Ostrich	42	NF
Peregrine falcon	28–29	35–38
Pheasant	23–25	NF
Royal albatross	80 (!)	243 (!)
Skylark	11–14	9–10
Stork	31–34	54–55
Winter wren	14–16	15–17
Wood pigeon	15–17	21–28

**Table 1.9.15: Incubation Dates of Selected, Well-Known Birds Native to Germany**

For incubation and nesting times, see Table 1.9.14.

Roman numerals are used to indicate the months. The Arabic numbers 1, 2, and 3 after the slash stand for the first, second, and third “third” of the month.

Figures from FLINDT 1985

Species	Incubation in months	Species	Incubation in months
Barn swallow	IV–VIII	Eurasian curlew	IV–VI/1
Black redstart	IV–VIII	Eurasian jay	IV–VI
Blackbird	III–VII	Eurasian nuthatch	IV–V
Blackcap	V–VII	Eurasian reed warbler	V–VIII
Black-headed gull	IV/3–VI/1	European goldfinch	V–VI
Blue tit	IV–VI	European greenfinch	IV–VI
Carrion crow	III–VI	European nightjar	V–VI
Chaffinch	IV–VI	European serin	IV–VI
Chiffchaff	IV/3–VI	European starling	IV–VI
Common buzzard	III/3–VII/1	Firecrest	V–VII
Common kestrel	IV–VII/2	Garden warbler	V–VI
Common moorhen	IV/2–V/2	Golden oriole	V–VI
Common redstart	V–VI	Grasshopper warbler	IV/3–VII
Common swift	V–VI	Gray heron	III/3–VI
Crested lark	IV/3–VI	Gray partridge	IV/2–VI/1
Duncock	III–VII	Great reed warbler	V–VI
Eurasian bullfinch	V–VII	Great spotted woodpecker	V/3–VII
Eurasian coot	IV/3–V	Great tit	IV–VII

Species	Incubation in months	Species	Incubation in months
Green woodpecker	IV/2-VI/2	Rook	III-VI
Hoopoe	V-VI	Sedge warbler	V-VII
House martin	IV-VIII	Skylark	III-VIII
Jackdaw	IV-V	Snipe	IV/3-VII
Lesser whitethroat	V-VII	Song thrush	IV-VIII
Linnet	III-VIII	Sparrow	IV-VIII
Long-eared owl	III/2-V/2	Sparrowhawk	V-VI/1
Magpie	IV-VII	Spotted flycatcher	V-VI
Mallard	III-V	Stork	IV-V
Marsh tit	IV-VI	Tawny owl	III/2-V
Marsh warbler	V/3-VI	Tree pipit	V-VII
Mistle thrush	IV-VII	White wagtail	IV-VII
Mute swan	IV-V	Whitethroat	V-VI
Nightingale	V-VI	Willow warbler	IV/3-VI
Oystercatcher	V-VI/2	Winter wren	V-VII
Pheasant	III/3-VI	Wood pigeon	IV/3-VIII/1
Red kite	IV-VI	Wood warbler	V/2-VI
Red-backed shrike	V-VII	Woodlark	III-VII
Reed bunting	V-VIII	Wryneck	V-VI
Robin	IV-VII	Yellowhammer	IV-VIII

**Table 1.9.16: Composition of the Chicken Egg**

From STARCK 1975

	Yolk	Albumen	Shell	Total
	32 %	57 %	1 %	
Water	50 %	86 %	-	65 %
Proteins	16 %	13 %	-	13 %
Fats	32 %	-	-	10 %
Calcium	-	-	94 %	} 11 %
Keratin of the shell	-	-	4 %	
Additional substances	2 %	1 %	2 %	1 %

**Table 1.9.17: Embryonal Development of the Chick**

Table 1.9.18 gives data on the times at which embryonal stages are reached.

After PFLUGFELDER 1962, modified

Age	Weight (g)	Daily relative weight increase (%)
1 day	0.0002	
2 days	0.003	1,400
3 days	0.02	570
4 days	0.05	150
5 days	0.13	160
6 days	0.29	125
7 days	0.57	97
8 days	1.15	102
9 days	1.53	33
10 days	2.26	48
11 days	3.68	63
12 days	5.07	38
13 days	7.37	45
14 days	9.74	32
15 days	12.0	23
16 days	15.98	33
17 days	18.59	16
18 days	21.83	17
19 days	25.62	17
20 days	30.21	18
21 days (Chick hatches)	Approx. 35	16

**Table 1.9.18: Embryogenesis in Selected Mammals and Birds**

Times given are from fertilization until the stage in question (h = hours). On embryogenesis, see also Siewing 1980.

Data after ALTMAN and DITTMER 1972, AUSTIN and SHORT 1978, LANGMANN 1976, SPECTOR 1956

Species	2-cell stage	4-cell stage	Start of im-plantation	Primitive streak	Eyes closed	Eyes open	Birth or hatching
	(h)	(h)	(days)	(days)	(days)	(days)	(days)
Chicken	3	3.25	–	1.5	13	21	22
Golden or Syrian hamster	16	40	4.5	6.5–7	–	–	16
Human	38	48	6.5	19	70	140	267

Species	2-cell stage	4-cell stage	Start of im-plantation	Primitive streak	Eyes closed	Eyes open	Birth or hatching
	(h)	(h)	(days)	(days)	(days)	(days)	(days)
Opossum	40	56	6	6.5	12.25	72	12.5
Pig	30	40	–	11	50	90	112
Rabbit	8	11	7	6.5	19	42	32
Rat	24	48	6	8.5	18	38	22
Rhesus monkey	24	36	9	19	48	–	164
Sheep	30	34	10	13	42	84	150
Sparrow	–	–	–	1.5	11	20	14

**Table 1.9.19: Relative Length of Time of Sexual Maturation in Selected Mammals**

Sexual maturation time as percentage of average lifespan. For age at sexual maturity, see Table 1.9.4; for lifespan, see Table 1.1.2.

Listed according to percentage, in ascending order.

After KRUMBIEGEL 1955

Species	Maturation time as share of lifespan (%)	Species	Maturation time as share of lifespan (%)
Polar bear	4	Wild cat	10
Wild boar	6	Marmot	11
Hare	6	Chamois	12
Marmoset	6	Camel	13
Roe deer	7	Brown bear	14
Rat	8	Ermine	15
Fat dormouse	8	Moose (in Europe: elk)	15
Hippopotamus	9	Baboon	16
Fox	10	Human	21
Eurasian badger	10	Chimpanzee	25

**Table 1.9.20: Duration of Cycle and Estrus in Selected Mammals**

Data after AUSTIN 1967, AUSTIN and SHORT 1978, KOLB 1974, NIETHAMMER 1979

Species	Cycle duration	Estrus duration
Cat	14 days	7–10 days
Cattle	20 days	12–22 h
Chimpanzee	35 days	–
Common house mouse	4–5 days	10–20 h
Dog	–	9 days
Fox	–	2–4 days
Golden or Syrian hamster	4 days	12 h
Guinea pig	17 days	6–11 h
Horse	22 days	4–6 days
Human	28 days	–
Pig	21 days	2–3 days
Rat	5 days	10–20 h
Rhesus monkey	28 days	–
Sheep	16 days	30–36 h

**Table 1.9.21: Duration of Gravidity (Gestation Time) and Number of Young of Selected Mammals**

Gestation time is normally the same as the fetal period. In some animals, e.g., in the marten or roe deer, an “extended gestation” results from an ova rest period. In these cases, the actual time of fetal development is given in parentheses. The greatest number of offspring in humans has been recorded for the wife of the Russian farmer F. Wassilet. She gave birth 27 times, bringing a total of 69 children into the world. She had 16 sets of twins, 7 sets of triplets, and 4 sets of quadruplets.

Data after ALTMAN and DITTMER 1972, AUSTIN and SHORT 1978, BERTELSMANN 1979, HARMS 1966, KARCHER 1975, KRUMBIEGEL 1953, MEYER 1964, MICHEL 1986, NIETHAMMER 1979, PFLUGFELDER 1962, SLIJPER 1956, STARCK 1975, WEISMANN 1976, WOOD 1982, ZISWILER 1976

Species	Duration of gravidity (days)	Offspring per litter or birth ( <i>n</i> )
Bat	50	1
Beaver	180	2–4
Beech marten	260 (42)	3–5
Blue whale	320–360	1
Brown bear	240	2–4
Camel	390–398	1
Cat	55–66	4
Cattle	280	1
Chamois	147–190	1–2
Chimpanzee	231–253	1

Species	Duration of gravidity (days)	Offspring per litter or birth ( <i>n</i> )
Common house mouse	21– 24	3–10
Common or Harbor seal	300	1
Common shrew	20	6– 7
Common vole	21	4
Dog (according to race)	59– 65	1–10
Dolphin	276	1
Donkey	365	1
Dromedary	388	1
Elephant	623–660 (!)	1
Eurasian badger	200 (56)	2–5
Fat dormouse	28	3– 7
Fox	49– 55	3– 7
Gibbon	210	1
Giraffe	431–465	1
Goat	150	2– 3
Golden or Syrian hamster	16	1–12
Gorilla	251–289	1
Guinea pig	63– 68	2
Hare	42	2– 4
Hedgehog	34– 49	4–10
Hippopotamus	237–247	1
Horse	314–373	1
Human	274	1
Kangaroos	30– 40	1
( + in pouch)	135–240	
Lion	108	2– 6
Macaque	168	1
Mole	28– 42	1– 6
Opossum	13 (!)	up to 12
Orangutan	233	1
Pig	114	6–12
Polar bear	240	2– 4
Polecat	180 (43)	3–7
Rabbit	30– 32	4–12
Rat	21	7– 9
Red deer (Wapiti)	234	1
Red kangaroo	38– 40	1
Reindeer	242	1
Rhesus monkey	163	1
Rhinoceros	548–578	1
Roe deer	280 (150)	1– 2
Squirrel	35	3
Tiger	105	2– 3
Walrus	330–370	1

(Cont.) →



Species	Duration of gravidity (days)	Offspring per litter or birth ( <i>n</i> )
Wild boar	133–139	4–10
Wolf	62– 66	4– 9
Wood mouse	25	2– 3

**Table 1.9.22: Relative Birth Weight of Selected Mammals**

Weight given as percentage of weight of mother. Listed according to relative size, in ascending order. Here, see also Table 1.1.10.

Figures from KRUMBIEGEL 1955, NIETHAMMER 1979, SCHULTZ 1972, SLIJPER 1967, ZISWILER 1976

Species	Relative birth weight (%)	Species	Relative birth weight (%)
Kangaroo	0.0003	Human	5.0
Siberian brown bear	0.166	Baboon	7.1
Puma	0.7	Spiny mouse	9.0
Rat	1.0	Common or Harbor seal	10.0
Hippopotamus	1.0	Etruscan shrew	10.0
Chimpanzee	2.5	Marmoset	12.1
Gorilla	2.6	Brazilian porcupine	30.0
Blue whale	3.0	Dolphin	30.0
African elephant	4.0	Bats	10–40.0

**Table 1.9.23: Normal Growth (Mean Values of Body Weight) of Selected Pets and Laboratory Animals**

Numbers apply to the most frequently used animal lines in research. Figures in grams. For maximum weights, see Table 1.1.10.

Data after ALTMAN and DITTMER 1972

	Guinea pigs		Golden or Syrian hamster		Common house mouse		Brown rat	
	♂	♀	♂	♀	♂	♀	♂	♀
1 day	80	78	2.9	3.0	1.9	1.9	6.7	6.5
1 week	115	110	6.9	7.8	4.4	4.3	18.2	16.0

	Guinea pigs		Golden or Syrian hamster		Common house mouse		Brown rat	
	♂	♀	♂	♀	♂	♀	♂	♀
2 weeks	155	145	18.3	17.5	6.5	6.0	43.0	40.8
3 weeks	200	180	40.0	40.3	10.7	9.6	59.4	55.6
4 weeks	240	218	48.7	44.2	13.7	12.4	98.9	94.9
6 weeks	322	297	86.1	93.0	21.7	20.9	162.3	153.4
8 weeks	405	374	91.5	94.5	25.5	22.8	235.7	202.0
10 weeks	482	449	99.5	103.3	28.5	25.8	292.7	239.1
12 weeks	546	518	103.9	114.9	33.4	29.9	358.7	246.6
16 weeks	656	625	121.9	135.9	34.5	32.4	388.0	259.9
20 weeks	760	720	131.8	149.6	36.7	34.7	439.4	281.2
24 weeks	840	796	140.5	157.8	39.8	36.8	452.0	288.4
28 weeks	899	837	–	–	–	–	491.2	291.8

**Table 1.9.24: Times for Doubling Birth Weight in Selected Mammals**

Number of days required until birth weight is doubled. For the development of weight in selected species, see Table 1.9.23. Listed in order of size, from shortest to longest times required.

Figures from OPPENHEIMER and PINCUSSEN 1927

Species	Time needed for doubling weight (days)
Mouse	4 – 6
Rat	5 – 9
Rabbit	6
Pig	6.5– 16
Dog	8
Cat	9.5
Sheep	10 – 12
Guinea pig	13 – 17
Goat	18 – 20
Common or Harbor seal	42
Cattle	47
Horse	60
Donkey	70
Human	127 – 180

**Table 1.9.25: Composition of Milk in Selected Mammals**

Data after *Documenta Geigy* 1975, GRZIMEK 1970, HIRSCH 1977, KLEIBER 1967, Meyer 1964, OP-PENHEIMER and PINCUSSEN 1925, SPECTOR 1956

Species	Water (%)	Protein (%)	Fat (%)	Carbohydrates (%)
Baboon	85.4	1.6	5.1	7.5
Black bear	79.5	7.6	10.9	1.6
Blue whale	45.0	12.0	42.0	1.0
Buffalo	89.6	4.0	1.8	4.6
Camel	87.1	3.7	4.2	4.1
Cat	82.3	9.1	3.3	4.9
Cattle	88.5	3.2	3.7	4.6
Dog	81.5	6.8	8.6	4.1
Dolphin	51.0	4.0	44.0	1.0
Donkey	90.0	2.0	2.0	6.0
Elephant	66.7	3.2	22.1	7.4
Fox	81.6	6.6	5.9	4.9
Giraffe	78.3	5.8	12.5	3.4
Goat	86.0	3.6	4.2	4.8
Guinea pig	81.9	7.4	7.2	2.7
Horse	91.1	2.1	1.25	6.3
Human	87.7	1.03	4.4	6.9
Mouse	60.0	12.0–13.0	21.0–33.0	2.0
Orangutan	88.5	1.4	3.5	2.7
Pig	80.9	5.8	8.5	4.8
Rabbit	71.0	10.5	16.5	2.0
Rat	68.0	12.0	15.0	3.0
Red kangaroo	78.0	6.0–8.0	2.0–10.0	4.0–15.0
Reindeer	64.7	10.3	22.5	2.5
Rhinoceros	89.3	3.2	0.3	7.2
Roe deer	76.0	9.0	10.5	4.5
Sheep	81.6	5.6	7.5	4.4
Yak	72.5	5.2	7.0	5.3

**Table 1.9.26: Annual Milk Production of Domestic Animals**

Figures represent averages. Cattle reach top production values of over 10,000 liters annually. High-performance cows in Israel produce up to 13,000 l milk per year.

Figures after BERTELSMANN 1979, MANN 1979

Species	Average annual milk production (liters)
Cattle	4,000–5,000
Goat	600– 800
Sheep	500– 700
Zebu	180– 250

**Table 1.9.27: Lactation Periods of Selected Mammals**

Figures from FRÄDRICH and FRÄDRICH 1973, KOLB 1974

Species	Lactation period
Brown bear	3– 4 months
Cat	4– 6 weeks
Cattle	8–10 weeks
Chimpanzee	> 1 year
Common or Harbor seal	4– 6 weeks
Deer	3– 4 months
Dog	6 weeks
Donkey	12–20 weeks
Elephants	up to 2 years
Fox	7– 8 weeks
Gorilla	1.5 years
Guinea pig	2– 3 weeks
Hedgehog	18–20 days
Horse	12–20 weeks
Lion	10 weeks
Orangutan	3– 4 years
Pig	8–10 weeks
Rabbit	8 weeks
Rhesus monkey	7–14 months
Rhinoceri	2 years
Roe deer	2– 3 months
Sheep	6–12 weeks
Tiger	8 weeks
Wild boar	2– 3 months
Wolf	7– 8 weeks

**Table 1.9.28: Closed Seasons for Huntable Animals in Germany**Figures from *DJV-Handbuch* 1978

	Closed season (months)
Red deer (in N. Am.: elk), ♂, ♀	II–VII
Red deer (in N. Am.: elk), calves	III–VII
Fallow deer, ♂, ♀	II–VIII
Fallow deer, calves	III–VIII
Roe deer, bucks	15. X–15. V
Roe deer, does	II–VIII
Chamoix	15. XII–VII
Wild boars	II–15. VI
Hares	15. I–IX
Beech and pine martens	III–15. X
Badgers	IX–VII
Capercaillie	VI–IV
Partridges	15. XII–VIII
Pheasants	15. I–IX
Pigeons (Wood pigeons, Eurasian collared doves)	V–VI
Mallards	15. I–VIII
All other wild ducks	15. I–IX
Wild geese	15. I–X
Eurasian woodcocks	15. I–15. X

## 1.10 Nervous System

**Table 1.10.0: Numbers that Amaze**

This table brings together some interesting numbers from the Sects. 1.10 Nervous System and 1.11 The Senses, which are cited again in the individual tables below, where they are accompanied by references to the literature.

Absolute brain weight	in the blue whale	4,925 g
	in the elephant	4,700 g
Relative brain weight as a percentage of body weight	in the spider monkey	6.6 %
	in the sparrow	2.9 %
As a point of comparison	in the human	2.5 %
Conduction velocity in A $\alpha$ fibers in mammals		120 m/s = 432 km/h
The electrical discharge	in the electric eel	up to 700 V
	in the electric ray	up to 350 V
Number of photoreceptors in the eye	in the brown rat	1,400,000
As a point of comparison	in the human	160,000
The visual acuity angle (minimum separable angle under which two points can still be optically distinguished)	in the peregrine falcon	25''
The number of ommatidia (unit eyes) per compound eye in arthropods	in the bee (drone)	7,500
	in the dragonfly	28,000
	in the ghost or sand crab	30,000
Flicker fusion rate of the eye (rate of images below which individual images are seen)	in dragonflies	200
	in pigeons/doves	148
As a point of comparison	in the human	21
Upper limit of hearing	in bats	400 kHz
	in nocturnal butterflies	240 kHz
	in the dolphin	200 kHz
As a point of comparison	in a young human	21 kHz

**Table 1.10.1: Brain Weight (Absolute) of Selected Mammals**

Figures represent mean values. Since absolute values, due to great variations in size within individual species, have little explanatory power, see the relative brain weights given in Table 1.10.2. For humans, see also Table 4.6.2.

Figures after HALTENORTH 1977, KRUMBIEGEL 1953

Species	Brain weight	Species	Brain weight
Blue whale	4,700 g	Hedgehog	3.4 g
Cat	31.4 g	Hippopotamus	580 g
Cattle	540 g	Horse	590 g
Chimpanzee	350–400 g	Human	1,200–1,500 g
Dog	135 g	Lion	222 g
Dolphin	700 g	Mouse	0.4 g
Elephant	4,925 g	Opossum	6.5 g
Gibbon	118 g	Orangutan	370–400 g
Gorilla	430–650 g	Pig	112 g
Guenon	106 g	Rat	3.05 g
Harbor porpoise	455 g	Wolf	114.4 g

**Table 1.10.2: Relative Brain Weight of Selected Vertebrates**

Figures given as percentage of body weight. A comparison only makes sense within closely related animal forms. For the absolute brain weights of selected species, see Table 1.10.1, and for the cerebralization index, see Table 1.10.4.

Data after BERTELSMANN 1979, HALTENORTH 1977, *Kosmos-Lexikon* 1953, KRUMBIEGEL 1953

Species	Relative brain weight (%)	Species	Relative brain weight (%)
Blue whale	0.007	Horse	0.25
Carp	0.4	Human	2–2.5
Cat	0.94	Lion	0.2
Cattle	0.07	Mouse	3.2
Chimpanzee	0.8	Orangutan	0.66
Dog	0.59	Ostrich	0.08
Eagle	0.6	Rat	1.22
Elephant	0.08	Shark	0.04
Frog	0.6	Sheep	0.33
Golden or Syrian hamster	0.88	Sparrow	2.9
Gorilla	0.2	Spider monkey ( <i>Ateles</i> )	6.6 (!)
Guinea pig	1.33	Tuna	0.003
Hippopotamus	0.05	Wolf	0.52

**Table 1.10.3: Brain Surface Area of Selected Mammals**

Figures refer to the surface area of one hemisphere in square millimeters.

After SALLER 1964

Species	Surface area of one hemisphere (mm <sup>2</sup> )
Cattle	49,849
Chimpanzee	39,572
Elephant	301,843
Gibbon	16,301
Goat	12,005
Guenon	14,641
Harbor porpoise	46,994
Horse	56,995
Human (European, of average size)	112,471
Pig	13,022
Sheep	14,014

**Table 1.10.4: Cerebralization Index of Birds and Mammals**

The cerebralization index or ratio is the quotient of the weight of the cerebrum spheres (in birds) or of the neopallium (in mammals) divided by the weight of the brain parts considered primal.

Listed in ascending order for birds and mammals, respectively.

After PORTMANN 1959 and 1965, STARCK 1974

Species	Cerebralization index	Species	Cerebralization index
Pheasant	3.18	Rabbit	4.6
Loon	3.69	Squirrel	6.15
Herring gull	4.31	Polecat	12.9
Little egret	5.32	Prosimian (mongoose lemur)	13.5
Mallard	6.08	Wild boar	14.1
Goshawk	7.24	Fox	16.8
Common raven	18.95	Zebra	29.5
Parrot (red-and-green macaw)	27.61	Guenon	33.9
		Baboon	47.9
Eurasian water shrew	0.759	Ape	49
Hedgehog	0.776	Asian elephant	104
Bat	1.13	Atlantic white-side dolphin	121
Muskrat	2.75	Human	170



**Table 1.10.5: Distribution of Important Ions on the Cell Membranes of Selected Excitable Structures**

Figures in millimoles. For data on resting potentials, see Table 1.10.6.

Figures from GAUER et al. 1971, PENZLIN 1970, SCHMIDT 1974

	Potassium		Sodium		Chloride	
	Inner	Outer	Inner	Outer	Inner	Outer
Cuttlefish, giant nerve fibers	410	10	50	460	60	540
Frog, nerve	120	2.5	37	120		
Frog, skeletal muscle	130	2.5	15	120	10	120
Rat, skeletal muscle	152	4	16	150		
Rat, cardiac muscle	140	2.7	13	150		
Cat, skeletal muscle	150	4	12	150	4	140
Cat, motoneuron	150	5.5	15	150	9	125

**Table 1.10.6: Resting Potentials of Nerve and Muscle Fibers**

On the generation of resting potential, see STEWING 1980.

Figures from FLOREY 1970, LAGET 1970, PENZLIN 1970, SCHMIDT 1974

#### Muscle fibers

Frog	-82 up to -100 mV
Rat	-100 mV
Dog, ventricle	-65 up to -95 mV
Dog, atrium	-85 mV
Dog, Purkinje fibers	-90 mV

#### Nerve fibers

Cuttlefish ( <i>Sepia</i> ), in situ	-70 mV
Cuttlefish ( <i>Sepia</i> ), ex situ	-62 mV
<i>Loligo</i>	-60 mV
Earthworm	-70 mV
<i>Cambarus</i>	-90 mV
Cockroach	-70 mV
<i>Carcinus</i>	-70 up to -94 mV
Frog, myelinated fiber	-71 mV

**Table 1.10.7: Nerve Conduction Velocity**

For the corresponding figures for plants, see Table 2.6.18.

After FLOREY 1970, GAUER et al. 1971, HANKE et al. 1977, KATZ 1971, LAGET 1970, SCHMIDT 1974

Animal species	Type of nerve fiber	Diameter (μm)	Nerve conduction velocity (m/s)
Plumose anemone ( <i>Metridium</i> )	Nerve net		0.13
Moon jelly ( <i>Aurelia</i> )	Nerve net	6 – 12	0.5
Earthworm	Med. giant fiber	50 – 90	30
	Lat. giant fiber	40 – 60	11.3
<i>Sepia</i>	Giant fiber	200	7
<i>Loligo</i>	Giant fiber	400 (!)	20
Lobster	Leg nerve	60 – 80	14 – 18
Crab	Giant fiber	100 – 250	15 – 20
Cockroach	Giant fiber	50	1.5– 3.5
Carp	Lateral fiber	20	47
Frog	A fiber	15	30
Cat	A fiber	13 – 17	78 – 102
	Spinal nerve	5.5	50
	C fiber	0.5– 1	0.6– 2
Human	Aα fiber	10 – 20	60 – 120 (!)
	Aβ fiber	7 – 15	40 – 90
	Aγ fiber	4 – 8	30 – 45
	Aδ fiber	2.5– 5	5 – 25
	B fiber	3	3 – 15
	C fiber	0.3– 1.3	0.6– 2.3

**Table 1.10.8: Size of the Discharge of Electric Fish**

On the anatomy and function of electric organs, see SIEWING 1980.

Figures from FLOREY 1970

Species	Voltage
Electric eel ( <i>Electrophorus electricus</i> )	700 V
Electric catfish ( <i>Malapterurus electricus</i> )	350 V
Electric rays ( <i>Torpedo nobiliana</i> )	60 V
Ray ( <i>Narcine brasiliensis</i> )	30 V
Ray ( <i>Raja clavata</i> )	4 V
Elephant fishes ( <i>Mormyridae</i> )	1– 12 V

## 1.11 Senses

**Table 1.11.1: Minimum Stimuli for Activating a Sensory Organ**

Data always for optimal stimuli quality.

Data after AUTRUM 1948

Sensory organ	Minimum stimuli strength
Subgenual organ, cockroach	$4 \times 10^{-10}$ Watt
Ear, grasshopper	$5 \times 10^{-17}$ Watt
Eye, human	$5.6 \times 10^{-17}$ Watt
Ear, human	$8 \times 10^{-18}$ up to $4 \times 10^{-17}$ Watt

**Table 1.11.2: Size of the Eyeball in Selected Animals**

Data after KÄSTNER 1973, OPPENHEIMER and PINCUSSEN 1925

Species	Diameter (mm)	Volume (mm <sup>3</sup> )
Bat	1	
Cat	21	4.9
Cattle	40 – 41	31.8
Chicken		1.78
Common house mouse	3	
Dog	20 – 21	5.1
Elephant	40	
Giant squid	400	
Horse	50 – 51	45.0
Human	24	6.5
Lion	35	
Pig	25 – 26	9.5
Rabbit	16.5	3.0
Rat	6	
Sheep	30.5– 31	11.65
Tawny owl		8.32

**Table 1.11.3: Focal Distance of the Lenses in the Eyes of Selected Animals**

The focal distance of a lens (in meters) can serve as the basis for deriving refractive power (in diopters) as its reciprocal value. Thus, the smaller the focal distance of a lens, the greater its refractive power. Focal distance varies according to the degree of accommodation (adjustment to proximity/distance). For this reason, the range is given for humans from non-accommodation to maximum accommodation.

Data after BERNDT and MEISE 1959, BUDDENBROCK 1924, VELHAGEN 1972

Species	Focal distance (mm)
Birds (most)	50
Chickens, pigeons/doves	80 – 125
Divers	20 – 25
Owls	250 – 500
Blue whale	40
Bowhead whale	20
Bristleworm ( <i>Alciopé</i> )	0.3
Electric rays	2.23
Frog	5
Hare	10
Human	69.9– 40.4
Lion	25.5
Pig	13.3

**Table 1.11.4: Number of Photoreceptors in the Eyes of Selected Animals**

Figures given per square millimeter. For the number of photoreceptors per axon, see Table 1.11.5; for the number of ommatidia in the compound eyes of arthropods, see Table 1.11.8.

Data after BUDDENBROCK 1924, KÄSTNER 1973, ZISWILER 1976

Species	Photoreceptors ( <i>n</i> )
Brown rat	1,400,000
Carp	510,000
Cat	397,000
Cattle	358,000
Chicken	265,000
Cuttlefish (squid)	115,000
Frog	95,000
Human	160,000
Tawny owl	680,000
Trout	303,000

**Table 1.11.5: Number of Photoreceptors per Dendrite in the Eyes of Selected Vertebrates**

Figures from BUDDENBROCK 1924, SIEBECK 1977, ZISWILER 1976

Species	Photoreceptors/dendrite ( <i>n</i> )
Blue whale	5,100
Chameleon, fovea	1–2
Human, fovea	1
Human, periphery	130
Pinniped	1,500
Porpoise	4,900
Shark	40
Shark, core	8
Sparrow	1
Tiger	2,500

**Table 1.11.6: Visual Acuity Angle (Angle of Minimum Separability) of Selected Animals**

The visual acuity angle designates the greatest angle at which two closely adjacent points can still just be discriminated from each other.

° = degree, ' = arcminutes, " = arcseconds.

As a point of reference: a 17.5-mm-high object 1 m from the eye appears at a 1° angle; a 0.3-mm-high object appears at 1 arcminute (1').

Figures from BERNDT and MEISE 1959, BUDDENBROCK 1956, NIETHAMMER 1979, PENZLIN 1970, RAHMANN 1967, SIEBECK 1977

Species	Visual acuity angle
Alligator	11'
Asian elephant	10' 20"
Bat	3–6°
Bee	1°
Blackbird	1' 20"
Cat	5' 30"
Chaffinch	1' 20"
Chicken	4' 14"
Chimpanzee	28"
Common frog	6' 53"
Common hermit crab	4° 12'
Donkey	8' 36"
Eurasian minnow	10' 50"
European pond turtle	2' 51"
Fruit fly	9° 17'

Species	Visual acuity angle
Golden or Syrian hamster	1° 4'
Horse	3' 15"
Human	25"
Peregrine falcon	25"
Rat (albino)	40'
Rat (wild)	20'
Red deer (Wapiti)	11' 18"
Rhesus monkey	34"
Robin	2' 38"
Rock dove	2' 42"
Sand lizard	11' 28"
Shrimp	4° 35'
Skylark	1' 20"
Yellowhammer	3' 7"

**Table 1.11.7: Visual Field (Horizontal) of Both Eyes in Selected Animals**

Figures represent mean values. Among primates there is considerable variation, depending on the placement of the eyes.

Data after SIEBECK 1977

Species	Visual field
Barn owl	160°
Common kestrel	300°
Crocodiles	295°
Dog	250°
Frogs	334–360°
Lizards	280–300°
Plaice	360°
Primates	180°
Rock dove	300°

**Table 1.11.8: Number of Unit Eyes (Ommatidia) in the Compound Eyes of Selected Arthropods**

Presented in ascending order.

For greater detail on anatomy and function, see SIEWING 1980.

After KÄSTNER 1973, OPPENHEIMER and PINCUSSEN 1936, WEBER 1966

Species	Ommatidia ( <i>n</i> )
Water flea	22
Woodlouse	30
Yellow meadow ants	80
Earwig	270
Firefly ♀	300
Red wood ant	600
Firefly ♂	2,500
Housefly	3,200
Honeybee (queen)	3,900
Blowfly	5,400
Cockchafer (May bug)	5,500
Shore crab	7,000
Honeybee (drone)	7,500
Walker	12,200
Dragonfly	28,000
Ghost or Sand crab	30,000

**Table 1.11.9: Flicker Fusion Rate of the Eyes of Selected Animals**

Figures represent images per second. At lower image frequencies, individual images are perceived. Listed in ascending order.

Data after *Lexikon der Biologie*, SIEBECK 1977

Species	Image frequency (per second)
Salamander	5
Human	20
Gecko	20
Beetle	20– 30
Cat	27– 30
Guinea pig	30
Frog	48
Bee	55
Rock dove	148
Dragonfly	300

**Table 1.11.10: Absorption Maxima of the Visual Pigments of Selected Invertebrates**

Figures represent the wavelength in nanometers at which light is maximally absorbed. For rhodopsin values for vertebrates, see Table 1.11.11.

Figures from ALTMAN and DITTMER 1973, PENZLIN 1970

Species	Maximum absorption at (nm)
Cockroach	500
Cuttlefish ( <i>Sepia</i> )	492
Honeybee	440
Horseshoe crab	520
Housefly	510, 437
Lobster	515
Octopus ( <i>Octopus</i> )	475
Shrimp	555, 496
Squid ( <i>Loligo</i> )	493

**Table 1.11.11: Absorption Maxima of the Rhodopsins of Selected Vertebrates**

Figures represent the wavelength in nanometers at which light is maximally absorbed. For data on visual pigments in selected invertebrates, see Table 1.11.10. On the basic processes of sight, see SIEWING.

Figures from ALTMAN and DITTMER 1973, PENZLIN 1980.

Species	Maximum absorption (nm) at	
	Retinal 1	Retinal 2
Alligator	499	
Carp		523
Chicken	560, 500	
Common house mouse	498	
Duck	502	
Eel	487	523
Frog	502	
Goldfish		522
Guinea pig	497	
Human	497, 493	
Lamprey	497	518
Monkey	500	
Pelican	502	
Rabbit	502	
Rat	498	
Rock dove	544, 502	
Tadpole	512	
Trout	503	527



**Table 1.11.12: Eardrum Surface Area of Selected Animals**

On hearing ability, see Table 1.11.13; for humans, see also Table 4.6.10.  
Presented in ascending order.

Figures from MANN 1972, REIN and SCHNEIDER 1971

Species	Eardrum surface (mm <sup>2</sup> )
Mouse	2.7
Tree frog	6.2
Natterjack toad	7.1
Hedgehog	16.0
Common frog	20.0
Marsh or Lake frog	28.0
Rhesus monkey	32.0
Cat	42.0
Dog	46.0
Human	55.0
Horse	75.0
Bullfrog	78.0
Cattle	86.0
Gorilla	97.0

**Table 1.11.13: Upper Limit of Hearing Ability in Selected Animals**

For humans, see also Table 4.6.10.

Data after BERNDT and MEISE 1959, BERTELSMANN 1979, GRZIMEK 1970, KÄSTNER 1973, MEYER 1964, NIETHAMMER 1979, PENZLIN 1970, STURKIE 1976

Species	Upper limit (kHz)	Species	Upper limit (kHz)
Axolotl	0.2	Dog	135
Bat	400	Dolphin	200
Brown bullhead	13	Duck	< 8
Budgerigar	14	Eagle owl	8
Bullfrog	4	Eel	0.6
Canary	10	Eurasian bullfinch	21
Cat	47	Eurasian minnow	7
Chaffinch	29	European starling	15
Chicken	38	Freshwater turtle	4
Chimpanzee	33	Goldfish	3
Cicadas	20	Grasshoppers	12
Crickets	8	Guinea pig	33
Crow	< 8	Human	21

Species	Upper limit (kHz)	Species	Upper limit (kHz)
Katydids (Bush crickets)	90	Robin	21
Lizards	8	Rock dove	12
Long-eared owl	18	Sharks	2
Mouse	100	Snakes	0
Nocturnal butterflies	240	Sparrow	18
Penguin	15	Tawny owl	21
Rat	80	Yacare caiman	6

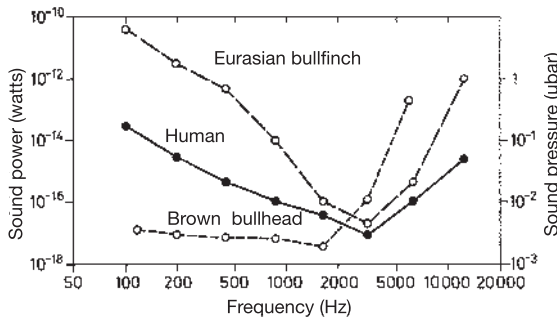


Fig. 1.11.13: Dependency of auditory threshold on frequency in humans and Eurasian bullfinches (auditory threshold data in watts) and in brown bullhead (threshold data in microbars). Cf. also Table 1.11.13, and for humans, Fig. 4.6.11.

From PENZLIN 1980, p. 381

#### Table 1.11.14: Auditory Acuity of Selected Animals

Figures given represent the smallest angle at which two sources of sound can still be discriminated.

As a point of comparison: At a  $1^\circ$  angle at a distance of 10 m, two sources of sound are 17.5 cm apart.

From BUDDENBROCK 1956

Species	Angle of auditory acuity
Cat	$1.5^\circ$
Chicken	$4^\circ$
Dog	$2.5^\circ$
Eurasian bullfinch	$20\text{--}25^\circ$
Human	$8.4^\circ$

**Table 1.11.15: Number of Taste Buds of Selected Vertebrates**

From STURKIE 1976, modified

Species	Taste buds ( <i>n</i> )
Bat	800
Cat	473
Cat shark	100,000
Cattle	25,000
Chicken	24
Duck	200
Eurasian bullfinch	46
European starling	200
Goat	15,000
Human	9,000
Parrot	350
Pig	15,000
Rabbit	17,000
Rock dove	37
Snakes	0

**Table 1.11.16: Dimensions of Olfactory Epithelium in Selected Animals**

Data after STARCK 1975

Species	Surface area (cm <sup>2</sup> )	Receptors ( <i>n</i> )
Cat	20.8	
Dog	85	$2.3 \times 10^8$
Human	2.5–5	$3 \times 10^7$
Rabbit	9.3	$1 \times 10^8$
Roe deer	90	$3 \times 10^8$

**Table 1.11.17: Vibration Threshold at Optimal Frequency**

The vibration threshold designates the amplitude at which a vibration is first perceived. Since this varies according to frequency, the optimal frequency is also provided. Presented in ascending order.

Figures from HEIDERMANNS 1957, KÄSTNER 1972

Species	Optimal frequency	Vibration threshold (nm)
Cockroach	1.4	0.004
Wart-biter bush cricket ( <i>Decticus</i> )	2	0.0366
Field cricket	1.5	0.1
Cockchafer (May bug)	1.8	0.1
Peacock	2	0.68
Bee	2.5	13
Earwig	1.2	19
Carrion beetle	1	40.5
Birds	0.8	100
Human	0.2	1,000
Assassin bugs ( <i>Reduvius</i> )	0.25	1,000
Flower fly	0.2	6,590
Blowfly ( <i>Calliphora</i> )	0.3	17,400

## Part 2: Botany

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For pragmatic reasons, fungi will be left in Part 2, since both the general public and biology as it is taught at school continue to consider them as part of the plant kingdom. [In the original German edition of this volume, the German names of local plants were adopted from SCHMEIL and FITSCHEN 1968.]

For fungi and bacteria, see also Part 4: Microbiology.

## 2.1 General Data: Dimensions, Age, etc.

**Table 2.1.0: Numbers that Amaze**

This table brings together several interesting figures from Part 2, which are cited again in the individual tables below, where they are accompanied by references to the literature.

Highest known age in a tree	Redwood (sequoia)	4,000 years
	Bristlecone pine	4,600 years
Root depth	Grape vine	12–16 m
	Desert plants (max.)	20 m
Speed of growth	Bamboo shoots	57 cm/day
	Banana leaf sheaths	160 cm/day
Single leaf with the greatest surface area	<i>Victoria regia</i> (max.)	2 m <sup>2</sup>
Beech tree has an overall leaf surface area of up to		446 m <sup>2</sup>
Water vessel diameter in	Lianas (max.)	700 μm
This allows a water conductance speed of up to		150 m/h
Heaviest wood	Guaiacum (or lignum vitae)	1.23 g/cm <sup>3</sup>
Lightest wood	Balsa wood	0.18 g/cm <sup>3</sup>
Tallest tree	Australian mountain ash ( <i>Eucalyptus regnans</i> )	152 m
Tree with the greatest trunk diameter	Baobab	15 m
Tree with the greatest trunk circumference	Baobab	47 m
Longest blooming period of a single blossom	<i>Odontoglossum rossii</i>	80 days
Blossom diameter	<i>Rafflesia arnoldii</i>	1 m
Number of seeds per tree	Birch	30,000,000
Number of seeds per capsule	Swan orchid	3,751,000
Seed weight	Broomrape	0.000001 g
	Avocado	60 g
Ballistic fruits catapult their seeds	Liana <i>Bauhinia purpurea</i>	15 m
	Lupin	7 m
Osmotic pressure in cell liquid	Common glasswort	113 atm
	Sod ( <i>Suaeda</i> )	130 atm

**Table 2.1.1: Number of Species of Plant Taxa and Fungi**

A total of over 400,000 species have now been described. For more specific figures on seed-bearing plants, see Table 2.1.2.

Data after HEYWOOD 1978, KRAUS and KUBITZKI 1982, STRASBURGER 1983

Prokaryotes (bacteria, cyanobacteria)	3600
Eukaryotic algae	33,000
of which: Green algae	7,000
Diatoms	6,000
Red algae	4,000
Brown algae	1,500
Fungi, including slime molds	90,000
of which: Ascomycota (sac fungi)	30,000
Basidiomycota	30,000
Mosses	26,000
Lichens	20,000
Fernlike plants	15,000
of which: Lycopodiophyta	400
Horsetails	32
Seed-bearing plants (spermatophytes)	236,000
of which: Gymnosperms	800
Angiosperms	235,000

**Table 2.1.2: Number of Species Within the Individual Taxa of Seed-Bearing Plants**

Figures from HEYWOOD 1978

I: Dicotyledoneae (= Magnoliatae)	177,000
1. Magnoliidae	13,200
Including: Ranunculales	2,800
Piperales	3,000
2. Hamamelididae	1,396
Including: Fagales	1,200
3. Caryophylliidae	11,000
Including: Caryophyllales	9,700
Polygonales	750
4. Dilleniidae	29,600
Including: Malvales	2,700
Urticales	6,000
Violales	5,250
Ericales	3,570
Primulales	2,000

5. Rosidae		57,700
Including:	Rosales	7,100
	Fabales	17,000
	Euphorbiales	5,100
	Geraniales	2,900
	Umbellales	3,700
6. Asteridae		64,000
Including:	Gentianales	5,600
	Scrophulariales	8,800
	Campanulales	2,200
	Asterales	25,000
II. Monocotyledoneae (=Liliatae)		52,800
1. Alismatidae		562
2. Commelinidae		19,700
Including:	Poales	9,000
	Cyperales	4,000
	Bromeliales	2,000
3. Arecidae		5,700
4. Liliidae		26,800
Including:	Liliales	8,700
	Orchidales	18,100

**Table 2.1.3: Maximum Age of Selected Plants**

In forestry, trees are felled before reaching their maximum age. This so-called rotation period is given in Table 2.1.4.

Plants are listed in ascending order, according to age.

After BERTELSMANN 1979, CZIHAK et al. 1976, MEYER 1964, SPECTOR 1956

Species	Age (years)	Species	Age (years)
Lycopodiophyta	7	European hornbeam	150
Oak fern	7	Goat willow	150
Moss (polytrichum moss)	10	Common aspen	150
Blueberry ( <i>Vaccinium</i> )	25	Apple	200
Common moonwort (fern)	30	Sycamore maple	200
Heather	42	Pear	300
Cyclamen	60	Cherry	400
European rowan	80	Dog rose	400
Mountain avens	100	Walnut	400
Hazelnut	120	Ivy	440
Birch	120	Juniper	500
Grape vine	130	Pine	500

(Cont.) →



Species	Age (years)	Species	Age (years)
Fir	500	Cedar	1,300
Elm	500	Platanus	1,300
Larch	600	Oak	1,300
Norway maple	600	Yew	1,800
Olive	700	Tilia (linden, lime)	1,900
Sweet chestnut	700	Fig ( <i>Ficus religiosa</i> )	2,000
European beech	900	Cypress ( <i>Cupressus</i> )	2,000
Spruce	1,100	Redwood (sequoia)	4,000
Swiss pine	1,200	Bristlecone pine	4,600

**Table 2.1.4: Rotation Periods of Important Harvested Trees**

The average age of trees in forestry is called their rotation period. Cf. this to the maximum ages of plants given in Table 2.1.3.

From *Schutzgemeinschaft Deutscher Wald* 1967, modified

Species	Rotation period (years)
Ash	100–140
Birch	60–80
Black alder	60–80
Black poplar	30–50
Douglas fir	60–100
Elm	120–140
European hornbeam	60–100
Fir	90–130
Larch	100–140
Norway maple	120–140
Oak	180–300
Pine	100–120
Spruce	80–120
Sycamore maple	120–140

**Table 2.1.5: Lifespan of Leaves and Needles of Selected Evergreen Plants**

In ascending order, according to age.

Figures from BERTELSMANN 1979, MEYER 1964, MOLISCH 1965

Species	Lifespan (years)	Species	Lifespan (years)
Cherry laurel	1–3	Swiss pine	3–6
Ivy	1–3	Juniper	4–5
Oleander	1–3	Bay laurel	4–6
Privet	1–3	Spruce	4–6
Cowberry (lingonberry)	2	Fir	5–7
Olive	2	Yew	6–8
Pine	2–3	Mountain pine	7.5
English holly	2–4	Norfolk Island pine	15
Redwood (sequoia)	2–4	Welwitschia	100

**Table 2.1.6: Root Depth of Selected Plants**

Presented in ascending order.

After BERTELSMANN 1979, HAGER 1960, MEYER 1964

Species	Root depth (m)	Species	Root depth (m)
Dandelion	0.30	Pea	2.10
Hellebore	0.35	White lupine	2.10
Cypress spurge	0.50	Red clover	2.10
Swallow-wort	0.60	Barley	2.60
Field bindweed	1.00	Oats	2.60
Dyer's greenweed	1.00	Winter wheat	2.80
Carline thistle	1.00	Winter rapeseed	2.90
Campanula	1.20	Forest trees	5.00–10.00
Broad bean	1.70	Grape vine	12.00–16.00
Spring wheat	1.90	Desert plants	10.00–20.00
Rye	2.00		

**Table 2.1.7: Leaf Surface Areas of Selected Plants**

Figures from SPECTOR 1956

Species	Leaf surface area (cm <sup>2</sup> )	Leaves per plant ( <i>n</i> )	Leaf surface area per plant (cm <sup>2</sup> )
Apple	18	20,000	318,000
Banana ( <i>Musa acuminata</i> )	up to 10,000		
Banana ( <i>Musa paradisiaca</i> )	2,700–5,200		
Bean	49		
Beech	22	35,000–200,000	4,460,000
Corn (maize)	600–1,320		7,900
Cucumber	29–33		180–1,100
Grape vine	125–150		
Lemon	20–33		
Liriodendron (tulip tree)	130		
Oleander	11		
Potato			17,800
Sunflower	38	59	2,260
<i>Victoria regia</i>	20,000		
Wheat	13–15	5	46–65

**Table 2.1.8: Diameter of the Blossoms of Selected Plants**

Presented in ascending order.

Data after KERNER v. MARILAUN 1898, MEYER 1964, PERREY 1972, supplemented with several field guides.

Species	Blossom diameter (mm)
Whitlow grass	2.5
Knotweed	3
Lily of the valley	9
Lilac	12
Cyclamen	15
Frostweed	8– 18
European hepatica	15– 30
Tall buttercup	25
Wood anemone	30
Ragged robin	30
Coconut palm (♀)	35
Dog rose	40
Marsh marigold	45
Campanula	50

Species	Blossom diameter (mm)
Hedge false bindweed	30– 60
Iris	50– 70
Poppy (genus)	70
Hibiscus	70
Passion flower ( <i>Passiflora caerulea</i> )	70– 100
Pumpkin	100– 120
Water lily	120
Opium poppy	160– 180
Cactus ( <i>Cereus grandiflorus</i> )	200– 220
Magnolia ( <i>Magnolia grandiflora</i> )	200– 250
Lotus	250
Angel's-tears ( <i>Datura suaveolens</i> )	250
<i>Victoria regia</i>	300– 400
<i>Rafflesia arnoldii</i> (largest blossom)	1,000 (!)

**Table 2.1.9: Specific Weight of Woods**

Figures refer to air-dry wood.

Wood consists of 40–50% cellulose, 20–30% hemicellulose, pectin, and sugar, and 20–30% lignin.

Plants are presented in ascending order of specific weight.

After FRANKE 1976, MEYER 1964

Species	Specific weight (g/cm <sup>3</sup> )	Species	Specific weight (g/cm <sup>3</sup> )
Balsa wood (the lightest wood)	0.18	Mahogany	0.55
Eastern white pine	0.39	Horse chestnut	0.57
Silver fir	0.41	Platanus	0.63
Redwood (sequoia)	0.42	European rowan	0.64
Douglas fir	0.44	Teak	0.64
Swiss pine	0.44	Birch	0.65
White poplar	0.45	Cherry	0.66
Spruce	0.45	Sweet chestnut	0.66
Pine	0.49	European black pine	0.67
Large-leaf linden	0.49	Sycamore maple	0.67
Common aspen	0.51	Walnut	0.68
Mountain pine	0.51	Elm	0.69
Little-leaf linden	0.52	Robinia	0.70
Black alder	0.53	Pear	0.72
Larch	0.55	Makoré	0.72

(Cont.) →

Species	Specific weight (g/cm <sup>3</sup> )	Species	Specific weight (g/cm <sup>3</sup> )
European beech	0.74	Yew	0.84
Norway maple	0.74	Oak	0.86
Plum	0.75	Boxwood (common box)	1.00
Ash	0.75	Ironwood	1.04
European hornbeam	0.77	Ebony	1.10
Hickory	0.80	Guaiacum (or lignum vitae)	
Palisander	0.82	(the heaviest wood)	1.23

**Table 2.1.10: Water Content of Selected Plant Organs**

Figures are percentage of fresh weight. See also Table 5.2.

Figures from STEWARD 1959, STRASBURGER 1983

Plant species and organ	Water content (%)
<b>Roots</b>	
Barley, top part of plant	93.0
Carrot	88.2
Pine ( <i>P. taeda</i> ), mycorrhiza root	74.2
Pine ( <i>P. taeda</i> ), top part of plant	90.2
Sunflower	71.0
<b>Sprout</b>	
Asparagus, edible tips	88.3
Pine ( <i>P. echinata</i> ), wood	50.0–60.0
Sunflower, entire sprout	87.5
<b>Leaves</b>	
Cabbage	86.0
Corn (maize)	77.0
Lettuce, inner leaves	94.8
Sunflower	81.0
<b>Fruits</b>	
Apple	84.0
Strawberry	89.1
Tomato	94.1
Watermelon	92.1
<b>Seeds</b>	
Barley	10.2
Kernel corn (maize), dry	11.0
Peanut	5.2
Sweet corn	84.8

## 2.2 Cellular Values

**Table 2.2.1: Dimensions of Selected Plant Fibers**

After SPECTOR 1956

Type of fiber	Fiber length (cm)	Fiber diameter (μm)	Tensile strength in kg/mm <sup>2</sup>
Coconut palm	21	18	
Egyptian cotton	3.6	16.4	44
Flax	15– 92	15	76
Hemp	92–183	18–23	84
Jute	150–360	15.5	41
Manila hemp (abaca)	150–350	14–35	40.7
Ramie	20– 30	25.5	91–99
Sisal	45– 90	10–30	40
As a point of comparison:			
Silk	up to 200,000 (= 2 km!)	5–21	45.5
Wool	3.75	25	17.2

**Table 2.2.2: Vessel Diameters in Woods**

There are sometimes considerable differences between the springwood and summerwood of individual species. On hydraulic conductance in plants, see also Table 2.6.11 and STRASBURGER 1983

Species	Vessel diameter (μm)
Vessel elements	
Alder	20– 90
Ash	120–350
Birch	30–130
Elm	130–140
European beech	16– 80
European hornbeam	16– 80
Horse chestnut	30– 60
Lianas (e.g. clematis)	up to 700 (!)
Maple	30–110
Oak	200–300
Pear	40– 80
Robinia	160–400

(Cont.) →

Species	Vessel diameter ( $\mu\text{m}$ )
Sweet chestnut	300–350
Tilia (linden, lime)	25– 90
Walnut	120–160
Willow	80–120
Tracheids	
Conifers	20– 40

**Table 2.2.3: Number of Stomata on the Leaves of Selected Plants**

Figures represent the number of stomata per square millimeter leaf surface area. The number of stomata can vary greatly according to environmental conditions. For instance, leaves in the light present different numbers from their counterparts in the shadows. On the anatomy and function of stomata, see STRASBURGER 1983.

After GREULICH and ADAMS 1962, HELLER 1969, OPPENHEIMER and PINCUSSEN 1929

Species	Upper epidermis	Lower epidermis
Alfalfa	170	140
Apple	0	290
Bean	40	280
Berberis	0	229
Bittersweet ( <i>Solanum dulcamara</i> )	60	263
Cabbage	140	230
Canadian waterweed	0	0
Cherry	0	250
Corn (maize)	52	68
Cypress spurge	0	259
Eastern white pine	140	0
English holly	0	170
English oak	0	450
European hepatica	15	74
Frostweed	61	194
Geranium	170	140
Iris	65	58
Lilac	0	330
Lily	0	330
Marsh marigold	78	78
Mercurialis	0	65
Military orchid	0	29
Mistletoe	71	75
Net-leaved willow ( <i>Salix retusa</i> )	78	134

Species	Upper epidermis	Lower epidermis
Oats	25	23
Olive	0	545
Pea	100	200
Peach	0	225
Poplar	20	115
Potato	50	160
Sea holly ( <i>Eryngium maritimum</i> )	118	108
Sedum	35	70
Snowdrop	30	45
Spiderworts ( <i>Tradescantie</i> )	7	28
Sunflower	175	325
Tomato	12	130
Water lily	490	0
Wheat	33	14
Wood anemone	0	67
Woodsorrel	0	35
Yellow Star-of-Bethlehem	27	27

**Table 2.2.4: Length of the Stoma Pore in Selected Plants**

Figures from OPPENHEIMER and PINCUSSEN 1928, STEWARD 1965

Species	Stoma pore length ( $\mu\text{m}$ )
Bishop's goutweed	15
Buckwheat	12
Cactus ( <i>Cereus</i> )	26
Campanula	19
Corn (maize)	19
Cotton grass	15
Cross-leaved heath	3
Fireweed	9
Hawkweed	12
Marsh marigold	28
Mountain arnica	21
Oak ( <i>Qu. falcata</i> )	5
Oats	38
Pelargonium	19
Primrose	30
Purple moor grass	10
Runner bean (scarlet runner)	7
Silver ragwort	21

(Cont.) →



Species	Stoma pore length ( $\mu\text{m}$ )
Strawberry	10
Sunflower	22
Violet	19
Wheat	38
Wood anemone	38
Woodsorrel	13

### Table 2.2.5: Size of Chloroplasts of Selected Plants

Figures represent the largest diameter.

Figures from OPPENHEIMER and PINCUSSEN 1929

Species	Diameter ( $\mu\text{m}$ )
Alder	5
Alga ( <i>Vaucheria</i> )	5
Asarabacca (European wild ginger)	4–5
Beet ( <i>Beta vulgaris</i> )	7–10
Canadian waterweed	4–6
Cuckoopint	5–7
Daisy	5
Dandelion	5–6
Ginkgo	3–5
Lily of the valley	5
Male fern	5
Maple	6
Moss ( <i>Mnium</i> )	5–6
Nasturtium	5
Peat moss	3–4
Pine	5
Pumpkin	5
Shepherd's purse	3–4
Spiderworts ( <i>Tradescantie</i> )	3–5
<i>Stellaria</i>	7–10
Strawberry	4–5
Tobacco	3–5
Tulip	5
Walnut	5
Water lily	4–5
Yew	3–5

**Table 2.2.6: Size of Starch Grains in Selected Useful Plants**

After KAUSSMANN 1963, ROHRLICH and BRÜCKNER 1967

Species	Size ( $\mu\text{m}$ )
Barley	20– 40
Common bean	max. 60
Corn (maize)	10– 35
Lentil	max. 40
Potato	70–100
Rice	2– 10
Rye	30– 60
Wheat	30– 45

**Table 2.2.7: Size of Pollen Grains in Selected Plants**

After KERNER v. MARILAUN 1898, MEYER 1964, NILSSON 1977, OPPENHEIMER and PINCUSSEN 1929

Species	Size ( $\mu\text{m}$ )
Alder	18–21 $\times$ 23– 30
Ash	20–22 $\times$ 25– 29
Barley	40– 48
Beech	40–50 $\times$ 45– 54
Birch	19–23 $\times$ 21– 27
Black poplar	25
Common aspen	28– 34
Common reed	24– 30
Common yarrow	35
Corn (maize)	76–100
Cyclamen	22
Elm	27–33 $\times$ 29– 36
European hornbeam	30–34 $\times$ 36– 40
Fir	90–110
Forget-me-not	2.5– 3.4
Foxtail grass	36
Hazel	20–25 $\times$ 25– 28
Hedge false bindweed	76– 84
Hops	28
Horse chestnut	22–24 $\times$ 19– 22
Ivy	23–28 $\times$ 26– 31
Lilac	24– 34
Male fern	28–34 $\times$ 50– 58
Maple	26–31 $\times$ 28– 36
Melon	200–240

(Cont.)  $\rightarrow$

Species	Size ( $\mu\text{m}$ )
Nettle	13–17 $\times$ 15– 20
Oak	23– 30
Oats	48– 54
Orchard grass	30– 38
Pine	65– 80
Pumpkin	190–240
Rye	47– 65
Sunflower	39
Tilia (linden, lime)	25–28 $\times$ 35– 38
Tobacco	31
Violet	62– 71
Viper's bugloss	10– 14
Water lily	38
Wheat	45– 60
Wild chervil	25–28 $\times$ 13– 16
Willow	19–21 $\times$ 20– 23
Zigzag clover	43

**Table 2.2.8: Dimensions of Spores of a Selection of Well-Known Species of Fungi**

Data after MAUCH and LAUBER 1975

Species	Length ( $\mu\text{m}$ )	Width ( $\mu\text{m}$ )
Basidiomycota		
Bare-toothed russula (also: flirt) ( <i>Russula vesca</i> )	6.0– 8.0	5.0– 6.0
Bay bolete	11.0–17.0	4.5– 6.0
Chanterelle	7.0– 9.0	4.0– 5.0
Clouded funnel or agaric ( <i>Clitocybe nearis</i> )	6.0– 7.0	3.0– 4.0
Common earthball	8.0–12.0	Spherical
Death cap	8.0–11.0	Spherical
Dry rot fungus ( <i>Serpula lacrymans</i> )	8.5–11.0	4.5– 6.0
Field mushroom	7.0– 8.0	4.0– 5.0
Fly agaric	9.0–11.0	6.0– 9.0
Honey fungus	7.0– 9.0	5.0– 6.0
Larch bolete	8.0–11.0	3.0– 4.0
Livid pinkgill ( <i>Entoloma sinuatum</i> )	8.0–10.0	7.0– 8.5
Orange oak bolete ( <i>Leccinum quercinum</i> )	13.0–17.0	4.0– 5.0
Oyster mushroom	8.0–12.0	3.0– 4.0
Panther (cap) ( <i>Amanita pantherina</i> )	10.0–12.0	7.0– 8.0
Parasol	15.0–20.0	10.0–13.0
Peppery milk cap ( <i>Lactarius piperatus</i> )	8.0– 9.5	5.5– 7.0
Porcini	13.0– 17.0	3.5– 6.0

Species	Length ( $\mu\text{m}$ )	Width ( $\mu\text{m}$ )
<i>Ramaria aurea</i> (coral fungus)	8.0–15.0	3.0– 6.0
Red-staining inocybe	9.0–14.0	5.0– 8.0
<i>Sarcodon imbricatus</i>	6.0– 7.0	5.0– 6.0
Shaggy ink cap ( <i>Coprinus comatus</i> )	12.0–16.0	7.0– 8.0
Sheathed woodtuft ( <i>Kuehneromyces mutabilis</i> )	6.0– 7.0	3.0– 4.5
Stinkhorn ( <i>Phallus impudicus</i> )	3.5– 5.0	1.5– 2.5
Sulphur tuft	6.0– 8.0	4.0
Tinder polypore	15.0– 20.0	5.0– 7.0
Ascomycota		
Black morel	18.0– 24.0	10.0–14.0
Ergot	100.0	1.0
False morel	17.0– 25.0	8.0–12.0

**Table 2.2.9: Chromosome Sets of Selected Plants**

Figures given refer to the diploid set. For diploid values for animals, see Table 1.9.3.

After BRESCH and HAUSMANN 1972, GÖTZ and KONRAD 1977, HESS, LANDOLT and HIRZEL 1967, NAGL 1976, NIGON and LUEKEN 1976, STARCK 1975

Species	Chromosomes ( <i>n</i> )	Species	Chromosomes ( <i>n</i> )
Adder's-tongue	480	Campanula	34
Alder	28	Canadian waterweed	24
Alga ( <i>Cladophora</i> )	32	Caraway	20
Almond	16	Carrot	18
Apple	34, 51, 68	Chamomile	18
Ash	46	Cherry, sour	32
Asparagus	20	Cherry, sweet	16, 24, 32
Autumn crocus	38		64, 144
Banana	22, 33, 44	Christmas rose	32
Barley	14	Clusterhead	30
Bedstraw, hedge	22	Coconut	32
Bee orchid	36	Coltsfoot	60
Birch	84	Common bean	22
Brackenfern	104	Common yarrow	36, 54
Burdock	36	Corn (maize)	20
Bush vetch	14	Corn poppy	14
Button mushroom	8	Cornflower	24

(Cont.) →

Species	Chromosomes ( <i>n</i> )	Species	Chromosomes ( <i>n</i> )
Cross-leaved heath	24	Pear	68, 85
Cucumber	14	Peppermint	68, 72
Cyclamen	48, 84	Pine	24
Cypress spurge	20	Plum	48
Dandelion	24	Poplar	38
Eelgrass	12	Potato	48
English oak	24	Primrose	22
<i>Euglena</i>	approx. 200	Privet	46
European beech	24	Pumpkin	40
European rowan	34	Rape	38
European spindle	64	Red clover	14
Field or hedge maple	26, 78	Sedge, hairy	112
Fir	24	Shepherd's purse	16, 32
Forget-me-not	22	Snowdrop	24
Ginkgo	24	Sorrel ♀	14
Gorse	96	♂	15
Heath	16	Spikemoss ( <i>Selaginella</i> )	18
Hellebore	32	Spinach	12
Horse chestnut	40	Spring gentian	28
Horsetail	216	Spruce	24
Juniper	22	Strawberry, garden	14, 28, 42, 56
Lady's slipper	20	Strawberry, woodland	14
Larch	24	Sundew	20
Lilac	46–48	Sunflower	34
Little-leaf linden	72	Tobacco	48
Male fern	164	Tomato	24
Marsh marigold	32, 48, 56	Vaccinium	24
Meadow sage	18	Valerian	18
Mistletoe	20	Venus flytrap	30
Mustard	24	Violet	20
Northern fir moss	68	Wheat	
Oats	42	Einkorn	14
Onion	16	Durum wheat, emmer	28
Opium poppy	22	Soft wheat, spelt	42
Oxeye daisy	36	Wild radish	18
Pansy	26	Willow	38
Parsley	23	Wine grape	38, 57
Pasque flower	32	Yew	76
Pea	14		24
Peach	16		
Pear	34, 51		

## 2.3 Germination and Growth

**Table 2.3.1: Germination Time and Optimal Germination Temperature of the Seeds of Selected Plants**

A range given for the germination temperature indicates that the plants prefer daily variation (16 h of the upper and 8 h of the lower temperature). On germination speed, see Table 2.3.2.

Figures after ALTMAN and DITTMER 1972

	Germination time (days)	Germination temperature (°C)
Asparagus	7–21	20–30
Barley	4–7	15
Broad bean	4–14	20
Carrot	6–21	20–30
Cauliflower	3–10	20–30
Corn (maize)	4–7	25
Cornflower	4–8	15
Dandelion	7–21	20–30
Forget-me-not	5–12	20
Hemp	3–7	20–30
Larkspur	10–21	15
Lentil	7–12	20
Lettuce	7	20
Lupin	4–10	20
Meadow sage	4–12	20–30
Nasturtium	14	18
Oats	5–10	15
Onion	6–10	20
Parsley	11–28	20–30
Pea	5–8	20
Pumpkin	4–7	20–30
Radish	4–6	20
Red beet	3–10	20–30
Rye	4–7	15
Spinach	7–21	10
Sunflower	3–7	20–30
Sweet william	8	20
Tobacco	7–14	20–30
Tomato	5–14	20–30
Violet	12	20–30
Wheat	4–7	15

**Table 2.3.2: Germination Speed of the Seed of Selected Useful Plants**

Figures given represent the number of hours until the radicles become visible. Since this is highly temperature dependent, values are provided for 10, 15, and 25 °C.

After MEYER 1964

	10 °C	15 °C	25 °C
Alfalfa	90	66	48
Barley	72	48	72
Carrot	162	102	56
Corn (maize)	272	78	56
Cucumber	–	–	96
Oats	90	66	48
Pea	72	42	–
Poppy (genus)	114	60	48
Pumpkin	–	258	52
Rape	48	24	24
Red clover	72	42	24
Rye	54	30	32
Sunflower	600	72	32
Wheat	84	48	33

**Table 2.3.3: Vernalization Temperatures and Periods of Selected Plants**

Vernalization is defined as the temporary effect of low temperatures on seeds or plants in initiating the flowering process. In many useful plants, there are great differences between individual varieties.

Figures after various authors in ALTMAN and DITTMER 1973

Species and plant part	Period (days)	Optimal temperature (°C)
Bean, seeds	30–35	2
Beet, plants	30–50	0–2
Beet, seeds	80	0–5
Cabbage, seeds	28	0
Carrot, plants	40–65	4
Cauliflower, plants	14	5
Celery, plants	15–30	4,5–10
Common evening primrose, seeds	30	4
Corn (maize), seeds	34	3
Crimson clover, seeds	40	0
<i>Dactylis glomerata</i> , plants	30–90	0–2
Endive, seeds	28	1–2.5

Species and plant part	Period (days)	Optimal temperature (°C)
<i>Festuca elatior</i> , plants	30–90	0–2
Kohlrabi, plants	60–90	5
Lentil, seeds	10–12	6 –10
Lettuce, seeds	10–20	2 – 5
<i>Lolium perenne</i> , seeds	0–90	0 – 5
Lupin, seeds	14–21	2 – 5
Oats, seeds	30–45	0–2
Opium poppy, seeds	35	2 – 3
Pea, seeds	20–30	2–7
Radish, seeds	10–46	0 – 5
Spinach, seeds	10–15	2 – 8
Spring barley, seeds	0–15	6 – 8
Spring rye, seeds	0–14	0 – 5
Spring wheat, seeds	0–14	0 – 8
Sunflower, seeds	35	2
Sweet william, plants	42–63	5
<i>Trifolium pratense</i> , seeds	10–40	3 – 8
White mustard, seeds	10–30	0 – 3
Winter barley, seeds	20–40	0 – 3
Winter rye, seeds	30–50	0 – 5
Winter wheat, seeds	40–70	0 – 3

**Table 2.3.4: Growth Speed of Selected Plant Organs Under Optimal Conditions**

The growth of plants is heavily temperature dependent; on this see Table 2.3.11. Most plants grow at a speed of less than 0.005 mm/min.

Figures after MEYER 1964, OPPENHEIMER and PINCUSSEN 1929

Plant species and organ	Growth speed
Asparagus, shoot	0.08 mm/min = 11.1 cm/day
Autumn crocus, pollen tubes	0.015 mm/min = 2.16 cm/day
Bamboo, shoot	0.4 mm/min = 57 cm/day
Banana, leaf sheath	1.1 mm/min = 160 cm/day
Broad bean, radicle	0.012 mm/min = 1.7 cm/day
Bryony, shoot	0.056 mm/min = 8 cm/day
Hemp, sprout	0.05 mm/min = 7.2 cm/day
Ink cap, fruiting body stalk	0.22 mm/min = 31.4 cm/day
Mold ( <i>Mucor</i> ), hyphae	0.026 mm/min = 3.74 cm/day
Oats, coleoptile	0.025 mm/min = 3.7 cm/day
Pea, root	0.02 mm/min = 2.88 cm/day

(Cont.) →



Plant species and organ	Growth speed	
Pumpkin, shoot	0.1	mm/min = 14.4 cm/day
Rye, filaments (max. unwinding time, 10 min)	2.5	mm/min
“Veiled” mushroom ( <i>Dictyophora</i> ), fruiting body (max. unwinding time, 15 min)	5	mm/min

**Table 2.3.5: Annual Vertical Growth Over Lifespan of Selected Important Harvested Trees Under Optimal Conditions**

For maximum sizes, see Table 2.3.6; for maximum ages, Table 2.1.3; and for rotation periods, Table 2.1.4.

After BERTELSMANN 1979, MEYER 1964

	1–20	21–40	41–60	61–80	81–100	101–120 years	
Fir	12.5	54.0	48.0	27.5	20.5	11.0	cm
Spruce	30.5	48.0	38.0	25.0	16.0	11.5	cm
Pine	44.5	40.0	27.0	19.0	19.0	11.5	cm
Beech	27.5	40.0	34.0	27.0	14.0	13.5	cm
Oak	46.5	45.0	19.5	19.5	17.0	10.5	cm

**Table 2.3.6: Height of Selected Trees**

For trunk circumferences, see Table 2.3.8; for trunk diameters, Table 2.3.7; and for slenderness ratio, see Table 2.3.9.

Data after BERTELSMANN 1979, HOFMEISTER 1977, MEYER 1964

Species	Normal height (m)	Maximum height (m)
Ash	20– 40	50
Australian mountain ash ( <i>Eucalyptus regnans</i> )	100–110	152
Black alder	10– 25	30
Black poplar	15– 30	35
Cedar	25– 30	40
Coconut palm	25– 30	32
Cypress ( <i>Cupressus</i> )	20– 50	52
Douglas fir	10– 25	25
English oak	20– 40	50

Species	Normal height (m)	Maximum height (m)
European beech	15– 40	44
European hornbeam	5– 25	28
Fern trees	10	22
Field or hedge maple	10– 15	22
Larch	30– 40	53
Large-leaf linden	15– 30	35
Pine	20– 40	48
Redwood (sequoia)	100	132
Robinia	10– 25	25
Silver fir	30– 50	75
Spruce	30– 50	60
Sycamore maple	15– 30	40

### Table 2.3.7: Maximum Trunk Diameters of Selected Tree Species

Presented in ascending order of size.

For maximum tree heights, see Table 2.3.6; for maximum tree circumferences, see Table 2.3.8; and for tree slenderness ratios, see Table 2.3.9.

After BERTELSMANN 1979, MEYER 1964

Species	Maximum trunk diameter (m)
Field or hedge maple	0.7
Birch	0.8
Juniper	0.9
European hornbeam	1.0
Pine	1.0
Larch	1.6
Ash	1.7
Spruce	2.0
European beech	2.0
Fir	3.0
Norway maple	3.0
Elm	3.0
Yew	4.9
Large-leaf linden	9.0
Redwood (sequoia)	11.0
Baobab	15.0

**Table 2.3.8: Greatest Recorded Trunk Circumferences for Selected Trees**

Figures represent individual trees with known locations that are provided here. Presented in ascending order.

For maximum tree heights, see Table 2.3.6; for maximum trunk diameters, see Table 2.3.7; and for slenderness ratios, see Table 2.3.9.

After MEYER 1964

Species	Circumference (m)	Location
Ivy	1.80	Gignac/France
English elm	12.45	Schimsheim/Germany
Oak	13.00	Newland/England
Tilia (linden. lime)	17.00	Staffelstein/Germany
Yew	18.00	Braburn/England
Sweet chestnut	20.00	Italy
Bald cypress	31.00	Santa Maria el Tule/Mexico
Redwood (sequoia)	35.00	Mariposa/USA
Platanus	47.00	Böjuk-Dere/Turkey
Baobab	47.00	Tanganyika/Africa

**Table 2.3.9: Slenderness Ratio and Height of Selected Plants**

The slenderness ratio is the quotient of the height of a plant divided by its diameter at the base. As a point of comparison, an architectural structure: the 211-meter Stuttgart television tower has a slenderness ratio of 19.

The slenderness ratio is only comparable in plants of the same absolute height, since in larger plants with the same slenderness ratio, their bending strength decreases.

Tree heights are also provided in Table 2.3.6.

Species are listed in ascending order, according to their slenderness ratio.

Values after HAGER 1960, HEYNERT 1976, NACHTIGALL 1977 and 1979

Species	Height (m)	Maximum slenderness ratio
Baobab	20.0	2.5
Giant sequoia	135.0	11
Evergreen redwood (sequoia)	100.0	15
Cedar	40.0	20
Eucalyptus	128.0	28
Fir	70.0	42
Spruce	60.0	60
Palm 30.0	60	
Sunflower	4.0	100
Bamboo	40.0	133
Sugarcane	6.0	200
Rye	1.5	500

**Table 2.3.10: Length of Runners of Selected Plants Over the Course of a Year**

In ascending order, according to length.

Data after KERNER v. MARILAUN 1898

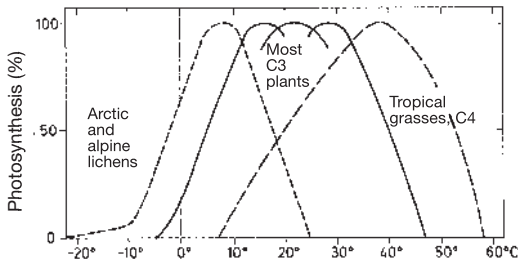
Species	Length (cm)
Yellow mountain saxifrage	4
Yellow anemone	5– 10
Oregano	5– 10
Lemon balm	5– 10
Common yarrow	10– 15
Field horsetail	10– 15
Sweet violet	13
Dentaria glandulosa	15– 20
Sand sedge	15– 20
Spearmint	15– 20
Common bugle	20
Woodruff	20– 25
Peppermint	20– 25
Common madder	20– 25
Mercurialis	25– 30
Quackgrass	25– 30
Bishop's goutweed	25– 30
Stiff clubmoss	30– 40
Field bindweed	30– 55
Soapwort	30– 55
Nettle	35– 45
Hairy sedge	35– 45
Sea milkwort	45– 55
Creeping avens	50
Broad-leaved ragwort	55– 60
Creeping buttercup	60
Coltsfoot	60– 75
Canada goldenrod	60– 75
Rosebay willow herb	85–100
Pestilence wort	100–150
Silverweed	110
Ground ivy	126
Creeping cinquefoil	130
Stone bramble	140
Strawberry	150
Periwinkle	200

**Table 2.3.11: Cardinal Temperature Points for the Growth of Selected Useful Plants**

Plant growth only occurs at a temperature between the minimum and maximum.

After BROUWER 1972, ELLENBERG 1978, GESSNER 1942, MADLE 1967, STILES and COCKING 1969, WALTER 1962

Species	Minimum (°C)	Optimum (°C)	Maximum (°C)
Alfalfa	1	30	37
Barley	3–4	20	30
Bean	10	32	37
Beech	– 5	20–22	43
Corn (maize)	8–10	34	46
Cucumber	15	35	50
Fir	– 7	14–20	38
Hemp	0– 5	37–44	44–50
Lentil	2		28
Maple ( <i>A. platanoides</i> )	7		28
Melon	15–18	31–37	44–50
Oats	4– 5	25	30
Pine	7		34
Pumpkin	10–15	37–44	44–50
Rye	2– 3	25	30
Spruce	– 7	12–18	36
Sunflower	5–10	31–37	37–44
Tobacco	13	28	35
Wheat	5– 6	29	40



**Fig. 2.3.11:** Dependence of the position of the cardinal points of net photosynthesis upon temperature in selected types of plants. See also Table 2.3.11.

From STRASBURGER 1983, p. 270

**Table 2.3.12: Optimal pH Soil Levels for Plant Growth**

Some specialists can populate soils with extreme pH levels. For instance, peat mosses (sphagnum) and cotton grass still grow at pH levels of 3.3-3.5. The lowest recorded pH value, of 1.6, was set by a Central American species of spikerush (*Eleocharis schaffneri*).

Data after various authors from ALTMAN and DITTMER 1973, LÖTSCHERT 1969

Species	pH optimum
Asparagus	6.0–8.0
Bilberry	4.5–6.0
Carrot	5.5–7.0
Common aspen	4.5–5.5
Corn (maize)	5.5–7.5
English holly	5.5–6.5
European beech	6.0–7.5
Fir	4.5–6.5
Ginkgo	5.5–7.0
Horse chestnut	5.5–7.0
Larch	4.5–7.5
Melon	6.0–8.0
Oak	6.0–7.5
Oats	5.0–6.8
Onion	6.0–7.5
Parsley	5.0–7.0
Pea	6.0–8.0
Pine	4.5–6.5
Potato	5.4–6.7
Pumpkin	5.5–7.0
Rhododendron	4.5–6.0
Rose	5.5–7.0
Rye	5.0–7.0
Sorrel	4.0–7.5
Spruce	4.5–6.5
Strawberry	5.0–6.5
Sunflower	6.0–7.5
Tilia (linden, lime)	6.0–7.5
Tobacco	5.5–7.5
Violet	6.0–7.5
Walnut	6.0–7.5
Wheat	5.5–7.5
Wine grape	6.0–8.0

**Table 2.3.13: Polar Limits for the Cultivation of Selected Useful Plants**

Figures are in degrees of northern latitude. As a point of reference, the latitudes of several important cities are also provided. Since crop cultivation is also heavily dependent on the amount of precipitation, see also Table 2.3.14.

After ANDREAE 1976

Plant	Northern boundary	Comparative approx. location of selected cities (and other geographical entities)
Coconut palm	15°	15° Manila, Dakar, Guatemala
Oil palm	16°	
Sisal	19°	19° Mexico City, Mumbai (Bombay) 21° Mecca, Hanoi
Cacao, coffee	22°	22° Kolkata (Calcutta)
Banana, cassava	23°	23° Havana
Caoutchouc	25°	26° Miami 30° Cairo 32° Tel Aviv
Sweet potato	35°	
Cotton	38°	38° Athens, Palermo, San Francisco
Sugarcane	39°	40° Madrid
Peanut, tea	41°	41° Naples, New York
Citrus	42°	42° Rome
Soy bean, millet, olive	45°	45° Turin, Bordeaux 48° Vienna, Munich 49° Paris, United States' northern border 50° Mainz, Winnipeg
Wine grape	51°	51° London
Rice	52°	52.5° Berlin
Tobacco	53°	
Kernel corn	54°	56° Moscow 59° Stockholm 60° St. Petersburg, Oslo
Beetroot	61°	
Wheat	63°	63° Trondheim 69° Murmansk
Barley, potatoes	70°	

**Table 2.3.14: Dryness Limits for the Cultivation of Selected Useful Plants**

Figures represent the minimum required annual precipitation in millimeters. As a point of reference, figures for the annual precipitation of several well-known locations in different climate zones are also provided. Since crop cultivation is also highly dependent on temperature, see also Table 2.3.13.

Data after ANDREAE 1976

Species	Required annual precipitation (mm)	Annual precipitation of selected cities
		Goa 2,506
		Mumbai (Bombay) 1,813
		New Orleans 1,545
Caoutchouc, oil palm	1,500	
Tea, yams	1,500	
Sugarcane	1,400	
Cacao, coconut palm	1,300	Chennai (Madras) 1,241
		Shanghai 1,120
		Milan 1,011
Coffea arabica	900	Munich 935
Rice	800	Rome 836
Kernel corn	760	Lisbon 754
		Algiers 728
		Palermo 644
		Vienna 644
		Frankfurt 604
		Adana 600
		Berlin 581
		Moscow 535
Sweet potato, cotton	500	Magdeburg 508
Cassava, tobacco	500	
Sugar beet	450	Los Angeles 440
Potatoes, sesame	400	
Peanut, wheat	300	
Sisal, barley	250	
Olive	200	Phoenix (Ariz.) 206
		Bagdad 145



## 2.4 Reproduction: Blossoms, Fruits, Seeds

**Table 2.4.1: Linnaeus' Flower-Clock**

The times apply to Uppsala, Sweden (60° north latitude).

After MEYER 1964

Time	The following blossoms open:	The following blossoms close:
3–5 a.m.	Yellow goat's beard	
4–5 a.m.	Chicory, bristly oxtongue	
5 a.m.	Tawny daylily, common sow thistle, Icelandic poppy	
5–6 a.m.	Dandelion	
6 a.m.	Narrowleaf hawkweed Spotted cat's-ear	
6–7 a.m.	Bladderpod, wall hawkweed, Common hawkweed	
7 a.m.	<i>Anthericum ramosum</i> , white water lily	
8 a.m.	Scarlet pimpernel, tunic flower	
8–10 a.m.		Dandelion
9–10 a.m.	Field marigold, Red sandspurry	Yellow goat's beard
10 a.m.		Chicory
11–12 a.m.		Common sow thistle
12 noon		Field marigold
1 p.m.		Tunic flower
2 p.m.		Common wall hawkweed Hawkweed
2–3 p.m.		Red sandspurry
3–4 p.m.		<i>Anthericum ramosum</i>
4 p.m.		Bladderpod
4–5 p.m.		Spotted cat's-ear
5 p.m.		Narrowleaf hawkweed, white water lily
7 p.m.		Icelandic poppy
7–8 p.m.		Tawny daylily

**Table 2.4.2: Floral Formulas of Selected Plant Families**

The table presents the floral formula typical for a given plant family. Where distinct formulas exist within one family, these are also presented here for important species; the same applies for exceptions in well-known species. The table focuses mainly on important European plant families.

A = Androecium (whorl of stamens), Ca = calyx (sepal whorl), Co = corolla (petal whorl), G = gynoecium (carpel or carpels), P = perigone (where corolla and calyx are indistinguishable); n = numerous. Parentheses indicate that the parts referred to are fused.

Data after GRAF 1975, SCHMEIL and FITSCHEN 1982, STRASBURGER 1983

Family		P	Ca	Co	A	G
Aster ( <i>Asteraceae</i> and <i>Cichoriaceae</i> )				(5)	(5)	(2)
Beech ( <i>Fagaceae</i> )						
E.g., European beech	♂ ♀	5-6 3+3				(4)-(15) (3)
Birch ( <i>Betulaceae</i> )						
Birch	♂ ♀	2+2			2	(2)
Hazel	♂ ♀				4	(2)
European hornbeam	♂ ♀				4-12	(2)
Bluebells ( <i>Campanulaceae</i> family)			5	(5)	5	(3)
Borage ( <i>Boraginaceae</i> )			5	(5)	5	(2)
Buttercup ( <i>Ranunculaceae</i> )						
<i>Anemone</i> sp.		3+3			n	n
<i>Ranunculus</i> sp.			5	5	n	n
Carrot ( <i>Apiaceae</i> )			5	5	5	(2)
Duckweed ( <i>Lemnaceae</i> )	♂ ♀				1	1
Figwort ( <i>Scrophulariaceae</i> )			(5)	(5)	5	(2)
<i>Veronica</i> sp.			(5)	(5)	2	(2)
Gentian ( <i>Gentianaceae</i> )			5	5	5	(2)
Geranium ( <i>Geraniaceae</i> )			5	5	(5)-(5+5)	(5)
Goosefoot ( <i>Chenopodiaceae</i> )		5			5	(2)
Honeysuckle ( <i>Caprifoliaceae</i> )			5	5	5	(2)-(3)
Heath ( <i>Ericaceae</i> )						
<i>Erica</i> , <i>Calluna</i> spp.			4	(4)	8	(4)
<i>Vaccinium</i> sp.			5	(5)	10	(5)
Ivy ( <i>Araliaceae</i> )			5	5	5	(3)-(5)

(Cont.) →

Family	P	Ca	Co	A	G
Knotweed ( <i>Polygonaceae</i> )					
<i>Rheum</i> sp.	6			9	(3)
<i>Rumex</i> sp.	6			6	(3)
Lily ( <i>Liliaceae</i> )	3+3			3+3	(3)
<i>Paris</i> , <i>Maianthemum</i> spp.	4	4	4+4	(4)	
Linden ( <i>Tiliaceae</i> )		5	5	n	(5)
Mallow ( <i>Malvaceae</i> )					
e.g., <i>Malva</i> sp.		5	5	n	(n)
Maple ( <i>Aceraceae</i> )		5	5	8	(2)
Mint ( <i>Lamiaceae</i> )		(5)	(5)	4	(2)
Mustard ( <i>Brassicaceae</i> )		4	4	4+2	(2)
Nettle	♂	4		4	
( <i>Urticaceae</i> )	♀	2-5			1
Nightshade ( <i>Solanaceae</i> )		(5)	(5)	5	(2)
Orchid ( <i>Orchidaceae</i> )	6			1-2	(3)
Orpine ( <i>Crassulaceae</i> )		5	5	10	5
Pea or legume ( <i>Fabaceae</i> )					
<i>Laburnum</i> sp.		(5)	5	(10)	1
<i>Vicia</i> sp.		(5)	5	(9)+1	1
Pink ( <i>Caryophyllaceae</i> )		(5)	5	5+5	(5)
Plantain ( <i>Plantaginaceae</i> )		4	(4)	4	(2)
Primrose ( <i>Primulaceae</i> )		(5)	(5)	5	(5)
Poppy ( <i>Papaveraceae</i> )		2	2+2	n	(2)
Rose ( <i>Rosaceae</i> )		5	5	5-?	1-?
Rush ( <i>Juncaceae</i> )	3+3			3+3	(3)
Saxifrage ( <i>Saxifragaceae</i> )		5	5	5+5	(2)
Sedge ( <i>Cyperaceae</i> )					
<i>Scirpus</i> sp.	3+3			3	(3)
<i>Carex</i> sp.				3	
Spurge	♂				(2)-(3)
( <i>Euphorbiaceae</i> )	♀			1	
Sundew ( <i>Droseraceae</i> )		5	5	5	(3)
Teasel ( <i>Dipsacaceae</i> )		4-5	(4)-(5)	4	1
True grass ( <i>Poaceae</i> )	(2)+2			3	(3)
Violet ( <i>Violaceae</i> )		5	5	5	(3)
Water lily ( <i>Nymphaeaceae</i> )		4	n	n	n
Willow ( <i>Salicaceae</i> )					
<i>Salix</i> sp.	♂			2	
<i>Populus</i> sp.	♀			3-30	(2)
Wood sorrel ( <i>Oxalidaceae</i> )	♂	5	5	5+5	5

**Table 2.4.3: Blossoming Period of Selected Plants**

Figures represent the lifespan of an individual blossom.  
Presented in ascending order, according to length.

Data after KERNER v. MARILAUN 1898, MOLISCH 1965

Species	Blossoming period (days)	Species	Blossoming period (days)
Common evening primrose	1	Yellow daylily	6
Angel's-tears	1	Pelargonium	7
Meadow cranesbill	2	Tall buttercup	7
Hill willow-herb	2	Marsh grass of Parnassus	8
Opium poppy	2	European hepatica	8
<i>Veronica aphylla</i>	2	Saxifrage ( <i>saxifraga bryoides</i> )	8
Field rose	2	Winter aconite	8
Wild mustard	2	Cyclamen	10
Common agrimony	3	Prickly saxifrage	12
Alpine rockrose	3	Saffron crocus	12
Dwarf honeysuckle	3	Cranberry	18
Pearlwort ( <i>sagina</i> )	4	Tropical orchids	
Red campion	4	<i>Cattleya labiata</i>	30
<i>Sedum atratum</i>	4	<i>Cypripedium insigne</i>	40
Snake's head fritillary	5	<i>Phalaenopsis grandiflora</i>	50
Flax ( <i>Linum viscosum</i> )	5	<i>Oncidium cruentatum</i>	60
Common centaury	5	<i>Cypripedium villosum</i>	70
Purple foxglove	6	<i>Odontoglossum rossii</i>	80
Branching centaury	6		

**Table 2.4.4: Critical Day Length for Inducing Blossoming in Long-Day and Short-Day Plants**

Figures from GREULACH and ADAMS 1962, JENSEN and SALISBURY 1972. See also STRASBURGER 1983

Species	Critical day length (h)
Long-day plants	
Bent grass ( <i>Agrostis palustris</i> )	< 16
Brome ( <i>Bromus inermis</i> )	< 12.5
Dill	< 11
English rye-grass ( <i>Lolium perenne</i> )	< 13
Henbane	< 10
Hibiscus	< 12
Italian rye-grass ( <i>Lolium italicum</i> )	< 11
Oats	< 9
Orchard grass	< 12

(Cont.) →

Species	Critical day length (h)
Radish	< 12
Red clover	< 12
Reed canary grass ( <i>Phaleria arundinacea</i> )	< 12.5
Rudbeckia	< 10
Spinach	< 13
Timothy grass ( <i>Phleum nodosum</i> )	< 14.5
Timothy grass ( <i>Phleum pratense</i> )	< 12
Wheatgrass ( <i>Agropyron smithii</i> )	< 10
Winter barley	< 12
Winter wheat	< 12
Short-day plants	
<i>Bryophyllum</i>	> 12
Chrysanthemum	> 15
Cosmos	> 14
Kalanchoe	> 12
Poinsettia ( <i>Euphorbia pulcherrima</i> )	> 12
Redwood (sequoia)	> 14
Strawberry ( <i>Fragaria chiloensis</i> )	> 10
Tobacco	> 14
Violet ( <i>Viola papilionacea</i> )	> 11
Winter rice	> 12

**Table 2.4.5: Blossoming Data for Selected Trees and Shrubs Native to Germany**

For data on monocotyledonous plants, see Table 2.4.6; for true grasses (*Poaceae*), see Table 2.4.7; and for dicotyledonous plants, see Table 2.4.8. Please note that in northern Germany, blossoms (e.g., of the apple tree) start 3 weeks later than in the Rhine valley or at Lake Constance.

Data from FLINDT 1985, SCHMEIL and FITSCHEN 1968

Species	Months	Species	Months
Alder	III-IV	Bog rosemary	V-VI
Alder buckthorn	V-VI	Boxwood (common box)	III-IV
Apple	IV-VI	Clematis	VI-IX
Apricot	III-IV	Common aspen	II-IV
Ash	V-VI	Common barberry	V-VI
Basket willow	III-IV	Cornelian cherry	III-IV
Birch	IV-V	Cowberry (lingonberry)	V-VII
Bird cherry	IV-VI	Cross-leaved heath	VII-VIII
Black poplar	III-IV	Crowberry	V-VI
Blackberry	VI-VII	Dictamnus	V-VI
Blackthorn	III-IV	Dog rose	VI

Species	Months	Species	Months
Dog rose	VI	Pear	IV-V
Douglas fir	IV-V	Platanus	V
Eared willow	IV-V	Plum	IV-V
Elderberry	VI-VII	Privet	VI-VII
English elm	III-IV	Quince	V-VI
English holly	V-VI	Raspberry	V-VI
European beech	IV-V	Rhododendrons	V-VII
European hornbeam	IV-VI	Robinia	V-VI
European rowan	V-VII	Rugosa rose	VI-VII
European spindle	V-VII	Scotch broom	V-VI
False medlar	IV-VI	Scotch pine	V-VI
Field or hedge maple	V	Siberian dogwood	V-VI
Forsythia	III-IV	Silver fir	V-VI
Goat willow	III-IV	Sour cherry	IV-V
Gooseberry	IV-V	Spiny restharrow	VI-VII
Hawthorn	V-VI	Spruce	IV-VI
Hazel	II-IV	Sweet chestnut	VI
Horse chestnut	IV-V	Sweet gale	IV-V
Ivy	IX-X	Swiss pine	VI-VII
Juniper	IV-V	Sycamore maple	IV-VI
Laburnum	IV-VI	Vaccinium	V-VI
Larch	IV-VI	Walnut	IV-V
Large-leaf linden	VI	Wayfaring tree	IV-V
Lilac	V-VI	White poplar	III-IV
Little-leaf linden	VI-VII	Whitebeam	V-VI
Mezereon	II-IV	Wild cherry	IV-V
Mistletoe	III-V	Wild rosemary	V-VI
Mugo pine	V-VI	Wine grape	VI-VII
Norway maple	IV-V	Winged broom	V-VII
Oak	IV-V	Yew	III-IV
Peach	IV-V		

**Table 2.4.6: Blossoming Data for Selected Monocotyledonous Plants Native to Germany**

Grasses not included here; for these, see Table 2.4.7. For figures on trees and shrubs, see Table 2.4.5; and for dicotyledonous plants, see Table 2.4.8.

Figures from FLINDT 1985, SCHMEIL and FITSCHEN 1968

Species	Months in bloom	Species	Month in bloom
Alpine squill	III-IV	Lesser rattlesnake plantain	VII-VIII
Anthericum	VI-VIII	Lily of the valley	V-VI
Arrowhead	VI-VIII	Martagon lily	VII-VIII
Asparagus	V-VI	Military orchid	V-V
Autumn crocus	VIII-IX	Orchid	
Bird's-nest orchid	V-VI	Bee	V-VII
Branched bur-reed	VI-VIII	Fly	V-VI
Broadleaf cattail	VI-VII	Late spider	V-VI
Canadian waterweed	V-VIII	Pondweed	
Common spikerush	VI-VII	Curly	V-IX
Common spotted orchid	V-VIII	Floating leaf	V-VIII
Cotton grass/sedge		Opposite-leaved	VI-VII
Common	III-V	Ramsons	V-VI
Sheathed	III-IV	Rannoch rush	V-VII
Crocus	III-IV	Round-fruited rush	VI-IX
Cuckoopint	IV-V	Sea club-rush	VII-VIII
Daffodil	III-IV	Sedge	
Early purple orchid	V-VI	Common	V-VIII
Eelgrass	VI-X	Hairy	IV-VI
False lily of the valley	IV-VI	Sand	V-VI
Flowering rush	VI-VIII	Star	V-VI
Fragrant orchid	V-VIII	Tufted	IV-V
Frog orchid	V-VI	White	V-VIII
Frog's bit	V-VIII	Snake's head fritillary	IV-V
Great woodrush	IV-V	Snowdrop	II-IV
Greater duckweed	V-VI	Solomon's seal	V-VI
Hellebore	VI-VIII	Spring snowflake	II-IV
Helleborine		Star of Bethlehem	
Broad-leaved	VI-IX	( <i>Gagea villosa</i> )	III-V
Marsh	VI-VIII	Twayblade	V-VII
Herb Paris	V	Water arum	V-VII
Lady's slipper	V-VII	Water plaintain	VI-IX
Lesser butterfly orchid	V-VII	Yellow flag	V-VI

**Table 2.4.7: Blossoming Data for Selected True Grasses (*Poaceae*) Native to Germany**

Data after FLINDT 1985, SCHMEIL and FITSCHEN 1968

Species	Months	Species	Months
Alkali grass	VI-IX	Orchard grass	V-VI
Barley	VII	Purple moor grass	VII-IX
Bearded darnel	VI-VIII	Quackgrass	VI-VII
Brome		Quaking grass	V-IX
Upright	V-VII	Redtop	VI-VIII
Soft	V-VII	Reed canary grass	VI-VIII
Common reed	VII-IX	Rye	V-VI
Common velvet grass	VI-VIII	Smooth meadow-grass (Kentucky bluegrass)	V-VII
Cordgrass	VII-IX	Sweet vernal grass	V-VIII
Crested dog's-tail	VI-VII	Tall oatgrass	VI-VII
European beach or marram grass	VI-VII	Timothy	V-VII
Feather grass	VII-VIII	Tufted hairgrass	VII-IX
Fescue ( <i>festuca varia</i> )	VII-VIII	Wheat	VI
Meadow	VI-VII	Wild barley	VI-XI
Loose silky-bent	VI-VII	Wild oat	VI-VIII
Mat grass	V-VII	Wood manna-grass	VI-VII
Millet grass	V-VII	Wood melick	V-VI
Oats	VI-VII	Wood small reed	V-VIII

**Table 2.4.8: Blossoming Data for Selected Dicotyledonous Plants Native to Germany**

Trees and shrubs are excluded here; for these, see Table 2.4.5. For data on monocotyledonous plants, see Table 2.4.6, for true grasses, see Table 2.4.7.

Data after FLINDT 1985, SCHMEIL and FITSCHEN 1968

Species	Months in bloom	Species	Months in bloom
Anemone, yellow	III-V	Buckbean	V-VI
Arnica	V-VIII	Bugle, common	V-VIII
Asarabacca		Bull thistle	VIII-X
(European wild ginger)	III-V	Burdock	VII-IX
Belladonna	VI-VIII	Burnet, Great	VI-IX
Bishop's goutweed	V-IX	Salad	V-VI
Biting or gold-moss stonecrop ( <i>Sedum acre</i> )	VI-VIII	Buttercup, Corn	V-VII
Black medick	V-IX	Creeping	V-VIII
British yellowhead	VI-IX	Tall	V-X
Bryony	VI-IX	Campion	
		Red	IV-IX

(Cont.) →



Species	Months in bloom	Species	Months in bloom
White	VI-IX	Cyclamen	VI-IX
Caraway	V-VII	Cypress spurge	IV-VII
Carlina thistle	VII-IX	Daisy	III-XI
Carrot, wild	V-VII	Dandelion	IV-VII
Centaury	VII-IX	Dead-nettle	
Chicory	VII-IX	Red	III-X
Christmas rose	II-VI	White	IV-VIII
Cleavers	V-X	Dodder	VI-IX
Clusterhead		Dog fennel or chamomile ( <i>Anthemis</i> )	
or carthusian pink	VI-VIII		VI-IX
Coltsfoot	III-IV	Dog violet	IV-VI
Comfrey	V-VII	Edelweiss	VII-IX
Common agrimony	VI-VIII	Enchanter's nightshade	VI-IX
Common alkanet or bugloss	V-IX	English or narrowleaf plantain	V-IX
Common bean	VI-IX	European columbine	VI-VII
Common bird's-foot trefoil	V-IX	European field pansy	V-X
Common butterwort	V-VIII	European hepatica	III-IV
Common chickweed		European speedwell	V-VIII
( <i>Stellaria media</i> )	III-X	European yellow-rattle	V-IX
Common evening		Fairy flax	VI-VIII
primrose	VI-IX	Field bindweed	V-X
Common figwort	VI-VII	Field pennycress	IV-VI
Common fumitory	IV-X	Field scabious	V-IX
Common glasswort	VIII-X	Field sow thistle	VII-X
Common groundsel	III-X	Forget-me-not	
Common hemp-nettle	VII-X	Woodland	V-VII
Common hogweed	VI-X	Frostweed	V-IX
Common mare's tail	V-VIII	Garden loosestrife	VI-VIII
Common milkwort	V-VIII	Garden orach(e)	VII-X
Common yarrow	VI-X	Garlic mustard	IV-VI
Corn cockle	VI-IX	Gentian	
Corn poppy	V-VII	Yellow	VI-VIII
Corn spurry	VI-X	Marsh	VII-X
Cornflower	VI-IX	<i>Gentiana sino ornata</i>	IV-VIII
Corydalis	III-V	German chamomile	V-IX
Cowslip	IV-V	Germander speedwell	V-VIII
Cow-wheat, small	V-VIII	Globe flower	V-VI
Cranesbill		Golden saxifrage	IV-VI
Bloody	V-IX	Good King Henry	IV-X
Meadow	VI-VIII	Greater celandine	V-IX
Creeping Jenny	V-VII	Ground ivy	IV-VI
Cuckoo flower	IV-VII	Harebell	VI-IX
Cucumber	VI-IX	Hedge false bindweed	VI-IX
Curly dock	V-VII	Hedge mustard	V-X

Species	Months in bloom	Species	Months in bloom
Hellebore, stinking	III-IV	Potato	VI-IX
Hemp agrimony	VII-IX	Purple foxglove	VI-VII
Henbane	VI-X	Purple loosestrife	VI-IX
Hens and chicks	VII-IX	Pussytoes	V-VII
Herb Robert	V-X	Ragged robin	V-VIII
Hoary alyssum	VI-X	Rampion, spiked	V-VIII
Hoary cress	V-VII	Red clover	IV-IX
Honesty	V-VI	Rosebay willow herb	VI-VIII
Hops	V	Sainfoin	V-VII
Hound's tongue	V-VI	Sea holly	
Kidney vetch	V-IX	( <i>Eryngium maritimum</i> )	VI-X
Knotweed	V-IX	Sedum	VI-IX
Lady's mantle	V-IX	Self-heal	VI-IX
Large pink	VI-IX	Shepherd's purse	II-IX
Lesser celandine	III-V	Silverweed	V-VIII
Livelong saxifrage	V-VIII	Small scorpion vetch	VI-VII
Lungwort	III-V	Soapwort	VI-IX
Lupin	VI-IX	Solid-stem	
Malve	V-IX	burnet saxifrage	VI-IX
Marsh angelica	VII-VIII	Sorrel	V-VI
Marsh cinquefoil	VI-VII	Spinach	V-IX
Marsh marigold	III-VI	Spring cinquefoil	III-V
Masterwort	VI-VIII	St. John's wort	VI-VIII
Meadow sage	V-VIII	Stinging nettle	VI-X
Meadowsweet	VI-VIII	Strawflower	VII-X
Mercurialis	IV-V	Sundew	VI-VIII
Monkshood	VII-VIII	Sunflower	VII-X
Moschatel	III-V	Swallow-wort	V-VIII
Mouse-ear chickweed	III-VI	Thyme	V-X
Mouse-ear hawkweed	V-X	Tomato	VII-X
Mustard		Tormentil	V-VII
Black	VI-IX	Touch-me-not	VII-IX
Wild	VI-IX	Tufted vetch	VI-VII
Oxeye daisy	V-X	Valerian	VII-VIII
Oxlip	III-V	Vetchling	
Parsley	VI-VII	Spring	IV-V
Pasque flower	III-V	Meadow	VI-VII
Pea	V-VI	Viper's bugloss	VI-X
Peppermint	VI-VII	Water avens	IV-V
Pestilence wort	III-V	Water chestnut	VI-IX
Pincushion flower	VII-X	Water crowfoot	VI-VIII
Pinesap	VI-VIII	Water hemlock	VII-IX
Poison hemlock	VI-IX	Water lily	VI-IX
Pond-lily, yellow	IV-IX	Water parsnip	VI-VIII

(Cont.) →

Species	Months in bloom	Species	Months in bloom
Watercress	V-VIII	Woodruff	IV-V
Whitlow grass	II-V	Woodsorrel	IV-V
Wild chervil	IV-VIII	Wormseed mustard/ wallflower	V-IX
Wild radish	VI-VIII	Yellow archangel	IV-VII
Wild strawberry	V-VI	Yellow or common toadflax	VI-IX
Winter cress	IV-VII	Yellow sweet clover	V-IX
Wood anemone	III-IV	Yellowcress, creeping	VI-IX
Wood betony	VI-VIII		
Wood sanicle	V-VII		

**Table 2.4.9: Time of Spore Maturation in Selected Ferns Native to Germany**

Data after FLINDT 1985, SCHMEIL and FITSCHEN 1968

Species	Month
Adder's-tongue	VI-VIII
Brackenfern	VII-X
Common clubmoss	VII-VIII
Common moonwort	V-VII
Common polypody	VI-IX
Deer fern	VII-IX
Field horsetail	III-IV
Ground cedar	VIII-IX
Hart's tongue fern	VII-IX
Lady fern	VII-IX
Long beech fern	VI-VIII
Maidenhair spleenwort	VII-IX
Male fern	VI-IX
Marsh clubmoss	VIII-X
Marsh horsetail	V-VII
Meadow horsetail	V-VI
Oak fern	VII-VIII
Royal fern	VI-VII
Spikemoss, Swiss ( <i>Selaginella helvetica</i> )	VI-VIII
Stiff clubmoss	VIII-X
Wall-rue	VI-VII
Woodland horsetail	V-VI

**Table 2.4.10: Formation Time of Fruiting Bodies of Fungi Native to Germany**

Data after MAUCH and LAUBER 1975, HENNIG and KREISEL 1978

Species	Months of appearance
Bay bolete	VI–XI
Beefsteak or brain mushroom	III–V
Black morel	III–V
Blusher ( <i>Amanita rubescens</i> )	VI–X
Brick tuft ( <i>Hypholoma lateritium</i> )	VIII–XI
Brown roll-rim	VII–XI
Cauliflower mushroom	VII–XI
Chanterelle	VI–X
Common earthball	VII–XI
Death cap	VII–X
Field mushroom	VI–X
Fly agaric	VII–X
Gypsy	VII–X
Honey fungus	IX–XI
Horn of plenty	VIII–XI
Horse mushroom	VI–X
<i>Hygrophorus marzuolus</i>	III–IV
Larch boletus	VII–X
Livid pinkgill ( <i>Entoloma sinuatum</i> )	V–IX
Orange oak bolete ( <i>Leccinum quercinum</i> )	VI–X
Oyster mushroom	XI–III
Panther (cap) ( <i>Amanita pantherina</i> )	VII–X
Parasol	VII–X
Peppery milk cap ( <i>Lactarius piperatus</i> )	VII–X
Porcini	VI–X
<i>Ramaria aurea</i> (coral fungus)	VIII–X
Red cracking bolete ( <i>Xerocomus chrysenteron</i> )	VI–XI
Red-staining inocybe ( <i>Inocybe erubescens</i> )	V–VIII
Saffron milk cap	VII–XI
Sarcodon imbricatus	VIII–XI
Scaly wood mushroom	VI–X
Shaggy ink cap ( <i>Coprinus comatus</i> )	IV–XI
Sheathed woodtuft ( <i>Kuehneromyces mutabilis</i> )	IV–XII
Sickener ( <i>Russula emetica</i> )	VI–X
Stinkhorn ( <i>Phallus impudicus</i> )	V–IX
Suede bolete ( <i>Xerocomus subtomentosus</i> )	VI–X
Velvet bolete ( <i>Suillus variegatus</i> )	VI–XI
White or elfin saddles ( <i>Helvella crispa</i> )	VIII–XI
White truffle	VII–X
Wood blewit ( <i>Lepista nuda</i> )	IX–XI
Wood hedgehog ( <i>Hydnum repandum</i> )	VII–XI
Yellow morel ( <i>Morchella esculenta</i> )	IV–V

**Table 2.4.11: Annual Number of Seeds of Selected Plants**

Presented in ascending order, according to number of seeds per plant.

After BERTELSMANN 1979, HANF (no date), MEYER 1964, MÜLLER-SCHNEIDER 1977

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Strict or true forget-me-not	56
Coconut palm	70
Wild radish	160
Red dead-nettle	200
Corn cockle	200
Herb Robert	300
Black nightshade	500
Field bindweed	550
Field forget-me-not	700
Common alkanet or bugloss	900
Field pennycress	900
Corn buttercup	900
Wild mustard	1,200
Cornflower	1,600
Pansy	2,500
Hedge mustard	2,700
Creeping bellflower	3,000
Wild carrot	4,000
Dandelion	5,000
Imperforate St. John's wort	10,600
Common chickweed	15,000
Canada thistle	19,000
Orach(e)	20,000
Corn poppy	20,000
Meadowsweet	34,000
Greater celandine	36,000
Groundsel	40,000
Henbane	45,000
Coltsfoot	60,000
Shepherd's purse	64,000
Common spotted orchid	100,000
Horseweed	120,000
Scentless mayweed	210,000
Galinsoga	300,000
Tobacco	360,000
Mugwort	700,000
Butterfly bush	20,000,000
Black poplar	28,000,000
Birch	30,000,000

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**Table 2.4.12: Number of Seeds per Capsule in Selected Plants**

Presented in ascending order, according to number. For the total number of seeds per year, see Table 2.4.11.

Data after BECHTEL et al.1980, EBEL and BIRNBAUM 1971, MEYER 1964

Species	Seeds per capsule ( <i>n</i> )
Cherry	1
Coconut	1
Almond	1
Plum	1
Walnut	1
Peanut	3– 4
Apple	5– 10
Pear	5– 10
Pea	8– 12
Shepherd's purse	30– 40
Henbane	300–400
Poppy	>1,000
<i>Maxillaria</i> (orchid)	1,756,440
Swan orchid ( <i>Cycnoches</i> )	3,751,000 (!)

**Table 2.4.13: Weight of Selected Seeds**

For the thousand seed weight and the hectoliter weight of the seeds of useful plants, see Table 2.4.14.

Presented in ascending order, according to weight

Data from BERTELSMANN 1979, GÖTZ and KONRAD 1977, MEYER 1964, ULBRICH 1928

Species	Weight (g)
Broomrape ( <i>Orobanche ionantha</i> )	0.000001
Plantain orchid ( <i>Goodyera repens</i> )	0.000002
One-flowered wintergreen or pyrola	0.000004
Fragrant orchid	0.000008
Birch	0.0006
Clover	0.002
Alder	0.002
Rape	0.004
Spruce	0.007
Elm	0.008
Douglas fir	0.01
Robinia	0.02
Rye	0.03
European hornbeam	0.035

(Cont.) →

Species	Weight (g)
Wheat	0.04
Oats	0.04
Fir	0.04
Barley	0.04
Ash	0.07
Lupin	0.08
Lentil	0.082
Maple	0.1
Pea	0.2
Corn (maize)	0.2
European beech	0.22
Broad bean	0.3
Common hogweed	0.4
Runner bean (scarlet runner)	0.5
Oak	3.0
Brazil nut	up to 25
Avocado	up to 60

**Table 2.4.14: Thousand Seed Weights (TSW) und Hectoliter Weights of the Seeds of Selected Useful Plants**

For seed weights, see also Table 2.4.13.

After BROUWER 1977, GÖTZ and KONRAD 1977

Species	TSW (g)	Hectoliter weight (kg)
Winter wheat	35– 45	74–76
Winter rye	25– 35	70–73
Spring barley	35– 45	63–63
Oats	32– 40	50–60
Corn seed	200–450	
Flint corn	115–300	
Sweet corn	240–310	
Popcorn	80–130	
Victoria peas	200–300	78–82
Field peas	150–250	75–82
Broad beans	250–350	75–85
Common vetches	40– 55	76–80
Lupin	100–120	76–80
Rape	4– 6	65–72
Clover	2– 3	70–80
Alfalfa	2– 3	70–80

**Table 2.4.15: Age of Seeds of Selected Plants**

Age of seeds is in part heavily dependent on storage conditions. The high numbers refer to individual seeds found under the datable foundations of buildings (e.g., churches). For those figures marked with an asterisk (\*), there is no information whether the seeds found were still germinable.

Figures from ALTMAN and DITTMER 1972, GESSNER 1942, MEYER 1964

Plant species	Max. age of seeds	Plant species	Max. age of seeds
Sweet chestnut	9 months	Onion	22 years
Horse chestnut	15 months	Melon	30 years
Lemon	16 months	Carrot	31 years
Coconut	16 months	Pea	31 years
Coffee	22 months	Barley	32 years
Beech	2 years	Rye	32 years
Hazelnut	2 years	Wheat	32 years
Common aspen	2 years	Corn (maize)	37 years
Oak	3 years	Celery	39 years
Walnut	5 years	Tobacco	39 years
Eastern white pine	10 years	Oats	41 years
Cornflower	10 years	Mustard	50 years
Pumpkin	10 years	Purple foxglove*	68 years
Poppy	10 years	Dandelion	68 years
Quackgrass	10 years	Common evening primrose*	80 years
Rape	16 years	Red clover	100 years
Millet	17 years	Potato	200 years
Flax	18 years	Sacred lotus	250 years
Cabbage	19 years	Creeping buttercup*	600 years
Hemp	19 years	White clover*	600 years
Lettuce	20 years	Corn spurry*	1,700 years
Bean	22 years		



**Table 2.4.16: Maximum Distance Seeds Catapulted by Ballistic Fruits**

Listed in ascending order.

Data after BÜNNING 1953, KERNER V. MARILAUN 1898, STRASBURGER 1983, ULBRICH 1928

Species	Distance catapulted (m)
Narrowleaf bittercress	0.90
Dog violet	1.00
Leopard's bane ( <i>Doronicum decumbens</i> )	1.00
Longstalk cranesbill	1.50
Marsh cranesbill	2.50
Early dog violet	3.75
Tall violet	4.65
Pansy	4.75
Lupin ( <i>Lupinus digitatus</i> )	7.00
Bear's breeches ( <i>Acanthus mollis</i> )	9.50
Squirting cucumber ( <i>Ecballium</i> )	12.70
Sandbox tree ( <i>Hura crepitans</i> )	14.00
<i>Bauhinia purpurea</i> (tropical liana)	15.00
As a point of comparison:	
Pilobolus fungus (ejects sporangium)	2.50

## 2.5 Constituents

**Table 2.5.1: Composition of Cereal Grains**

Figures are percentages for grains without shells/husks.

After BERTELSMANN 1979, FRANKE 1976, *rororo* 1976/77

	Water	Protein	Fat	Carbo- hydrates	Ash
Wheat	13.2	12.4	2.0	66.7	1.8
Rye	13.7	9.2	1.8	70.2	1.8
Oats	13.0	13.0	7.0	61.3	2.3
Barley	11.7	7.5	1.2	73.6	1.3
Rice	13.1	7.4	0.4	75.6	0.8
Corn (maize)	12.5	11.0	4.4	67.2	1.5
Millet	12.1	11.5	3.9	68.1	1.7

**Table 2.5.2: Composition of Legumes**

Figures represent percentages.

From FRANKE 1976

	Water	Protein	Fat	Carbo- hydrates	Crude fiber	Minerals
Pea, ripe seeds	10.9	22.90	1.40	60.7	1.40	2.70
Green peas	76.0	6.70	0.50	13.9	1.90	1.00
Bean, ripe seeds	11.6	21.30	1.60	57.6	4.00	3.90
Bean, green beans	90.4	2.24	0.26	5.0	1.36	0.74
Lentil	12.4	25.10	0.70	59.0	0.70	2.10
Broad bean	14.0	23.00	2.00	55.0	6.20	3.10
Soy bean	8.3	40.00	18.80	24.0	4.00	4.60
Peanut, roasted	2.8	26.50	46.60	19.0	2.40	2.70

**Table 2.5.3: Fat Content of Selected Plant Organs**

Figures represent a percentage of dry weight. See also Table 2.5.4, which provides fat content as a percentage of fresh weight.

Data from FRANKE 1976, STEWARD 1966

Plant species and organ	Fat content (% of dry weight)
<b>Seeds</b>	
Alfalfa	8–10
Almond	40–45
Bean	8
Beechnut	40–46
Cacao	50–58
Castor seed	35–57
Coconut. endosperm	65–72
Coffee	5–10
Corn (maize)	4.7
Cotton	16–24
Flax	24–43
Hazelnut	60–68
Hemp	30–35
Horse chestnut	3– 6
Oil palm	50
Parsley	16–19
Peanut	24–56
Pecan	65
Poppy	40–51
Rape	22–49
Rice	2.2
Sesame	44–54
Soy bean	17–22
Sunflower	40–65
Walnut	64
Wheat	2– 2.4
<b>Fruit pericarp</b>	
Avocado	70
Bay laurel	24–55
Oil palm	71–81
Olive	35–70
<b>Leaves/Blades</b>	
Alfalfa	2.3
Cabbage	1.7
Orchard grass	2.2

Plant species and organ	Fat content (% of dry weight)
Rye-grass ( <i>Lolium perenne</i> )	1.7
Spinach	0.4
<b>Roots</b>	
Beet ( <i>Beta vulgaris</i> )	7
Mangrove	70
<b>Sprouts</b>	
Black-eyed pea ( <i>Vigna sinensis</i> )	2.6
Soy bean	2.5
Tilia (linden, lime) ( <i>T. americana</i> ). rind	2.3

**Table 2.5.4: Fat Content of the Seeds and Fruits of Selected Plants as a Percentage of Fresh Weight**

Compare also to Table 2.5.3, which provides the fat content of the dry weight of selected plant organs.

Data from MENGEL 1968

Species	Fat content (% of fresh weight)
Barley	2
Corn (maize)	4.8
Flax	40
Oats	5
Olive	20
Olive (fruit flesh)	53
Pea	2
Peanut	45
Poppy	45
Rape	42
Soy bean	36
Sunflower (shelled)	50
Wheat	1.7

**Table 2.5.5: Raw Protein Content of Selected Seeds and Fruits**

Listed in ascending order.

From MENGEL 1968

Species	(%)
Rice	6.9
Corn (maize)	9.6
Barley	9.7
Oats	10.7
Millet	12.7
Flax	22.5
Pea	23.2
Broad bean	25.3
Sweet pea	25.9
Yellow lupine	38.3

**Table 2.5.6: Composition of Tubers**

Figures represent the mean values of amount present in an edible portion of 100 g.

From SOUCI, FACHMANN and KRAUT 1982

	Sweet potato	Cassava	Yams	Potatoes
Water	69.20 g	65.00 g	72.00 g	77.80 g
Protein	1.63 g	0.90 g	1.79 g	2.00 g
Fat	0.60 g	0.35 g	0.24 g	0.15 g
Carbohydrates	26.60 g	32.00 g	23.77 g	18.90 g
Raw fiber	0.90 g	0.80 g	0.71 g	0.78 g
Minerals	1.12 g	0.40 g	1.00 g	1.10 g
Vitamin B <sub>1</sub>	0.064 mg	0.07 mg	-	0.11 mg
Vitamin B <sub>2</sub>	0.05 mg	-	-	0.051 mg
Nicotinamide	0.60 mg	-	-	1.22 mg
Vitamin C	17.0 mg	25.0 mg	-	15.0 mg

**Table 2.5.7: Sugar Content of the Nectar of Selected Plants**

After SPECTOR 1956

Plant	Sugar content (g per 100 cm <sup>3</sup> nectar)	Sugar formation per blossom in 24 h (mg)
Alfalfa	33	0.1
Apple	75	0.8
Blackberry	15.4–45	
Borage	22 –29	
Cucumber	30	1.0
Fireweed	18.4–41	
Horse chestnut	69	1.1
Hound's tongue	36	0.3
Ivy	10 –11.5	
Jasmine	33	0.3
Lavender	24 –32	
Nasturtium	46	1.7
Pear	16	0.3
Pumpkin	28	28
Rape	47	0.5
Raspberry	46	7.6
Red clover	8.3–30	
Robinia	55	1.0
Snapdragon	45	1.5
Sour cherry	15	1.2
Sunflower	38	0.3
Tilia (linden, lime)	21 –42	
White dead-nettle	46	1.7
White clover	25 –39	
White mustard	9.3–17.6	
White sweet clover	36	0.04
Wild cherry	21	0.5

**Table 2.5.8: Energy Contents of Plant Material**

Expressed in kcal (kJ) per g dry weight. Figures are mean values

From MÜHLENBERG 1976, modified

Leaves	4.2 kcal (17,6 kJ)
Stalks and stems	4.3 kcal (18.0 kJ)
Roots	4.7 kcal (19.7 kJ)
Seeds	5.1 kcal (21.3 kJ)
Straw	4.3 kcal (18.0 kJ)

## 2.6 Physiological Values

**Table 2.6.1: Speed of Plasma Flow in Selected Plant Organs**

See also Table 5.6.

After OPPENHEIMER and PINCUSSEN 1927

Plant	Cell	Speed ( $\mu\text{m/s}$ )
Arrowhead	Leaf	2.9
Canadian waterweed	Leaf	15.4
Frog's bit	Root hair	9.5
Henbane	Hair	12
Mouse-ear chickweed	Leaf	1.5
Mucor mold	Hyphae	55
Nettle	Hair	6
<i>Nitella flexilis</i>	Internode	27.1
Onion	Onion scale epidermis	7 – 8
<i>Phycomyces nitens</i>	Hyphae	55
Pumpkin	Hair	8.3–10
Tradescantia	Stamen hair	10.8–13.8
<i>Vallisneria spiralis</i>	Leaf	12 –26

**Table 2.6.2: Osmotic Pressure in the Cell Sap of Selected Plant Leaves**

For figures for entire plants, see Table 2.6.3.

After ALTMAN and DITTMER 1966, SPECTOR 1956

Plant	Osmotic pressure atm	(hPa)	Plant	Osmotic pressure atm	(hPa)
Acacia	18–35	(18,239–35,464)	Common glasswort	30.9–113	(31,309–114,497)
Alfalfa	16.3–24.1	(16,516–24,419)	Corn (maize)	5.7–16.2	(5,776–16,415)
Apple	24–27	(24,318–27,358)	English holly	15.5–19.5	(15,705–19,758)
Asarabacca (European wild ginger)	9.0	(9,119)	European beach or marram grass	13.8–40.0	(13,983–40,530)
Ash	15–22.5	(15,199–22,798)	European hornbeam	17.7–24.3	(17,935–24,622)
Barley	7.2	(7,295)	Fig	14.6	(14,793)
Birch	12–23	(12,159–23,305)	Fir	17.1–22.3	(17,327–22,595)
Canadian waterweed	6.7	(6,789)	Fodder beets	11.3	(11,450)
Carrot	13.2–16.7	(13,375–16,921)	Gypsophila	15–70	(15,199–70,928)
Cattail	18.1–20.8	(18,340–21,076)			

Plant	Osmotic pressure atm	(hPa)	Plant	Osmotic pressure atm	(hPa)
Hellebore	23.8	(24,115)	Poplar	17.8	(18,036)
Holm oak	9.8–20.1	(9,930–20,366)	Potato	5.2–9.3	(5,269–9,423)
Ivy	12–25	(12,159–25,331)	Pumpkin	7.5–9.8	(7,599–9,930)
Larch	13.3–21.3	(13,476–21,582)	Rubber tree	7.9–9.9	(8,005–10,031)
Mangrove	30	(30,398)	Sod ( <i>Suaeda</i> )	130	(131,723)
Mistletoe	25–30	(25,331–30,398)	Sunflower	8.6–16.4	(8,714–16,617)
Oats	9.4–15.8	(9,525–16,009)	Tobacco	7.7–19.0	(7,802–19,252)
Onion	9.2–11.6	(9,322–11,754)	Tomato	9.5–14.4	(9,626–14,591)
Peach	25–35	(25,331–35,464)	Wheat	9.6–28.0	(9,727–28,371)
Pine	16.1	(16,313)	Wine grape	9.3–23.1	(9,423–23,406)

**Table 2.6.3: Osmotic Values in Plants**

Unless otherwise indicated, the figure given holds for the plant as a whole. For leaf data, see Table 2.6.2. Listed in ascending order.

After ALTMAN and DITTMER 1966, GESSNER 1942, MADLE 1967, WALTER 1962

Plant	Osmotic pressure atm	(hPa)
Hydrophytes	1 – 3	(1,013–3,040)
Succulents	5 – 7	(5,066–7,093)
Potato, tuber	7	(7,093)
Watermilfoil	8	(8,106)
Tomato, fruit	9	(9,119)
Helophytes (marsh plants)	9 –14	(9,119–14,186)
Potato, shoot	10	(10,133)
Cereal grains	10 –17	(10,133–17,225)
Pondweed	11	(11,146)
Alga ( <i>Spirogyra</i> )	11.1–12.4	(11,247–12,564)
Canadian waterweed	11.5	(11,652)
Lemon	14	(14,186)
Sugar beet, root	14 –21	(14,186–21,278)
Conifer, needles	16 –22	(16,212–22,292)
Apple, fruit	18 –23	(18,239–23,305)
Desert xerophytes	20 –40	(20,265–40,530)
Lilac, upper epidermis	23.4	(23,710)
Red alga ( <i>Ceramium</i> )	35 –37	(35,464–37,490)
Sea lettuce (Alga)	37 –46	(37,490–46,610)

(Cont.) →



Plant	Osmotic pressure	
	atm	(hPa)
Wine grape, fruit	38	(38,504)
Sargassum (brown algae)	39– 42	(39,517–42,557)
Sugar kelp ( <i>Laminaria</i> )	50– 55	(50,663–55,729)
Palmleaf cinquefoil	73.8	(74,778)
Wall germander	83	(84,100)
Halophytes	>100	(>101,325)

**Table 2.6.4: Acidity in the Pressed Juice of Fruits and Vegetables**

After SPECTOR 1956, WALTER 1962

Species	Acidity level	Species	Acidity level
Apple	pH 3.4	Orange. ripe	pH 3.8
Blackberry	pH 2.7	Orange. unripe	pH 2.9
Celery	pH 5.2	Pineapple	pH 4.4
Cowberry (lingonberry)	pH 2.4	Potato	pH 5.6
Grapefruit	pH 3.0	Rhubarb	pH 3.2
Lemon	pH 2.4	Tomato	pH 4.4
Onion	pH 4.3	Turnips	pH 5.8

**Table 2.6.5: Temperature Tolerances of Plants**

Temperature tolerances vary with adaptation temperature. Specimens from colder regions have a greater tolerance for low temperatures and a lesser tolerance for high ones. The reverse holds for specimens from warm regions. Values are also strongly dependent upon the water content of the given plant and upon the plant organ studied.

Data after various authors in ALTMAN and DITTMER 1973

Species	Minimum (°C)	Maximum (°C)
<b>Algae</b>		
Bladder wrack	– 20	41.9
<i>Chlamydomonas nivalis</i>	– 36	4
Marine red algae	– 2 up to + 3	32–35
<i>Oscillatoria filiformis</i>	59	83
Sea lettuce ( <i>Ulva</i> )	– 8	30

Species	Minimum (°C)	Maximum (°C)
Spirogyra	– 7	40
Sugar kelp	– 4	24
<b>Lichens</b>		
Lung lichen (“lungwort”)	– 196	73
Reindeer lichen	– 196	
<b>Mosses</b>		
<i>Bryum</i> sp.	– 7	42
<i>Frullania dilatata</i>		70–75
<i>Plagiothecium curvifolium</i>		60–75
<b>Ferns</b>		
Brackenfern (rhizome)	– 2.5	
Common polypody	– 18.1	48.5
Hart’s tongue fern	– 14.8	47.5
<b>Spermatophytes (seed-bearing plants)</b>		
Alder, buds	– 28	
Alder, leaves	– 3	
Ash, buds	– 27	
Ash, leaves	– 2	
Barley	– 15 up to – 10	
Canadian waterweed		39–39.5
Cross-leaved heath	– 20	50.5
European beech, buds	– 22	
European beech, leaves	– 2.5	
Field or hedge maple, buds	– 23	
Field or hedge maple, leaves	– 2.5	
Oats	– 12 up to – 9	
Rye	– 25 up to – 15	
Silver fir (summer)	– 4	46
Spruce (summer)	– 8 up to – 3.5	42.5
Spruce (winter)	– 38	40.5
Swiss pine (summer)	– 10	
Swiss pine (winter)	– 40	
Wheat	– 22 up to – 10	
Woodsorrel	– 11.5	40.5
Yew (summer)	– 4	50.5
Yew (winter)	– 40	47.5

### Table 2.6.6: Annual Levels of Evaporation of Selected Plants

For further figures on the evaporation levels of plants, see Tables 2.6.7 and 2.6.8. Figures represent averages.

After MADLE 1967

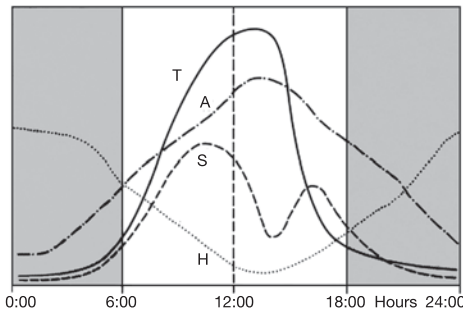
Plant	Annual evaporation level
1 corn (maize) plant	100–180 liters
1 ha grain	1.5–2.5 million liters
1 ha beech forest	3.6 million liters
1 ha spruce forest	3.2–3.9 million liters
1 ha pine forest	1.6–2.7 million liters

### Table 2.6.7: Transpiration Levels of Selected Plants

Transpiration values (cuticular + stomatal) in milligrams water per 100 cm<sup>2</sup> leaf surface area and hour. For figures on cuticular transpiration, see Table 2.6.8. Evaporation is dependent upon many external factors, such as temperature (T), soil moisture (SM), relative air humidity (RH), light, and wind levels. In so far as these values are known, they are provided here under “External conditions.”

Figures from ALTMAN and DITTMER 1974

Species	Water loss (mg per 100 cm <sup>2</sup> /h)	External conditions
Banana	1,100	T = 25 °C, RH = 32 %
Barley	958	SM = 15 %
Bean	450	T = 30 °C, RH = 35 %
Millet	42	T = 30 °C
Oats	1,542	SM = 15 %
Pineapple	140	T = 25 °C
Sunflower	576	T = 30 °C, RH = 35 %
Wheat	84	T = 30 °C
Wine grape	473	T = 20 °C



**Fig. 2.6.7:** Daily course of transpiration (schematic depiction) of a plant. See also Table 2.6.7. T = transpiration, A = air temperature, S = openness of stomata, H = humidity.

From SCHMEIL and SEYBOLD 1958

**Table 2.6.8: Cuticular Transpiration in Selected Plants**

Values obtained under standard conditions. Figures represent milligrams water per hour and per gram fresh weight. Listed in descending order of transpiration.

Figures from PISEK and BERGER 1938

Species	Cuticular transpiration (mg per h/g fresh weight)
Touch-me-not	130
Lungwort	71
Marsh marigold	56.5
Wood stitchwort ( <i>Stellaria nemorum</i> )	56
European speedwell	55
Hazel	47
Yellow woundwort	33.5
Crown vetch	33
Field bindweed	25
European white birch	25
European beech	25
Oak	24.5
Asarabacca (European wild ginger)	24
Alpine rose, rust-colored	7.25
Witch's moneybags ( <i>sedum telephium</i> )	5.1
Bearberry	5.0
Ivy	3.1
Spruce	1.58
Pine	1.53
Prickly pear cactus	0.12

**Table 2.6.9: Water Consumption for Selected Plants Required for Production of 1 Kg Plant Dry Matter (So-Called Transpiration Coefficient)**

For figures on evaporation, see also Tables 2.6.6 - 2.6.8.

After BERTELSMANN 1979, MADLE 1967, MENGEL 1968, WALTER 1962

Species	(liters)	Species	(liters)
Alfalfa	900	Red clover	700-800
Barley	530	Rye	400-700
Bean	625	Spruce	300
Beech	400	Sugar beet	400-440
Corn (maize)	300-400	Sunflower	570
Flax	780	Vegetables	800
Oats	400-600	Wheat	450-600
Pine	160	Wild mustard	910
Potato	300-600		

**Table 2.6.10: Hydraulic Conductivity of Selected Woods**

Figures represent the amount of water that can flow, per square centimeter, through a section of sprout under controlled experimental conditions (15-cm-long section, pressure of 30 mmHg). Since the experimental conditions do not correspond to natural ones, the resulting figures can only be compared in a relative sense. Presented in ascending order, according to amount. On vessel sizes, see also Table 2.2.2.

After FARNER 1918

Species	Hydraulic conductivity	Species	Hydraulic conductivity
Ruscus	1.0	Field or hedge maple	45.0
Mezereon	6.5	Apple	45.0
Tree heath	8.0	European spindle	47.0
Cherry laurel	10.0	Birch	51.0
Yew	12.0	Ivy	60.0
Larch	14.5	European beech	65.0
Scotch broom	25.0	Oak	75.0
Hazelnut	31.0	Eurasian aspen	81.0
Privet	37.0	Basket willow	95.0
Hawthorn	44.0		

**Table 2.6.11: Speed of Hydraulic Conductance in Selected Plants**

Speed is dependent upon the transverse diameter of the water vessels; here, see Table 2.2.2.

After GESSNER 1942, KAUSSMANN 1963, KREMER 1980, MEYER 1964, ZIEGLER 1977

Species	m/h	Species	m/h
Algae ( <i>Macrocystis</i> )	0.65–0.78	Willow	3.00
Horse chestnut	0.80	Tilia (linden, lime)	3.43
European beech	1.07	Walnut	4.12
European hornbeam	1.25	Elm	6.00
Conifers	1.50	Ash	25.70
Birch	1.60	Robinia	28.80
Alder	2.00	Oak	43.60
Maple	2.40	Lianas	150.00
Olive	2.40		

**Table 2.6.12: Respiration Rates of Selected Lower Plants (Thallophyta)**

Figures are in cubic millimeters of O<sub>2</sub> per gram and per hour of either dry or fresh weight. For the respiration rates of seed-bearing plants (spermatophytes), see Table 2.6.13; for that of bacteria and fungi, see Table 3.6.

Figures from ALTMAN and DITTMER 1974

Species	O <sub>2</sub> consumption/h and	
	per 1 g fresh weight	per 1 g dry weight
<b>Algae</b>		
Bladder wrack	200	
<i>Cladophora</i>	330	
Red alga ( <i>Delesseria</i> )		41
Sargassum		24
Sea lettuce ( <i>Ulva</i> )		810
Toothed wrack ( <i>Fucus serratus</i> )	190	
<b>Mosses</b>		
<i>Hypnum cupressiforme</i>	300	
Peat moss		71
<i>Riccia fluitans</i>	3,000	
<b>Lichens</b>		
Iceland moss		48
<i>Lobaria linita</i>		72
<i>Parmelia acetabulum</i>		31
Reindeer lichen		85

**Table 2.6.13: Respiration Rates of Selected Plants and Plant Parts**

Figures are in cubic millimeters of O<sub>2</sub> per gram and per hour of either dry or fresh weight. Figures are not always comparable to one another, since there is a strong dependence of the respiration rate upon the temperature, moisture content, and general condition of the plant. For figures on lower plants (thallophyta), see Table 2.6.12; for bacteria and fungi, see Table 3.6.

Data after ALTMAN and DITTMER 1974, STEWARD 1960, STILES and COCKING 1974

Species and organ	O <sub>2</sub> consumption/h and	
	Per 1 g fresh weight	Per 1 g dry weight
Apple, fruit	20– 35	
Barley, leaves	266	
Barley, seeds	0.06	0.05
Bean, entire plant	96.6	
Bean, leaf	260– 570	

(Cont.) →

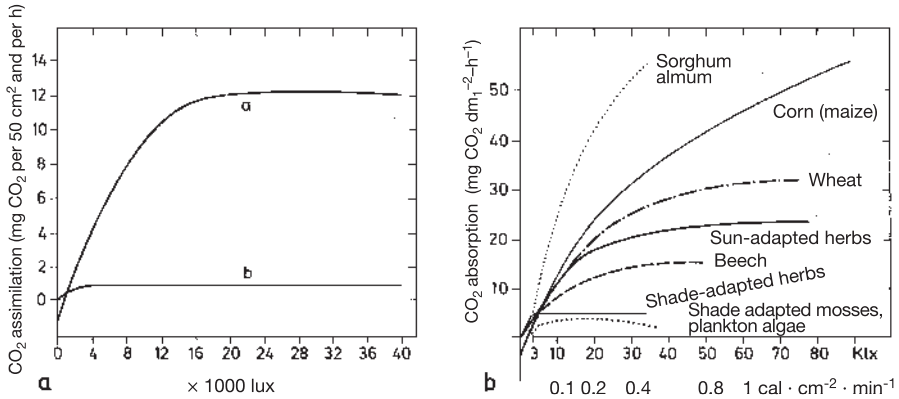
Species and organ	O <sub>2</sub> consumption/h and	
	Per 1 g fresh weight	Per 1 g dry weight
Beet ( <i>Beta vulgaris</i> ), root	9	
Canadian waterweed, shoot	900	
Carrot, root	25–30	
Carrot, young leaves	1,133	
Corn (maize), seeds		2.4
Cuckoopint, shoot	15,600–31,800	
Fir, shoot	250	
Flax, seeds		0.3
Lily, blossom		12,670
Oats, seeds		0.2
Onion, root	11,400	
Pea, leaf		4,300
Pineapple, fruit	30	
Potato, tuber	33	
Rye, seeds		0.02
Snowdrop, entire plant	77.6	
Spinach, leaf	620	
Spruce, entire plant	44.1	
Timothy grass, blade		1,240
Tobacco, entire plant	77	
Tobacco, leaf		3,300
Tomato, leaf		3,900
Tulip, blossom		3,000
Wheat, entire plant	291	
Wheat, seeds		0.05

**Table 2.6.14: Sugar and Starch Production in Photosynthesis**

Figures are per 1 m<sup>2</sup> leaf surface and per hour under optimal conditions

From MEYER 1964

Species	Result of photosynthesis	
	Sugar (g)	Starch (g)
Autumn crocus	1.217	
Cuckoopint	1.004	
Dock		2.215
Lauch	1.193	
Sunflower		1.823
Tobacco		1.378
Tulip	1.267	
Water lily		2.273



**Fig. 2.6.14:** Dependence of results of photosynthesis on leaves upon level of illumination. *a* Here *a* represents a white mustard sun leaf, and *b* represents a woodsorrel shade leaf. See also Table 2.6.14. From GUTTENBERG 1963, p. 503. *b* Dependence of net photosynthesis upon exposure to light in selected plants. From LARCHER 1976, p. 62

**Table 2.6.15: Annual Worldwide Photosynthesis Production and Carbon Exchange**

Figures from JENSEN and SALISBURY 1972, LIBBERT 1979

	Surface area (10 <sup>6</sup> km <sup>2</sup> )	Net annual primary production (10 <sup>12</sup> kg)	Annual production of organic carbon (10 <sup>12</sup> kg)	Annual consumption of CO <sub>2</sub> (10 <sup>12</sup> kg)	Annual energy storage (10 <sup>12</sup> kJ)
Oceans	361	55.00	25.0	92	1.0
Land, total	149	108.00	50.0	183	2.0
Rivers and lakes	2	1.00			
Swamps, moors	2	4.00			
Marshes					
Tropical forests	20	40.00			
Forests, mixed zones	18	23.40			
Taiga	12	9.60			
Brushland (macchias, dwarf pine region, and similar)	7	4.20			
Tropical savannahs	15	10.50			
Grasslands, mixed zones	9	4.50			
Tundra	8	1.10			
Deserts	18	1.30			

(Cont.) →



	Surface area ( $10^6$ km <sup>2</sup> )	Net annual primary production ( $10^{12}$ kg)	Annual production of organic carbon ( $10^{12}$ kg)	Annual consumption of CO <sub>2</sub> ( $10^{12}$ kg)	Annual energy storage ( $10^{12}$ kJ)
Rocks, ice	24	0.07			
Area under cultivation	14	9.10			
Earth as a whole	510	165	75	275	3.0

**Table 2.6.16: Speed of Rotation in Selected Twining Plants**

Figures represent the time it takes for a twining plant to complete a circle while making searching movements. Listed in descending order, according to time taken.

Data after KERNER v. MARILAUN 1896, STILES and COCKING 1969

Species	Hours per round
<i>Roxburghia viridifolia</i>	24
Bellflower ( <i>Lapageria rosea</i> )	14
Jasmine ( <i>Jasminum pauciflorum</i> )	7
Fern ( <i>Lygodium scandens</i> )	6
Glycine ( <i>Wistaria sinensis</i> )	3
<i>Ruscus androgynus</i>	3
Bryony ( <i>Tamus communis</i> )	3
Hops	2
Runner bean (scarlet runner)	2
Hedge false bindweed	2
Grape vine	1

**Table 2.6.17: Resting Potential of Plant Cells and Concentration of Potassium Ions in the Membrane (Plasmalemma)**

For figures on animal cells, see Tables 1.10.5 and 1.10.6.

Data from ALTMAN and DITTMER 1973

Species	Resting potential (mV)	K <sup>+</sup> ion concentration (mmol)	
		Outside cell	Inside cell
<i>Chara corallina</i>	– 140	0,2	120
<i>Enteromorpha intestinalis</i>	– 42	11,0	450
<i>Nitella translucens</i>	– 138	0,1	119
<i>Valonia ventricosa</i>	– 71	11,0	434
<i>Hydrodictyon africanum</i>	– 116	0,1	93

**Table 2.6.18: Conduction Velocity in Selected Plants**

For the corresponding figures in animals, see Table 1.10.7. On the production and generation of excitation in plants, see also STRASBURGER 1983.

Data after GESSNER 1942, STRASBURGER 1983

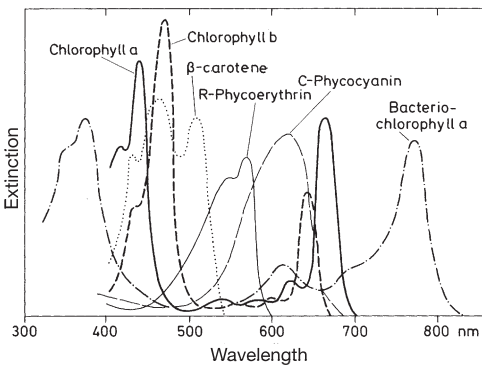
Species and organ	Conduction velocity
<i>Nitella</i> , internodal cell	2.3 cm/s
Mimosa, primary petiole	0.4– 3 cm/s
	max. 10 cm/s
Venus flytrap, leaf	6–20 cm/s
Waterwheel plant ( <i>Aldrovanda</i> ), leaf	6–20 cm/s

**Table 2.6.19: Absorption Maxima of Plant Pigments**

Figures represent wavelengths measured in nanometers. Since absorption is also dependent on the solvent used, it is also provided. The wavelength with the main absorption is underlined.

Data after SPECTOR 1956

Pigment	Absorption maxima (nm)	Solvent
Phycoerythrin	576	Acidic $\text{CHCl}_3$
Phycocyanin	630	Acidic $\text{CHCl}_3$
Beta-carotene	497, 466	Chloroform
Xanthophyll	487, 456, 428	Chloroform
Flavone	298, 250	Ethanol
Chlorophyll a	<u>660</u> , 617, 575, 430, 410	Ether
Chlorophyll b	<u>640</u> , 595, 535, <u>455</u>	Ether
Chlorophyll c	<u>627</u> , <u>597.5</u> , 545, 446	Ether
Chlorophyll d	<u>686</u> , 645, 595, 545, <u>445</u> , 390	Ether
Protochlorophyll	<u>623</u> , 571, 535, 432	Ether



**Fig. 2.6.19:** Absorption spectra of several important biological pigments. After LIBBERT. From STRASBURGER 1983, p. 233

## Part 3: Microbiology

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**Table 3.1: Size and Structure of Viruses**

The term virion is the more recent designation for an infective viral particle; capsomer refers to the morphological subunit that builds the capsule that envelops the nucleic acid. The virus that triggers AIDS is one of the retroviruses. For data on the size of bacteria, see Table 3.2.

Data after GRAFE 1977, LASKIN and LECHEVALIER 1973, OTTE and BRANDIS 1978, RIESNER 1979, WEIDE and AURICH 1979

Virus group	Diameter of virion (nm)	Capsomers ( <i>n</i> )	Molecular weight of the genome ( $\times 10^6$ )
Adenoviruses	70– 90	252	20 – 30
Arenaviruses	50–300		3.2– 5.6
Bacteriophage $\lambda$	54		33
Coronaviruses	80–160		9
Herpesviruses	160–200	162	92 –102
Iridoviruses	130		130
Orthomyxoviruses (influenza viruses)	80–120		6
Papovaviruses	45– 55	72	3 – 5
Paramyxoviruses	150–300		5 – 8
Parvoviruses	16– 26	32 ?	1.5– 2.2
Picornaviruses	20– 30	32 ?	2.5
Pox viruses	170–260 $\times$ 300–450		130 –240
Reoviruses	60– 80	92 ?	15
Retroviruses	80–120		7 – 10
Rhabdoviruses	70 $\times$ 130 –300		3.5– 4.5
Togaviruses	40– 70	32	3 – 4
Viroid	40 $\times$ ? 2		0.12

**Table 3.2: Dimensions of Bacteria**

For data on viruses, see Table 3.1.

Data after KUNSTYR et al. 1988, OTTE and BRANDIS 1978, SCHLEGEL 1976

Species	Length ( $\mu\text{m}$ )	Width ( $\mu\text{m}$ )
<i>Bacillus anthracis</i>	3.0–10.0	1.0–1.5
<i>Bacillus megatherium</i>	5.0	2.0
<i>Bordetella pertussis</i>	0.5– 1.0	0.3–0.5
<i>Brucella</i> spp.	0.6– 1.5	0.5–0.7
<i>Corynebacterium diphtheriae</i>	0.2	
<i>Clostridium botulinum</i>	2.0–10.0	0.5–1.0
<i>Clostridium tetani</i>	2.4– 5.0	0.5–1.1

(Cont.) →

Species	Length ( $\mu\text{m}$ )	Width ( $\mu\text{m}$ )
Enterobacteria	2.0– 3.0	0.5–1.0
<i>Francisella tularensis</i>	0.2– 0.7	
<i>Haemophilus influenzae</i>	0.3– 0.5	
Leptospire	7.0– 25.0	0.12
<i>Leptotricha buccalis</i>	5.0– 15.0	1.0–1.5
<i>Metabacterium criceti</i>	20.0	4.0
<i>Micrococcus</i>	0.2	
<i>Mycobacterium tuberculosis</i>	3.0	0.4
Mycoplasmas	0.3– 0.8	
<i>Neisseria gonorrhoeae</i>	0.8	
<i>Pseudomonas</i> spp.	0.5– 1.0	1.5–4.0
Rickettsia	1.0– 2.0	0.3–0.7
Spirochetes	30.0–500.0	
<i>Staphylococcus</i>	0.8– 1.0	
<i>Streptococcus pneumoniae</i>	0.8– 1.0	
<i>Vibrio cholerae</i>	1.5– 3.0	0.5

**Table 3.3: Generation Time of Selected Bacteria**

Generation time in bacteria represents the time interval from one cell division to the next. Since it is heavily dependent upon temperature, the table also gives the latter. The in part very large ranges result from the fact that generation time can be dependent upon the given culture medium.

Data after ALTMAN and DITTMER 1972, SPECTOR 1956

Bacterial species	Temperature ( $^{\circ}\text{C}$ )	Generation time (min)
<i>Bacillus cereus</i>	37	18.8
<i>Bacillus subtilis</i>	36	35
<i>Clostridium botulinum</i>	37	35
<i>Diplococcus pneumoniae</i> , Type I	37	20.5–29
<i>Diplococcus pneumoniae</i> , Type II	37	23.0–33
<i>Escherichia coli</i>	37	12.5–17
<i>Lactobacillus acidophilus</i>	37	60.0–87
<i>Proteus vulgaris</i>	37	21.5–46
<i>Pseudomonas aeruginosa</i>	37	31.0–34
<i>Rhizobium leguminosarum</i>	25	79.0–187
<i>Salmonella typhimurum</i>	37	24.0–35
<i>Salmonella typhosa</i>	37	23.5–33
<i>Serratia marcescens</i>	35	28
<i>Staphylococcus aureus</i>	37	27.0–32
<i>Streptococcus lactis</i>	37	26.0–37
<i>Vibrio cholerae</i>	37	21.2–38

**Table 3.4: pH Ranges for the Growth of Bacteria and Fungi**

Figures from THIMANN 1964

	Optimum	Minimum	Maximum
<b>Bacteria, cocci</b>			
<i>Diplococcus pneumoniae</i>	7.8	7.0	8.3
<i>Neisseria meningitidis</i>	7.4	6.1	7.8
<i>Neisseria gonorrhoeae</i>	7.3	5.8	8.3
<i>Streptococcus pyogenes</i>	7.8	4.5	9.2
<b>Bacteria, rods</b>			
<i>Agrobacterium tumefaciens</i>		5.7	9.2
<i>Azotobacter chroococcum</i>	7.4–7.6	5.8	
<i>Bacillus subtilis</i>	6.0–7.5	4.5	8.5
<i>Clostridium tetanis</i>	7.0–7.6	5.5	8.3
<i>Escherichia coli</i>	6.0–7.0	4.3	9.5
<i>Mycobacterium tuberculosis</i>	6.8–7.7	5.0	8.4
<i>Pasteurella pestis</i>	6.2–7.0	5.0	8.2
<i>Proteus vulgaris</i>	6.5	4.4	9.2
<i>Salmonella paratyphosum</i>	6.2–7.2	4.0	9.6
<i>Salmonella thyphosum</i>	6.8–7.2	4.0	9.6
<i>Serratia marcescens</i>	6.0–7.0	4.6	8.0
<i>Vibrio cholerae</i>	7.0–7.4	5.6	9.6
<b>Fungi</b>			
<i>Fusarium oxysporium</i>		1.8	11.1
<i>Mucor glomerula</i>		3.2	9.2
<i>Penicillium variabile</i>		1.9	9.3
<i>Pilobulus kleinii</i>		6.2	10.1
<i>Saccharomyces cerevisiae</i>	4.0–5.0	2.4	

**Table 3.5: Lethal Temperatures for Selected Microorganisms**

Temperature values are accompanied by figures for the time required to kill the respective organism. For data on viruses, see Table 3.6.

Figures from ALTMAN and DITTMER 1973, SCHLEGEL 1976

Microorganism	Lethal temperature (°C)	Time required (min)
<b>Bacteria</b>		
<i>Aerobacter aerogenes</i>	55	30
<i>Bacillus anthracis</i> , vegetative form	60	30

(Cont.) →

Microorganism	Lethal temperature (°C)	Time required (min)
<i>Bacillus anthracis</i> , spores	100	5–10
<i>Bacillus subtilis</i> , veg. form	95	36
<i>Bacillus subtilis</i> , spores	100	15–20
<i>Clostridium botulinum</i> , spores	120	5
<i>Clostridium tetani</i> , veg. form	105	3–25
<i>Clostridium tetani</i> , spores	105	3–25
<i>Diplococcus pneumoniae</i>	55	20
<i>Escherichia coli</i>	60	15
<i>Lactobacillus thermophilus</i>	71	30
<i>Mycobacterium tuberculosis</i>	60	15
<i>Neisseria gonorrhoeae</i>	55	<5
<i>Neisseria meningitidis</i>	55	<5
<i>Pseudomonas aeruginosa</i>	55	60
<i>Salmonella typhi</i>	60	4.3
<i>Staphylococcus aureus</i>	60	10
<i>Streptococcus pyogenes</i>	55	30
<i>Vibrio cholerae</i>	55	15
<b>Fungi</b>		
<i>Aspergillus niger</i> , spores	55	30
<i>Candida albicans</i>	60	10
<i>Fusarium</i> sp.	55	10
<i>Monilia fruticola</i> , spores	52	2–3
<i>Mucor</i> sp.	57.5	30
<i>Penicillium</i> sp.	50–60	30
<i>Saccharomyces cerevisiae</i>	68	30

**Table 3.6: Inactivation Temperatures and Times for Selected Viruses**

For the corresponding figures for bacteria and fungi, see Table 3.5.

Data after GRAFE 1977

Virus	Inactivation temperature (°C)	Inactivation time (min)
Adenoviruses	50	20
Avian flu virus	60	10
Foot-and-mouth disease virus	56	30
Herpes simplex virus	50	30
Influenza virus	56	30



Virus	Inactivation temperature (°C)	Inactivation time (min)
Mumps virus	55	20
Parnoviruses	56	60
Poliomyelitis virus	50	30
Yellow fever virus	60	10

**Table 3.7: Respiration Rate of Selected Bacteria and Fungi**

Figures given in cubic millimeters O<sub>2</sub> per milligram dry weight and per hour. For data on the respiration rates of lower plants, see Table 2.6.12 and for those of seed-bearing plants, see Table 2.6.13.

Figures from ALTMAN and DITTMER 1974

Species	O <sub>2</sub> consumption (mm <sup>3</sup> O <sub>2</sub> /mg per h)
<b>Bacteria</b>	
<i>Azotobacter chroococcum</i>	2,000
<i>Bacillus subtilis</i>	170
<i>Escherichia coli</i>	272
<i>Lactobacillus bulgaricus</i>	
<i>Leuconostoc</i> sp.	8
<i>Micrococcus aurantiacus</i>	14
<i>Mycobacterium tuberculosis</i>	4
<i>Neisseria meningitidis</i>	56
<i>Pseudomonas aeruginosa</i>	26
<i>Sarcina lutea</i>	18.3
<i>Streptococcus pneumoniae</i>	27
<i>Streptococcus pyogenes</i>	57–63
<b>Fungi</b>	
<i>Aspergillus niger</i>	2.99
<i>Candida albicans</i>	29
<i>Fusarium graminearum</i>	13.6
<i>Monilia fruticola</i>	3.21
<i>Neurospora crassa</i>	29.6
<i>Penicillium</i>	6.5
<i>Puccinia graminis</i>	3
<i>Saccharomyces cerevisiae</i>	47
<i>Saprolegnia</i>	0.75

**Table 3.8: Incubation Times of Several Important Infectious Diseases**Figures from GRAFE 1977, *Lexikon der Biologie*, OTTE and BRANDIS 1978, SIEWING 1985

Disease	Incubation times
AIDS	2 weeks – 6 years
Amoebic dysentery	1 day – 4 weeks
Anthrax	2– 3 days
Chicken pox	11–21 days
Cholera	1– 5 days
Diphtheria	2– 5 days
Dysentery (shigellosis)	2– 7 days
Epidemic hepatitis	1– 7 weeks
German measles (rubella)	14–21 days
Gonorrhoea	1– 2 days
Herpes zoster (shingles)	2– 3 weeks
Influenza	1– 3 days
Leprosy	9 months to several years
Malaria ( <i>M. tropica</i> )	7–12 days
Measles	9–14 days
Mumps	18–21 days
Pertussis (whooping cough)	8–15 days
Poliomyelitis	7–14 days
Rabies	20–60 days
Scarlet fever	2– 7 days
Smallpox	5–14 days
Syphilis	14–21 days
Tetanus	4–14 days
Typhus	5–21 days
Typhus	1– 3 days
Yellow fever	3– 6 days

## Part 4: Human Biology

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Isolated data pertaining to humans can also be found in most of the tables in Part I, Zoology. More comprehensive data can also be gained from the follow-on volume: KUNSCH and KUNSCH (2001) *Der Mensch in Zahlen*

## 4.1 General Data

**Table 4.1.0: Numbers that Amaze**

This table brings together some interesting numbers on humans, which are cited again in the individual tables below, where they are accompanied by references to the literature.

Number of cells	in the skin	110,000,000,000
	per cm <sup>2</sup>	6,000,000
	in the brain	14,000,000,000
Number of mucous membrane cells	in the small intestine	200,000,000,000
Number of hairs on a blonde person	on the head	150,000
	+ body hair	25,000
Number of perspiratory glands in total	on the skin	1,800,000
	per cm <sup>2</sup>	100
Number of heart beats	in 70 years	3,000,000,000
Amount of blood conveyed	in 70 years	250,000,000 liters
Length of the blood capillaries	in total	1,200 km
Number of alveoli	in the lung	850,000,000
Length of capillaries	in the alveoli	13 km
Number of salivary glands in total	in the mouth	6,000,000
Number of intestinal villi	in the small intestine	7,000,000
Number of renal corpuscles (glomeruli)		2,000,000
Length of the loops of Henle	in total	100 km
Number of synapses	in the brain	1,000,000,000,000
Length of nerve fibers in total	in the cerebrum	500,000 km
Number of retinal cones	in the eye	7,000,000
Number of retinal rods	in the eye	125,000,000
Number of hair cells on the basilar membrane	in the ear	14,000

**Table 4.1.1: Life Span of Cells in Selected Organs of the Human Body**

Data after KLIMA 1967, RUCKER 1967

Organ	Average life span (days)
Stomach (pylorus)	1.8– 1.9
Stomach (cardia)	9.1
Small intestine	1.3– 1.6
Liver	10.0– 20.0
Large intestine	10.0
Rectum	6.2
Anus	4.3
Trachea	47.5
Lungs (alveoli)	8.1
White blood cells	1.0– 3.0
Red blood cells	120.0
Bladder	64.0
Epidermis	
Lips	14.7
Soles	19.1
Abdominal skin	19.4
Ear	34.5
Nervous system	No regeneration

**Table 4.1.2: DNA and RNA Contents of Selected Human Cells**

Figures in picograms (1 pg = 1 trillionth of a gram = 0.000 000 001 g) per cell. For comparative figures for animals, see Table 5.11.

Figures from ALTMAN and DITTMER 1972

Cell	DNA (pg/cell)	RNA (pg/cell)
Bone marrow	0.87	0.69
Brain	0.68	2.63
Kidney	0.83	1.10
Liver	1.0	2.48
Leukocytes	0.73	0.25
Sperm	0.31	0.24

**Table 4.1.3: Composition of the Human Body from the Elements**

Figures refer to a human weighing 70 kg. For comparable figures for plants and animals, see Table 5.1.

After HEIDERMANNS 1957, KLEIBER 1967

Element	As approx. percentage of total weight (%)	Approx. weight
Oxygen (O)	63	44 kg
Carbon (C)	20	14 kg
Hydrogen (H)	10	7 kg
Nitrogen (N)	3	2.1 kg
Calcium (Ca)	1.5	1 kg
Phosphorus (P)	1	0.7 kg
Potassium (K)	0.25	170 g
Sulphur (S)	0.2	140 g
Chlorine (Cl)	0.1	70 g
Sodium (Na)	0.1	70 g
Magnesium (Mg)	0.04	30 g
Iron (Fe)	0.004	3 g
Copper (Cu)	0.0005	300 mg
Manganese (Mn)	0.0002	100 mg
Iodine (I)	0.00004	30 mg

**Table 4.1.4: Composition of the Body of an Adult Human**

For composition in terms of the chemical elements, see Table 4.1.3; a comparison between men and women is found in Table 4.1.5.

Figures after MITCHELL 1945

	Relative body weight (%)	Water (%)	Fat (%)	Protein (%)	Ash (%)
Skin	7.81	64.68	13.00	22.10	0.68
Skeleton	14.84	31.81	17.18	18.93	28.91
Teeth	0.06	5.00	0.00	23.00	70.90
Striated musculature	31.56	79.52	3.35	16.50	0.93
Brain, bone marrow	2.52	73.33	12.68	12.06	1.37
Liver	3.41	71.46	10.35	16.19	0.88
Heart	0.69	73.69	9.26	15.88	0.80
Lungs	4.15	83.74	1.54	13.38	0.95
Spleen	0.19	78.69	1.19	17.81	1.13
Kidneys	0.51	79.47	4.01	14.69	0.96

(Cont.) →

	Relative body weight (%)	Water (%)	Fat (%)	Protein (%)	Ash (%)
Pancreas	0.16	73.08	13.08	12.69	0.93
Intestine	2.07	79.07	6.24	13.19	0.86
Adipose tissue	13.63	50.09	42.44	7.06	0.51
All other tissue	13.63	70.40	12.39	16.06	1.01
Blood, lymph	3.79	93.33	0.17	5.68	0.94
Total		67.85	12.51	14.39	4.84

**Table 4.1.5: Relative Share of Individual Tissues in Body Composition of Men and Women**

From SCHWIDETZKY 1965

	♀ (%)	♂ (%)
Musculature	35.8	41.8
Fat	28.2	18.2
Skeleton	15.1	15.9
Glands and remaining tissue	20.9	24.1

**Table 4.1.6: Growth of the Human Embryo During Pregnancy**

Figures from *Documenta Geigy* 1975, LACHMANN 1976, MEYER 1964

Age	Somites (n)	Length (Crown/ rump)	Length (Crown/ heel)	Weight (g)
20 days	1–4			
21 days	4–7	2 mm		
22 days	7–10			
23 days	10–13			
24 days	13–17			
25 days	17–20			
26 days	20–23			
27 days	23–26	4 mm		
28 days	26–29			0.02 g
30 days	34–35			

Age	Somites (n)	Length (Crown/ rump)	Length (Crown/ heel)	Weight (g)
35 days	42-44	5-8 mm		
6 weeks		10-14 mm		
7 weeks		17-22 mm	1.9 cm	
8 weeks		28-30 mm	3.0 cm	1 g
12 weeks		5.6 cm	7.3 cm	14 g
16 weeks		11.2 cm	15.7 cm	105 g
20 weeks		16.0 cm	23.9 cm	310 g
24 weeks		20.3 cm	29.6 cm	640 g
28 weeks		24.2 cm	35.5 cm	1,080 g
32 weeks		27.7 cm	40.9 cm	1,670 g
36 weeks		31.3 cm	45.8 cm	2,400 g
40 weeks (birth)		35.0 cm	50.0 cm	3,300 g

**Table 4.1.7: Normal Growth of Boys and Girls**

Figures given for height and weight. Numbers represent the range covering 80% of all individuals. The shortest documented adult was Pauline Musters, at a height of 0.48 m; the tallest was R.P. Wadlow, at 2.72 m.

Figures from *Documenta Geigy* 1975, SCHMIDT 1984

Age	Boys		Girls	
	Height (cm)	Weight (kg)	Height (cm)	Weight (kg)
Birth	49.0- 52.5	2.80- 3.90	47.0- 52.0	2.70- 3.96
1 month	52.5- 56.8	3.57- 4.58	51.4- 55.5	3.44- 4.42
3 months	59.0- 63.2	5.40- 6.66	58.0- 61.6	4.89- 6.23
6 months	65.1- 71.3	7.00- 8.77	64.0- 69.3	6.53- 8.27
9 months	71.0- 75.0	8.30-10.36	68.6- 73.5	7.62- 9.71
1 year	73.4- 79.0	9.71-11.13	72.0- 77.0	8.40-11.05
18 months	79.9- 86.0	10.36-12.91	78.5- 85.0	10.15-12.42
2 years	81.7- 92.3	9.70-15.10	81.4- 91.6	10.10-13.70
3 years	91.0-101.6	11.90-17.30	89.6-100.8	11.70-16.90
4 years	97.9-109.1	14.00-19.40	96.5-108.1	13.30-19.30
5 years	104.2-116.2	16.10-21.70	103.5-114.9	15.20-21.40
6 years	110.2-122.8	18.00-24.00	109.4-122.4	16.80-24.40
7 years	115.8-129.0	19.80-26.60	115.3-129.5	18.40-28.60
8 years	121.3-134.7	20.80-29.80	121.7-134.7	20.70-32.70
9 years	126.7-139.9	21.70-33.30	126.5-139.9	22.60-35.00
10 years	131.2-145.4	23.50-37.50	130.2-144.8	24.80-38.20

(Cont.) →



Age	Boys		Girls	
	Height (cm)	Weight (kg)	Height (cm)	Weight (kg)
11 years	134.9–150.5	27.10–42.90	133.4–150.2	26.40–43.20
12 years	138.2–155.8	30.60–48.40	138.7–158.3	29.40–48.60
13 years	143.3–163.5	34.20–54.00	144.8–163.4	33.60–55.00
14 years	150.2–171.0	38.30–58.90	150.8–165.6	39.40–60.80
15 years	157.1–176.5	42.50–63.70	153.8–168.4	44.30–62.10
16 years	163.3–180.1	47.40–68.00	155.3–170.5	46.40–63.80
17 years	166.7–181.9	52.10–69.50	155.8–171.8	47.70–65.30

**Table 4.1.8: Number of Bones in the Human Body**

After BERTELSMANN 1979, MEYER 1964, RUCKER 1967

Skull	25
Spine	34
Rib cage	25
Shoulder girdle	4
Upper arm	2
Forearm	4
Carpal (wrist) bones	16
Metacarpal bones	10
Fingers	28
Pelvis	6
Thigh	2
Lower leg	4
Tarsal bones	14
Metatarsal bones	10
Toes	28
<b>Total</b>	<b>212</b>

**Table 4.1.9: Dimensions and Weight of Selected Human Organs**

Figures represent mean values.

Data after BERTELSMANN 1979, MEYER 1964, RUCKER 1967

	Length	Width	Circumference	Weight
Heart	15 cm	9 cm	25 cm	300 g
Lung	25 cm			1,100–1,200 g
Stomach (empty)	25–35 cm	12–15 cm		300 g
Liver	30–35 cm	20–25 cm		1,200–1,700 g
Pancreas	12–15 cm	8–9 cm		70–80 g
Kidney	10–12 cm	6–7 cm		120–160 g
Brain				1,200–1,500 g
Eyeball	2.4 cm	2.4 cm	7.4 cm	7.4 g

**Table 4.1.10: Specific Weight of Selected Human Organs**

Figures from OPPENHEIMER and PINCUSSEN 1925

Organ	Specific weight
Bone	1.936
Spongiosa	1.825–1.901
Musculature	1.058
Nerves	1.035
Brain and bone marrow	1.03
Liver	1.05
Kidney	1.05
Adipose tissue	0.924–0.932
Human as a whole	1.027–1.059

**Table 4.1.11: Water Content of Human Organs and Tissue**

After ALTMAN and DITTMER 1973, BERTELSMANN 1979, HEIDERMANNS 1957, MITCHELL et al. 1945

Organ/Tissue	Water content (%)
Brain	77
White matter	70
Gray matter	84
Bone marrow	71
Peripheral nerve	66
Striated muscle	79.5
Skin	64.7

(Cont.) →

Organ/Tissue	Water content (%)
Hair	4.1
Bone	43.9–55
Tooth, overall	9.2
Dental enamel	2.8
Dentin	11.1
Cartilage	75
Elastic tissue	50
Adipose tissue	15
Liver	71.5
Kidney	79.5
Heart	73.7
Spleen	78.7
Lung	83.7
Digestive tract	79.1
Uterus	79.9
Blood	80
Blood cells	65
Lens of the eye	67.6
Sclera	65
Vitreous humor	99
Cornea	75–80

**Table 4.1.12: Temperature of Selected Organs and Parts of the Human Body**

After BERTELSMANN 1979, MEYER 1964

Lung	35.2–35.6 °C
Oral cavity	36.5 °C
Auditory canal	36.7 °C
Superior vena cava	36.8 °C
Armpit (axilla)	36.9 °C
Stomach	37.0–37.3 °C
Rectum	37.2 °C
Gluteus muscle	37.7 °C
Inferior vena cava	38.1 °C
Pectoralis major	38.3 °C
Left atrium	38.6 °C
Aorta	38.7 °C
Right atrium	38.8 °C
Liver	41.3 °C

**Table 4.1.13: pH-Values of Human Bodily Fluids**

Figures represent mean values.

Figures from *Dokumenta Geigy* 1975

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Cerebrospinal fluid	7.349
Synovial fluid (knee joint)	7.434
Arterial blood (adult)	7.39
Venous blood (adult)	7.398
Lymph	7.4
Saliva	6.4
Gastric juice, men	1.92
Gastric juice, women	2.59
Bile	7.15–7.5
Feces	7.15
Urine	5.7–5.8
Sweat	4–6.8
Sperm	7.19

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## 4.2 Skin, Skin Adnexa (Hair, Nails, Glands)

**Table 4.2.1: Human Skin in Numbers**

Figures from BERTELSMANN 1979, *Documenta Geigy* 1975, MEYER 1964, RUCKER 1967

Surface area	1.8 m <sup>2</sup>
Thickness	up to 9 mm
Weight	5.5 kg
Number of cells	110,000,000,000 (= 6,000,000 per cm <sup>2</sup> )
Number of sebaceous glands	250,000 (= 15 per cm <sup>2</sup> )
Number of perspiratory glands	1,800,000 (= 100 per cm <sup>2</sup> )
Number of Ruffini's corpuscles (heat)	40,000
Number of Krause's end bulbs (cold)	240,000
Number of Vater-Pacini corpuscles (pressure, vibration)	40,000
Number of Meißner's tactile corpuscles	500,000
Number of Merkel's disks (touch)	60,000,000
Number of free nerve endings	4,000,000

**Table 4.2.2: Number of Human Hairs**

For the distribution of hair across the body, see Table 4.2.3.

After BERTELSMANN 1979, MEYER 1964, RUCKER 1967

	Hairs, approx. ( <i>n</i> )
1. Head hair	
A blonde person has	150,000
A brown-haired person has	110,000
A black-haired person has	100,000
A red-haired person has	90,000
In addition, all have	
2. Body hairs	25,000
3. Eyelashes	420
4. Eyebrows	600

**Table 4.2.3: Number of Hairs per cm<sup>2</sup> on Various Parts of the Body**

Values from BERTELSMANN 1979, MEYER 1964, OPPENHEIMER and PINCUSSEN 1925

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At the part in the hair	300–320
Back of the head	200–240
Forehead	200–240
Chin	44
Breast	9
Mons pubis	30–35
Forearm	24
Back of the hand	18
Upper arm	16
Thigh	15
Kneecap	22
Lower leg, calf	9

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**Table 4.2.4: Hair Diameters (Averages) in an Adult Male**

Figures from OPPENHEIMER and PINCUSSEN 1925

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Head hairs, overall	0.071 mm
Temples	0.066 mm
Crown of the head	0.067 mm
Forehead	0.069 mm
At the part in the hair	0.075 mm
Back of the neck	0.056 mm
Mustache	0.115 mm
Cheek whiskers	0.104 mm
Chin whiskers	0.125 mm
Eyebrows	0.080 mm
Eyelashes	0.076 mm
Tactile hairs	0.056 mm
Underarm hairs	0.077 mm
Pubic hairs	0.121 mm

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**Table 4.2.5: Speed of Hair and Nail Growth**

Data after ALTMAN and DITTMER 1972, BERTELSMANN 1979

Head hair	0.35	mm/day
Facial hair	2.1–3.5	mm/week
Eyebrows	0.16	mm/day
Underarm hair	0.3	mm/day
Arm hair	1.5	mm/week
Thigh hair	0.2	mm/day
Fingernails	0.086	mm/day
Thumbnail	0.095	mm/day
Toenail	0.004	mm/day
Nail of the big toe	0.006	mm/day

**Table 4.2.6: Number of Perspiratory Glands**

Figures represent the number of glands per square centimeter of skin surface in different parts of the body. Overall, there are approximately 1.8 million perspiratory glands in the body.

From *Documenta Geigy* 1975, MEYER 1964

	Number/cm <sup>2</sup>
Back	55
Buttocks	55
Cheeks	75
Leg	80
Top of the foot	125
Forearm (top)	150
Abdomen	155
Breast	155
Forearm (underside)	160
Forehead	170
Throat	185
Back of the hand	200
Sole of the foot	350–400
Palm of the hand	375–425
Elbow	750





**Table 4.3.3: Dimensions of the Human Blood Vessel System**

From REIN and SCHNEIDER 1971, supplemented

Arteries	Number	Length (cm)	Total length	Diameter (mm)	Total cross-section (cm <sup>2</sup> )	Total surface area (cm <sup>2</sup> )	Total volume (cm <sup>3</sup> )
Aorta	1	40	40 cm	10	0.8	126	30
Major arteries	40	20	8 m	3	3.0	754	60
First-order arterial branches	600	10	60 m	1	5.0	1,884	50
Second-order arterial branches	1,800	1	18 m	0.6	5.0	339	5
Arterioles	40,000,000	0.2	80 km	0.02	125	50,240	25
Capillaries	1,200,000,000	0.1	1,200 km	0.008	600	301,440	60
Venules	80,000,000	0.2	160 km	0.03	570	150,720	110
Second-order venous branches	1,800	1	18 m	1.5	30	848	30
First-order venous branches	600	10	60 m	2.4	27	4,522	270
Major veins	40	20	8 m	6.0	11	1,507	220
Vena cava	1	40	40 cm	12.5	1.2	157	50

**Table 4.3.4: Diameter of the Arteries of an Adult Human**

Data after OPPENHEIMER and PINCUSSEN 1925

Arteria pulmonalis	24 mm
Aorta ascendens	22.4 mm
Aorta renalis	13.3 mm
Carotis communis dexter	6.7 mm
Subclavia dextra	6.2 mm
Femoralis dextra	6.2 mm
Renalis dextra	5.3 mm
Capillaries	8 $\mu$ m

**Table 4.3.5: Blood Pressure at Different Points in the Human Circulatory System**

Figures in millimeters of mercury (mmHg) and, in parentheses, in hectopascals (hPa). For data on blood pressure in animals, see Table 1.6.4.

After REIN and SCHNEIDER 1971

	Systole	Diastole
Aortic root	110 (147)	80 (107)
Aorta descendens	115 (153)	75 (100)
Arteria iliaca	120 (160)	70 (93)
Arteria brachialis	110 (147)	80 (107)
Arterioles	70–30 (93–40)	
Capillaries	30–15 (40–20)	
Veins	15– 0 (20– 0)	

**Table 4.3.6: Age and Sex Dependency of Blood Pressure in Humans**

Figures are mean values in millimeters of mercury (mmHg) and, in parentheses, in hectopascals (hPa).

From *Documenta Geigy* 1975, modified

Age (years)	Females		Males	
	Systolic	Diastolic	Systolic	Diastolic
1	95 (127)	65 (87)	96 (128)	66 (88)
2	92 (123)	60 (80)	99 (132)	64 (85)
3	100 (133)	64 (85)	100 (133)	67 (88)
5	92 (123)	62 (83)	92 (123)	62 (83)

(Cont.) →

Age (years)	Females		Males	
	Systolic	Diastolic	Systolic	Diastolic
10	103 (137)	70 (93)	103 (137)	69 (92)
12	106 (141)	72 (96)	106 (141)	71 (95)
15	112 (149)	76 (101)	112 (149)	75 (100)
20–24	116 (155)	72 (96)	123 (164)	76 (101)
25–29	117 (156)	74 (99)	125 (167)	78 (104)
30–34	120 (160)	75 (100)	126 (168)	79 (105)
35–39	124 (165)	78 (104)	127 (169)	80 (107)
40–44	127 (169)	80 (107)	129 (172)	81 (108)
45–49	131 (175)	82 (109)	130 (173)	82 (109)
50–54	137 (183)	84 (112)	135 (180)	83 (111)
55–59	139 (185)	84 (112)	138 (184)	84 (112)
60–64	144 (192)	85 (113)	142 (189)	85 (113)
65–69	154 (205)	85 (113)	143 (191)	83 (111)
70–74	159 (212)	85 (113)	145 (193)	82 (109)
75–79	158 (211)	84 (112)	146 (195)	81 (108)
80–84	157 (210)	83 (111)	145 (193)	82 (109)
85–89	154 (205)	82 (109)	145 (193)	79 (105)
90–94	150 (200)	79 (105)	145 (193)	78 (104)

**Table 4.3.7: Blood Flow Through Selected Human Organs**

Values represent cubic centimeters of blood per minute and per 100 g organ weight. See also Table 4.3.8.

Values from HEIDERMANNS 1957, KOLB 1974

Brain	138
Skeletal muscles (at rest)	13
Skeletal muscles (working)	85
Thyroid gland	591
Kidney	150
Adrenal gland	700
Liver	26
Intestine	31

**Table 4.3.8: Proportional Blood Flow Through Selected Human Organs**

Figures represent the proportion (%) of the heart minute volume flowing through the given organ. See also Table 4.3.7.

Figures from BAUER et al. 1977

Organ	(%)
Lung	100
Heart	100
Heart arteries	5
Brain	15
Musculature	15
Liver and intestine	35
Kidneys	20
Skin and skeleton	10

**Table 4.3.9: Composition of Human Blood**

From *Enzyklopädie* 1979

	Quantity per 100 cm <sup>3</sup> blood	Quantity per 100 g erythrocytes
Water	81 g	63 g
Hemoglobin	15 g	33 g
Total protein	19 g	35 g
Total fat	560 mg	600 mg
Neutral fats	135 mg	95 mg
Phosphatide	245 mg	350 mg
Total cholesterol	175 mg	–
Glycogen	5 mg	–
Glucose	90 mg	75 mg
Lactic acid	15 mg	–
Nonprotein nitrogen	30 mg	–
Urea	15 mg	–
Creatine	3.9 mg	8 mg
Creatinine	0.9 mg	1.8 mg
RNA	64 mg	–
Sodium	190 mg	42 mg
Potassium	190 mg	370 mg
Calcium	7 mg	2 mg
Magnesium	3.8 mg	6.2 mg
Iron	48 mg	100 mg
Chloride	290 mg	270 mg

(Cont.) →

	Quantity per 100 cm <sup>3</sup> blood	Quantity per 100 g erythrocytes
Anorganic phosphate	2.5 mg	4 mg
Total phosphate	35 mg	66 mg
Bicarbonate	220 mg	-

**Table 4.3.10: Most Important Proteins in Human Blood Plasma**

Molecular weight and concentration in plasma.

After GANONG 1972, GAUER et al. 1971, *Documenta Geigy* 1975, KARLSON 1974

	Molecular weight	Concentration (mg/100 cm <sup>3</sup> )	Relative concentration (as % of proteins)
Prealbumin + Albumin			55.3
Prealbumin	61,000	10– 40	
Albumin	69,000	3,900–5,500	
$\alpha_1$ globulins			4.8
Acid $\alpha_1$ glycoprotein	44,000	70– 110	
$\alpha_1$ lipoprotein	200,000	290– 770	
$\alpha_1$ antitrypsin	54,000	200– 400	
$\alpha_1$ antichymotrypsin	68,000	30– 60	
$\alpha_2$ globulins			8.2
Ceruloplasmin	132,000	15– 60	
$\alpha_2$ macroglobulin	720,000	150– 350	
Haptoglobin	100,000	100– 200	
$\beta$ globulins			11.2
$\beta$ lipoprotein	2,400,000	220– 740	
Transferrin	80,000	200– 400	
$\beta_{1C}$ globulin		80– 140	
Fibrinogen	341,000	200– 450	
$\gamma$ globulins			20.5
$\gamma$ G globulin	150,000	800–1,800	
$\gamma$ A globulin	160,000	90– 450	
$\gamma$ M globulin	900,000	60– 250	
$\gamma$ D globulin		0.3– 40	

**Table 4.3.11: Quantity of Hemoglobin (Hb) and Number of Blood Cells in Humans**

More precise figures for white blood cells are found in Table 4.3.12.

After MERCK 1966

	g Hb/100 cm <sup>3</sup> blood	Red blood cells (10 <sup>6</sup> /mm <sup>3</sup> )	White blood cells (1,000/mm <sup>3</sup> )	Blood platelets (1,000/mm <sup>3</sup> )
Males	14–18	4.5–5.5	5– 9	250
Females	12–16	4.0–5.0	5– 9	250
Newborns	16–26	4.0–6.0	16–22	230
Infants	10–15	4.0–6.0	9–15	280
Children	10–15.5	4.5–5.5	8–12	340

**Table 4.3.12: Number of Leukocytes in Humans**

Normal values per cubic millimeter. The average number of leukocytes is currently constantly rising among Europeans and Americans. The cause of this is not known.

From MERCK 1966, modified

	Adults		Children		Infants	
Leukocytes per mm <sup>3</sup>	5,000–9,000		8,000–12,000		9,000–15,000	
	Absolute ( <i>n</i> )	(%)	Absolute ( <i>n</i> )	(%)	Absolute ( <i>n</i> )	(%)
Rod neutrophils	150–450	3–5	0–1,200	0–10	0–1,500	0–10
Segmented neutrophils	2,500–6,300	50–70	2,000–7,800	23–65	2,250–9,700	25–65
Eosinophils	100–360	2–4	50–600	1–5	90–1,000	1–7
Basophils	0–50	0–1	0–140	0–1	0–300	0–2
Monocytes	100–600	2–6	–1,000	1–6	–3,000	7–25
Lymphocytes	1,000–3,600	20–40	2,000–6,000	25–50	1,500–10,000	20–70

**Table 4.3.13: Composition of Lymph and Blood Plasma in Humans – A Comparison**

From FLOREY 1970

	Blood plasma	Lymph	
Protein	6.85	2.61	%
Sugar	123	124	mg/100 cm <sup>3</sup>
Nonprotein nitrogen	27.2	27	mg/100 cm <sup>3</sup>
Urea	22	23.5	mg/100 cm <sup>3</sup>
Amino acid nitrogen	4.9	4.8	mg/100 cm <sup>3</sup>
Calcium	10.4	9.2	mg/100 cm <sup>3</sup>
Chloride	392	413	mg/100 cm <sup>3</sup>

**Table 4.3.14: Percentual Distribution of Blood Groups in Selected Peoples**

Data after BERTELSMANN 1979, MEYER 1964, SCHWIDETZKY 1962

	O	A	B	AB
Germans	39.1	43.5	12.5	4.9
Hungarians	35.7	43.3	15.7	5.3
Finns	34.1	41.0	18.0	6.9
Sinti and Roma	28.5	26.6	35.3	9.6
Persians	37.9	33.3	22.2	6.6
Eskimos	54.2	38.5	4.8	2.0
Sioux (North Am. Indians)	91.0	7.0	2.0	0.0
Navajo (North Am. Indians)	72.6	26.9	0.2	0.5
Cayapa (South Am. Indians)	100.0	0.0	0.0	0.0
Australians	53.2	44.7	2.1	0.0
Bushmen	56.0	33.9	8.5	1.6
Bantu	63.2	16.4	17.4	3.0
Ainu	17.0	31.8	32.4	18.4
Papuans	62.7	18.5	16.7	2.1

## 4.4 Respiration

**Table 4.4.1: Numbers on the Human Lung and Respiration**

Data after MEYER 1964, RUCKER 1967

Length of a lung	25	cm
Weight of a lung	1,200	g
Number of pulmonary alveoli	850,000,000	
Interior surface area	90	m <sup>2</sup>
Lung capacity		
Vital capacity	4.1	l
Inspiratory capacity	0.5	l
Expiratory reserve volume	1.8	l
Inspiratory reserve volume	1.8	l
Daily oxygen intake	700	l
Length of capillaries in the alveoli	13,000	m

**Table 4.4.2: Age and Sex Dependency of Vital Capacity in Humans**

Vital capacity is defined as the total amount of air that is set in motion by one breath, given maximum inhalation and exhalation. Figures represent mean values.

After *Documenta Geigy* 1975

Age (years)	Females (cm <sup>3</sup> )	Males (cm <sup>3</sup> )
4	717	855
5	959	1,001
8	1,513	1,585
10	1,806	2,022
12	2,217	2,357
14–19	3,330	4,030
20–29	3,600	5,440
30–39	3,460	5,030
40–49	3,680	4,530
50–59	3,250	4,650
60–64	3,140	3,860



**Table 4.4.3: Average Air and Energy Consumption of an Adult During Selected Activities**

Figures represent consumption per hour.

Data after AURICH 1978

Activity	Air required (liters)	Energy required (kcal) / (kJ)
Sleeping	280	65 / 273
Lying down	400	77 / 323
Standing	450	
Walking	1,000	200 / 840
Biking	1,400	
Swimming	2,600	500 / 2,100
Mountain climbing	3,100	1,000 / 4,200
Rowing	3,600	

**Table 4.4.4: Changes in O<sub>2</sub> and CO<sub>2</sub> During Human Respiration**

Figures from KEIDEL 1973, REIN and SCHNEIDER 1971

	O <sub>2</sub> (%)	Oxygen partial pressure (pO <sub>2</sub> ) (mmHg / hPa)	CO <sub>2</sub> (%)	Carbon dioxide partial pressure (pCO <sub>2</sub> ) (mmHg) / (hPa)
Inspired air	20.9	150 / 200	0.03	0.2 / 0.3)
Alveolar air	14.0	100 / 133	5.6	40 / 53
Expired air	16.0	116 / 155	4	29 / 39
Arterial blood		95 / 127		40 / 53
Venous blood		40 / 53		46 / 61

**Table 4.4.5: Age and Sex Dependency of Human Basal Metabolic Rate**

Figures are given in kilocalories (and kilojoules) per square meter body surface area per hour.

After *Documenta Geigy* 1975

Age (years)	Males (kcal/m <sup>2</sup> per h) / (kJ/m <sup>2</sup> per h)	Females
1	53.0 / 222	53.0 / 222
2	52.4 / 219	52.4 / 219
5	49.3 / 206	48.4 / 203
8	46.3 / 194	43.8 / 183

Age (years)	Males		Females	
	(kcal/m <sup>2</sup> per h) / (kJ/m <sup>2</sup> per h)			
10	44.0	/ 184	42.5	/ 178
12	42.5	/ 178	41.3	/ 173
15	41.8	/ 175	37.9	/ 159
20	38.6	/ 162	35.3	/ 148
25	37.5	/ 157	35.2	/ 147
30	36.8	/ 154	35.1	/ 147
40	36.2	/ 152	34.9	/ 146
50	35.8	/ 150	33.9	/ 142
60	34.9	/ 146	32.7	/ 137
70	33.8	/ 141	31.7	/ 133
75 and older	33.2	/ 139	31.2	/ 131

**Table 4.4.6: Oxygen Consumption and Heat Generation in Human Organs**

Figures refer to a person at rest. On the blood flow through organs, see Tables 4.3.7 and 4.3.8.

Data after GAUER et al. 1971, HALTENORTH 1977, REIN and SCHNEIDER 1971

Organ	Oxygen intake (cm <sup>3</sup> )		Organ weight as % of body- weight	Oxygen consump- tion of organ as % of total consump- tion	Heat generation (cal)	
	Organ per min	100 g organ per min			Organ per min	100 g organ per min
Skin	5.0	0.10	7.0	1	24	0.48
Muscle	43.0	0.16	41.0	18	203	0.75
Brain	43.0	3.20	2.0	19	208	15.40
Lung	12.0	2.00	0.8	5	57	9.50
Heart	29.0	10.00	0.5	14	138	48.00
Kidneys	20.3	7.00	0.4	6	100	34.50
Stomach-Intestine (+ liver, spleen, pancreas)	90.0	3.60	4.0	22	435	17.40

## 4.5 Nutrition, Digestion, Excretion

**Table 4.5.1: Standard Food Requirements for Adults**

Figures for the Federal Republic of Germany (FRG) and recommendations of the FAO (Food and Agriculture Organization of the United Nations) for persons 25 years of age. See also Table 4.5.2.

After ALTMAN and DITTMER 1974

					Vitamins			Minerals		
	Weight (kg)	Calories	Protein (g/day)	Thiamine (mg/day)	Riboflavin (mg/day)	Niacin (mg/day)	Vit. C (mg/day)	Vit. A (IE/day)	Ca (g/day)	Fe (mg/day)
FRG										
♂	72	2,550	72	1.7	1.8	18	75	5,000	0.8	10
♀	60	2,200	60	1.5	1.8	14	75	5,000	0.8	12
FAO										
♂	65	3,200	46	1.3	1.8	21.1	–	–	0.4–0.5	–
♀	55	2,300	39	0.9	1.3	15.2	–	–	0.4–0.5	–

**Table 4.5.2: Recommended Daily Protein and Overall Energy Intake in the Human Diet**

Figures for protein intake represent grams of protein per kilogram of body weight and per day ( $\pm 20\%$ ); figures for overall energy intake are given in kilocalories and kilojoules, calculated for a primarily sedentary activity. For breast-feeding women, 5 g protein should be added to the figures given for every 100 g of breast-fed milk.

See also Table 4.5.1.

After *Verbraucherdienst* 1979

	Protein intake (g)		Energy intake (kcal) / (kJ)	
	♂	♀	♂	♀
Adults (age)				
25 years	0.9	0.9	2,600 / 10,900	2,200 / 9,200
45 years	0.9	0.9	2,400 / 10,000	2,000 / 8,400
65 years	1.0	1.0	2,200 / 9,200	1,800 / 7,500

	Protein intake (g)		Energy intake (kcal) / (kJ)	
	♂	♀	♂	♀
<b>Pregnant women</b>				
5 months or less		0.9		2,200 / 9,200
More than 5 months		1.5		2,600 / 10,900
<b>Breast-feeding women</b>		0.9		2,800 / 11,700
<b>Children</b>				
6 months		2.5		600 / 2,500
6–12 months		2.2		900 / 3,800
1 to < 4 years		2.2		1,200 / 5,000
4 to < 7 years		2.0		1,600 / 6,700
7 to < 10 years		1.8		2,000 / 8,400
10 to < 13 years	1.5	1.4	2,400 / 10,000	2,100 / 8,800
13 to < 15 years	1.5	1.4	2,700 / 11,300	2,400 / 10,000
15 to < 19 years	1.2	1.0	3,100 / 13,000	2,500 / 10,500

**Table 4.5.3: Human Digestive Capacity for Selected Nutrients**

Figures represent the digestive capacities of a normal person (70 kg body weight) whose basal metabolic rate is ca. 1,700 kcal (7,200 kJ) daily and whose energy requirements are ca. 2,400 kcal (10,000 kJ) daily.

Data after FÖRSTER 1980, modified

Nutrient	Digestive capacity	Energy content (kcal) / (kJ)
<b>Carbohydrates</b>		
Starch	1,000 g	3,800 / 16,000
Glucose oligosaccharide	2,000 g	7,600 / 32,000
Saccharose	800 g	3,200 / 13,500
Lactose	200 g	760 / 3,200
<b>Fats</b>		
Long-chain triglycerides	500 g	4,050 (17,000)
<b>Proteins</b>		
High-grade protein	400 g	1,700 (7,000)
Oligopeptides	180– 250 g	710– 950 (3,000–4,000)

**Table 4.5.4: Components of a Chemically Defined Diet (CDD) that Meets Human Nutritional Needs**

The amounts given here are the equivalent of 300 kcal (= 1,255 kJ). On human vitamin requirements, see also Table 4.5.7. IU = international units

From GRIMME 1975, modified

**Amino acids**

L-Isoleucine	0.275	g
L-Leucine	0.435	g
L-Lysine monohydrochloride	0.327	g
L-Methionine	0.282	g
L-Phenylalanine	0.313	g
L-Threonine	0.275	g
L-Tryptophan	0.085	g
L-Valine	0.303	g
L-Alanine	0.293	g
L-Arginine hydrochloride	0.537	g
L-Aspartic acid	0.625	g
L-Glutamine	1.032	g
Glycine	0.478	g
L-Histidine monohydrochloride monohydrate	0.133	g
L-Proline	0.329	g
L-Serine	0.202	g
L-Tyrosine ethylester hydrochloride	0.343	g
	<hr/>	
	6.330	g

**Carbohydrates**

Glucose monohydrate	24.000	g
Oligosaccharide (from enzymatically and hydrolytically decomposed cornstarch)	45.500	g
	<hr/>	
	69.500	g

**Essential lipid acids**

Safflower oil	0.222	g
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**Vitamins and other substances**

Vitamin A acetate	0.287	mg (834 IU)
Vitamin C	11.700	mg
Vitamin D <sub>2</sub>	1.670	mg (67 IU)
Vitamin E acetate	3.330	mg
Vitamin B <sub>1</sub> (aneurine chloride hydrochloride)	0.200	mg
D-Biotin	0.033	mg
Calcium D-pantothenate	1.670	mg
Choline hydrogen tartrate	14.170	mg
Vitamin B <sub>12</sub> (cyanocobalamin)	0.830	µg
Folic acid	0.017	mg
Inositol	19.420	mg

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Nicotinamide	2.220 mg
Vitamin B <sub>6</sub> (pyridoxine hydrochloride)	0.330 mg
Vitamin B <sub>2</sub> (riboflavin 5-phosphate ester, sodium salt)	0.200 mg
Vitamin K <sub>1</sub> (phytomenadione)	0.020 mg
Sodium glycerophosphate	430.000 mg
Glucono- $\delta$ -lactone	1.060 g
Sorbic acid	150.000 mg

#### Minerals and trace elements

Sodium chloride	978.000 mg
Potassium chloride	672.000 mg
Calcium chloride	489.000 mg
Magnesium oxide	43.200 mg
Ferrous sulfate [iron (II) sulfate]	8.260 mg
Copper (II) acetate	1.030 mg
Manganese (II) acetate	2.090 mg
Zinc chloride	0.140 mg
Potassium iodide	0.030 mg

**Table 4.5.5: Energy Requirements in Humans for Selected Physical Activities**

Figures represent the amount exceeding the basal metabolic rate required per hour.

After FÖRSTER 1980

Activity	Energy requirement per hour	
	(kcal)	(kJ)
Walking	50– 200	200– 800
Biking	100– 300	400–1,200
“Fitness path”*	200– 400	800–1,600
Endurance run	200– 400	800–1,600
Dancing	300– 400	1,200–1,600
Soccer	400– 500	1,600–2,000
Tennis	400– 500	1,600–2,000
Swimming	200– 600	800–2,400
Jogging	500–1,000	2,000–4,000
Skiing	400– 800	1,600–3,200

\*Forest paths set up with calisthenics stations

**Table 4.5.6: Composition and Energy Content of Selected Foodstuffs**

Calculated for 100 g edible substance.

For the energy values of plant parts, see Table 2.5.8.

From *Documenta Geigy* 1975, modified

	Water	Proteins	Fats	Carbo- hydrates	Energy content (kcal)	(kJ)
Apples, sweet	84.0	0.3	0.6	15.0	58	243
Bananas	75.7	1.1	0.2	22.2	85	356
Strawberries	89.9	0.7	0.5	8.4	37	155
Cherries	83.4	1.2	0.4	14.6	60	251
Oranges	87.1	1.0	0.2	12.2	49	205
Plums	85.7	0.7	0.1	12.3	50	210
Raisins	18.0	2.5	0.2	77.4	289	1,210
Grapes	81.4	0.6	0.3	17.3	67	280
Watermelon	92.6	0.5	0.2	6.4	26	109
Rhubarb	94.9	0.5	0.1	3.8	16	67
White kidney bean	11.6	21.3	1.6	61.6	338	1,415
Cucumbers	95.6	0.8	0.1	3.0	13	55
Carrots	88.6	1.1	0.2	9.1	40	167
Potatoes	79.8	2.1	0.1	17.7	76	318
White cabbage	92.1	1.4	0.2	5.7	25	105
Cauliflower	91.0	2.7	0.2	5.2	27	113
Brussel sprouts	84.8	4.7	0.4	8.7	47	197
Sauerkraut	92.8	1.0	0.2	4.0	18	75
Leek	87.8	2.0	0.3	9.4	44	184
Pepper (green)	92.8	1.2	0.2	5.3	24	100
Radish	93.7	1.1	0.1	3.6	18	75
Red beets	87.3	1.6	0.1	9.9	43	180
Lettuce	95.1	1.3	0.2	2.5	14	59
Celeriac	88.4	1.8	0.3	8.5	40	167
Asparagus	92.9	2.1	0.2	4.1	21	88
Spinach	90.7	3.2	0.3	4.3	26	109
Tomatoes	93.5	1.1	0.2	4.7	22	92
Onions	89.1	1.5	0.1	8.7	38	159
Agaricus mushrooms	90.8	2.8	0.2	3.7	22	92
Porcini mushrooms	88.6	2.8	0.4	5.9	31	130
Baker's yeast	71.0	12.1	0.4	11.0	87	360
Peanuts (roasted)	1.8	26.2	48.7	20.6	582	2,436
Hazelnuts	6.0	12.7	60.9	18.0	627	2,624
Coconuts	48.0	4.2	34.0	12.8	351	1,469
Walnuts	3.5	14.8	64.0	15.8	651	2,725
Almonds	4.7	18.6	54.2	19.5	598	2,503

	Water	Proteins	Fats	Carbo- hydrates	Energy content (kcal)	(kJ)
Wheat flour	12.6	12.1	2.1	71.5	331	1,385
Rye flour	14.3	10.8	1.5	71.8	310	1,297
Wheat germ	11.5	26.6	10.9	46.7	363	1,519
Oatmeal	10.3	13.8	6.6	67.6	387	1,620
Bread roll	34.0	6.8	0.5	58.0	269	1,126
Rye bread	38.5	6.4	1.0	52.7	227	950
Spaghetti	10.4	12.5	1.2	75.2	369	1,544
Honey	17.2	0.3	0.0	82.3	304	1,272
Marzipan	8.8	8.0	18.0	64.0	428	1,792
Milk chocolate	0.9	7.7	32.3	56.9	520	2,176
Dextrose	0.0	0.0	0.0	99.5	385	1,611
Butter	17.4	0.6	81.0	0.7	716	2,996
Cod-liver oil	0.0	0.0	99.9	0.0	901	3,771
Margarine	19.7	0.5	78.4	0.4	698	2,921
Lard	1.0	0.0	99.0	0.0	901	3,771
Chicken egg	74.0	12.8	11.5	0.7	162	678
Cow milk	88.5	3.2	3.7	4.6	64	268
Whipped cream	64.1	2.2	30.4	2.9	288	1,205
Yogurt	86.1	4.8	3.8	4.5	71	297
Low-fat quark (curd cheese)	79.4	17.2	0.6	1.8	86	360
Camembert	51.3	18.7	22.8	1.8	287	1,201
Emmentaler	34.9	27.4	30.5	3.4	398	1,666
Duck	54.0	16.0	28.6	0.0	326	1,365
Roast chicken	72.7	20.6	5.6	0.0	138	578
Rabbit	73.0	22.3	0.9	0.2	103	431
Calf's liver	70.7	19.2	4.7	4.1	140	586
Veal chop	70.0	19.5	9.0	0.0	164	686
Lamb chop	52.0	14.9	32.0	0.0	352	1,473
Fillet of beef	75.1	19.2	4.4	0.0	122	511
Pork	71.2	18.6	9.9	0.0	168	703
Pork chop	53.9	15.2	30.6	0.0	341	1,427
Cervelat sausage	55.6	12.5	27.6	1.8	256	1,072
Veal sausage	65.2	11.1	21.7	0.0	241	1,009
Trout	77.6	19.2	2.1	0.0	101	423
Herring	62.8	17.3	18.8	0.0	243	1,017
Carp	72.4	18.9	7.1	0.0	145	607
Haddock	80.5	18.3	0.1	0.0	79	331
Tuna	52.5	23.8	20.9	0.0	290	1,214

(Cont.) →



	Water	Proteins	Fats	Carbo- hydrates	Energy content (kcal)	(kJ)
Oysters	83.0	9.0	1.2	4.8	68	285
Mussels	84.1	11.7	1.9	2.2	76	318
Edible snails	82.0	15.0	0.8	2.0	75	314
Cuttlefish	82.2	15.3	0.8	0.0	73	306
Shrimps	78.2	18.7	2.2	0.0	97	406
Lobster	78.5	16.9	1.9	0.5	91	381

### Table 4.5.7: Daily Human Vitamin Requirements

For the vitamin content of foodstuffs, see Table 4.5.8.

From KARLSON 1980, modified

A	Retinol	1.5– 2	mg
D	Calciferol	0.02	mg
E	Tocopherol	20	mg
K	Menaquinone	1	mg <sup>a, b</sup>
B <sub>1</sub>	Thiamine	1.4	mg
B <sub>2</sub>	Riboflavin	1.7	mg
B <sub>3</sub>	Nicotinamide	20	mg <sup>a, b</sup>
B <sub>5</sub>	Pantothenic acid	10	mg <sup>a</sup>
B <sub>6</sub>	Pyridoxine	2	mg <sup>a</sup>
B <sub>9</sub>	Folic acid	0.4	mg <sup>a</sup>
B <sub>12</sub>	Cobalamin	0.005	mg
C	Ascorbic acid	60	mg
H	Biotin	0.25	mg <sup>a</sup>

<sup>a</sup>Estimated value, <sup>b</sup>synthesized by intestinal bacteria

**Table 4.5.8: Vitamin Content of Selected Foodstuffs**

Figures refer to 100 g edible substance. For daily human vitamin requirements, see Table 4.5.7. IU = international units, t = only present as trace element. (B<sub>1</sub> = Thiamine, B<sub>2</sub> = Riboflavin, B<sub>3</sub> = Nicotinamide, B<sub>5</sub> = Pantothenic acid, B<sub>6</sub> = Pyridoxine, B<sub>9</sub> = Folic acid, B<sub>12</sub> = Cabolamin

Figures from *Documenta Geigy 1975*

	A (IU)	B <sub>1</sub> (mg)	B <sub>2</sub> (mg)	B <sub>3</sub> (mg)	B <sub>5</sub> (mg)	B <sub>6</sub> (mg)	B <sub>9</sub> (mg)	B <sub>12</sub> (mg)	C (mg)	D (IU)	E (mg)	Biotin (mg)	K (mg)
Apples, sweet	90	0.04	0.02	0.1	0.1	0.03	0.002	-	5	-	0.3	0.001	-
Bananas	190	0.05	0.06	0.6	0.2	0.32	0.01	-	10	-	0.2	0.004	-
Blackberries	200	0.03	0.04	0.4	0.25	0.05	0.012	-	21	-	-	0.0004	-
Strawberries	60	0.03	0.07	0.6	0.26	0.04	0.005	-	60	-	-	0.0011	-
Grapefruit juice	10	0.03	0.02	0.2	0.16	0.014	0.001	-	45	-	-	0.0007	-
Elderberries	600	0.07	0.08	1.5	0.18	0.25	0.017	-	18	-	-	0.002	-
Red currants	120	0.04	0.02	0.3	0.06	0.05	-	-	41	-	-	0.0026	-
Black currants	220	0.05	0.03	0.3	-	0.08	-	-	136	-	-	0.0026	-
Cherries	1,000	0.05	0.06	0.3	0.08	0.05	0.006	-	10	-	-	0.0004	-
Oranges	200	0.1	0.03	0.2	0.2	0.03	0.005	-	50	-	0.23	0.01	-
Lemons	20	0.04	0.02	0.1	0.2	0.06	0.007	-	45	-	-	-	-
Carrots	11,000	0.06	0.06	0.6	0.27	0.12	0.008	-	2-10	-	0.45	0.003	-
Potatoes	5	0.11	0.04	1.2	0.3	0.2	0.006	-	20	-	0.06	0.0001	0.08
White cabbage	70	0.05	0.04	0.32	0.26	0.11	0.08	-	46	-	0.7	-	-
Cress	9,300	0.08	0.26	1.0	-	-	-	-	69	-	-	-	-
Parsley	8,500	0.12	0.26	1.2	0.03	0.2	0.04	-	172	-	-	0.0004	-
Lettuce	970	0.06	0.07	0.3	0.1	0.07	0.02	-	8	-	0.6	0.003	-
Asparagus	900	0.18	0.20	1.5	0.62	0.14	0.11	-	33	-	2.5	-	-
Spinach	8,100	0.1	0.2	0.6	0.3	0.2	0.075	-	51	-	2.5	0.007	0.04
Tomatoes	900	0.06	0.04	0.6	0.31	0.1	0.008	-	23	-	0.27	0.004	-
Onions	40	0.03	0.04	0.2	0.17	0.1	0.01	-	10	-	0.26	0.004	-

(Cont.) →

	A	B <sub>1</sub> (mg)	B <sub>2</sub> (mg)	B <sub>3</sub> (mg)	B <sub>5</sub> (mg)	B <sub>6</sub> (mg)	B <sub>9</sub> (mg)	B <sub>12</sub> (mg)	C (mg)	D (IU)	E (mg)	Biotin (mg)	K (mg)
Agaricus mushrooms	-	0.1	0.44	6.2	2.1	0.05	0.03	-	5	150	0.83	0.016	-
Walnuts	30	0.3	0.13	1.0	0.7	1.0	0.077	-	2	-	1.5	0.037	-
Oatmeal	-	0.55	0.14	1.1	0.92	0.75	-	-	-	-	0.25	-	-
Wheat flour	-	0.06	0.05	0.9	-	-	-	-	-	-	-	-	-
Honey	-	t	0.04	0.3	0.06	0.01	0.003	-	1	-	-	-	-
Milk chocolate	270	0.01	0.34	0.3	-	-	-	-	-	-	1.1	-	-
Butter	3,300	t	0.01	0.1	t	t	-	-	t	40	2.4	-	-
Margarine	3,000	-	-	-	-	-	-	-	-	-	-	-	-
Cod-liver oil	85,000	-	-	-	-	-	-	-	-	8,500	-	-	-
Chicken egg, raw	1,180	0.12	0.34	0.1	1.6	0.25	0.005	0.002	-	200	1.0	0.02	0.002
Cow milk, fresh	140	0.04	0.15	0.07	0.33	0.05	0.0001	0.0006	1	0.5-4	0.06	0.002	-
Buttermilk	35	0.04	0.18	0.04	0.36	0.04	0.0003	0.0003	1	-	0.05	0.002	-
Camembert	1,010	0.05	0.45	0.25	0.1-0.9	0.25	-	-	-	100	-	0.005	-
Emmentaler	1,140	0.05	0.33	0.1	-	0.09	-	-	0.5	40	0.35	-	-
Low-fat quark (curd cheese)	35	0.04	0.31	0.1	0.1	0.01	0.03	-	1	50	-	0.002	-
Calf's liver	22,500	0.28	2.72	17	9.7	1.2	0.05	0.06	32	50	0.9-1.6	0.075	0.15
Fillet of beef	-	0.1	0.13	4.6	-	-	-	-	-	-	0.5	-	-
Pork chops	-	0.8	0.19	4.3	0.4	0.48	0.002	0.001	-	-	0.6	0.005	-
Pork heart	30	0.43	1.24	6.6	2.5	0.43	-	0.003	3	-	1.4	0.02	-
Pork liver	10,900	0.43	2.7	16.4	7.0	0.85	0.22	0.01	27	-	1.0	0.1	-
Salami	-	0.18	0.2	2.6	-	-	-	-	-	-	0.11	-	-
Mussels	180	0.16	0.22	1.6	-	-	-	-	-	-	-	-	-
Oysters	310	0.18	0.23	2.5	0.5	0.11	0.004	0.015	5	-	0.001	-	-
Trout	150	0.09	0.25	3.5	-	-	-	-	-	-	-	-	-
Cod	0.06	0.07	0.2	0.12	0.001	0.0005	2	2.2	-	0.0002	-	-	-
Tuna (canned)	90	0.05	0.06	10.8	0.2	0.25	0.003	0.001	-	-	-	0.0005	-

**Table 4.5.9: Adult Daily Requirements of Essential Amino Acids**

See also Table 4.5.4.

After *Documenta Geigy* 1975, KARLSON 1974

Amino acid	Absolute amount (g)		mmol/kg body weight
	Males	Females	
Valine	0.80	0.65	0.28
Leucine	1.10	0.62	0.39
Isoleucine	0.70	0.45	0.21
Lysine	0.80	0.50	0.24
Phenylalanine	0.30	0.22	0.18
Tryptophan	0.25	0.16	0.04
Methionine	0.20	0.35	0.07
Threonine	0.50	0.31	0.20

**Table 4.5.10: Fatty Acid and Cholesterol Content of Selected Foodstuffs**

Unsaturated fatty acids cannot be synthesized by the body and thus must be ingested. The most important of these essential fatty acids is linoleic acid.

Unless otherwise noted, figures are per 100 g.

Data after *Verbraucherdienst* 1979

Foodstuff	Fatty acids, polysaturated (g)	Fatty acids, polyunsaturated (g)	Cholesterol (mg)
Beef, lean	5	2	100
Pork, lean	5	1	90
Venison	1	1	110
Roast chicken	3	1	53
Duck	12	8	75
Brains	4	1	3,146
Kidney	4	1	350
Liver	4	3	250
Ham	20	4	400
Liverwurst	15	5	85
Trout	1	1	70
Herring	3	3	80
Lard	41	10	100
Butter	52	2	230

(Cont.) →

Foodstuff	Fatty acids, polysaturated (g)	Fatty acids, polyunsaturated (g)	Cholesterol (mg)
Margarine	24	24	–
Mayonnaise, 80% fat	12	48	55
1 egg (ca. 60 g)	2	1	280
Egg yolk (from ca. 5 eggs)	10	2	1,400
Milk, 3.5% fat	2	–	11
Cream, 30% fat	21	1	94
Quark (curd cheese), 20% fat i.d.m.	3	–	14
Edamer, 30% fat i.d.m.	9	–	42
Butter cheese, 60% fat i.d.m.	21	1	92
Whole-grain bread, white bread	1	–	–
Pasta	1	1	118
Milk chocolate	20	1	74

**Table 4.5.11: Numbers on the Human Digestive System**

After MEYER 1964, RUCKER 1967

Number of oral salivary glands	6,000,000
Saliva produced daily	1–2 l
Stomach capacity	3 l
Gastric juice produced daily	1–2 l
Bile produced daily	0.75 l
Pancreatic juice produced daily	1.2 l
Length of the small intestine	3 m
Intestinal juice produced daily	3 l
Number of villi in the small intestine	7,000,000
Total surface area of the villi	40 m <sup>2</sup>
Number of microvilli per villus	300,000
Contact surface area that microvilli provide food	2,000 m <sup>2</sup>
Number of mucous membrane cells per villus	30,000
Number of mucous membrane cells in small intestine	200,000,000,000

**Table 4.5.12: Teeth Eruption Times in Humans**

Data after PFLUGFELDER 1962, RUCKER 1967, STARCK 1975

## Deciduous (baby) teeth:

Central incisor	Months 6-8
Lateral incisor	Months 7-9
Front molar	Months 12-15
Canine	Months 16-20
Back molar	Months 20-24

## Permanent teeth:

Molar	Year 7
Central incisor	Year 8
Lateral incisor	Year 9
Premolar	Year 10
Canine	Years 11-13
Premolar	Years 11-15
2 <sup>nd</sup> molar	Years 13-16
3 <sup>rd</sup> molar (wisdom tooth)	Years 18-30

**Table 4.5.13: Numbers on the Human Kidney**

After BERTELSMANN 1979, MEYER 1964, RUCKER 1967

Weight of a single kidney	120–160 g
Length of a kidney	10–12 cm
Number of renal corpuscles (glomeruli)	2,000,000
Number of loops of Henle	2,000,000
Total length of the loops of Henle	100 km
Inner surface area of the loops of Henle	20 m <sup>2</sup>
Daily blood flow through kidney	1,500 l
Glomerular ultrafiltrate produced daily	180 l
Urine produced daily	0.5–4 l
Salt reabsorbed daily	1 kg
Sodium bicarbonate reabsorbed daily	0.5 kg
Daily renal oxygen consumption	30 l

**Table 4.5.14: Filtration and Reabsorption of Selected Substances in the Human Kidney**

Figures from KEIDEL 1970, REIN and SCHNEIDER 1971

	Mean concentration in blood plasma (%)	Amount in glomerular ultrafiltrate = daily filtration (g)	Daily reabsorption (g)	Daily excretion output (g)	Mean concentration in urine (%)
Water		170,000	168,500	1,500	
Protein	7–8	11	11	0	0
Glucose	0.1	170	169.5	0.5	0.01
Uric acid	0.0005	8.5	7.97	0.53	0.035
Urea	0.025	46	19	27	1.8
Creatinine	0.001	1.7	0	1.7	0.11
Sodium	0.333	566	561	5	0.333
Calcium	0.01	17	16.8	0.2	0.015
Potassium	0.017	28.9	26.2	2.7	0.18
Chloride	0.373	634	628.7	5.3	0.353
HCO <sub>3</sub>	0.159	270	269.7	0.3	0.02

**Table 4.5.15: Daily Urine Volume in Humans at Different Ages**

Figures represent mean values. Amounts can be greatly influenced by liquid intake, perspiration, and similar phenomena.

Data after *Merck* 1966

	Age (years)	Daily urine volume (cm <sup>3</sup> )
Children	1– 3	500– 600
	3– 5	600– 700
	5– 8	650–1,000
	8–14	1,000–1,400
Adults	(> 14)	1,000–1,600

## 4.6 Brain, Nerves, Senses

**Table 4.6.1: Numbers on the Human Nervous System**

Figures represent mean values. For further data on the nervous system, see Tables 4.6.2 and 4.6.3.

Values after RUCKER 1964

Weight of the brain	1.5 kg
Weight of the cerebrum	1.25 kg
Number of neurons in the brain	14,000,000,000
Number of interconnections between neurons (synapses)	7,000,000,000,000
Thickness of the cerebral cortex	2–5 mm
Number of neurons in the cerebral cortex	12,000,000,000
Number of interconnections in the cerebrum	1,000,000,000,000
Length of nerve fiber in the cerebrum	500,000 km
Length of nerve fiber outside of the brain	480,000 km
Daily loss of neurons	50,000–100,000

**Table 4.6.2: Brain Volumes of Hominids**

For the brain weights of animals, see Tables 1.10.1 and 1.10.2.

Figures from HEBERER 1968, v. KÖNIGSWALD 1960, PORTMANN 1959, SALLER 1964, STEITZ 1979

	Range of variation (cm <sup>3</sup> )	Mean value (cm <sup>3</sup> )
Chimpanzee	320– 480	394
Orangutan	295– 575	411
Gorilla	340– 685	498
Proconsul		500
Australopithecus	450– 750	576
<i>Homo erectus erectus</i> (Pithecanthropus)	835– 900	871
<i>Homo erectus pekinensis</i> (Sinanthropus)	915–1,225	1,046
<i>Homo heidelbergensis</i>	775– 900	
<i>Homo sapiens preneanderthalensis</i>	1,070–1,280	1,175
Steinheim man	1,100–1,200	
<i>Homo sapiens neanderthalensis</i>	1,300–1,610	1,438
Cro-Magnon man ( <i>Homo sapiens sapiens</i> )	1,250–1,700	1,400
Present humans ( <i>Homo sapiens sapiens</i> )	1,010–2,000	1,400



**Table 4.6.3: Brain Weights of Several Eminent Humans**

Brain weights are only comparable if those compared died at the same age, since cell division ceases in the human brain after the age of 15 and the brain thereafter continuously loses cellular material.

After BERTELSMANN 1979, MEYER 1964, SLIJPER 1967

	Weight (g)	Age (years)
Bismarck	1,807	83
Lord Byron	2,230	36
Cromwell	2,000	59
Cuvier	1,861	62
Dante	1,420	56
Gauß	1,492	78
Helmholtz	1,420	73
Kant	1,650	80
Liebig	1,350	70
Schiller	1,580	46

**Table 4.6.4: Sleep Requirements and Proportion of REM Sleep for Humans of Different Ages**

REM sleep is defined as that phase of sleep in which rapid eye movements (REM) and vivid dreams take place.

From GANONG 1972

Age	Daily sleep requirement (h)	Proportion of sleep spent in REM sleep (%)
1-15 days	16	50
3- 5 months	14	40
2- 3 years	13	25
5- 9 years	11	19
10-14 years	9	20
19-30 years	8	22
33-45 years	7	19
50-70 years	6	15

**Table 4.6.5: Number of Receptors and Afferent Nerve Fibers of Human Senses**

Data after KOLB 1974

Sense	Number of receptors	Number of nerve fibers
Eye	$2 \times 10^8$	$2 \times 10^6$
Ear	$3 \times 10^4$	$2 \times 10^4$
Taste	$10^7$	$2 \times 10^3$
Smell	$10^7$	$2 \times 10^3$
Pressure	$5 \times 10^5$	} $\times 10^6$
Pain	$3 \times 10^6$	
Heat	$10^4$	
Cold	$10^5$	

**Table 4.6.6: Numbers on the Human Eye and Eyesight**

Data after FRANCOIS and HOLLWICH 1977, MEYER 1964, RUCKER 1967

Diameter of the eyeball	24 mm
Weight of the eyeball	7.5 g
Volume of the eyeball	$6.5 \text{ cm}^3$
Circumference of the eyeball	74.9 mm
Thickness of the sclera (behind rectus muscles)	0.3 mm
Thickness of the sclera (near optic nerve)	1.35 mm
Thickness of cornea	0.52–0.67 mm
Surface area of the cornea	$1.3 \text{ cm}^2$
Diameter of the iris	12 mm
Diameter of the pupil	1.2–9 mm
Lens thickness	4 - 4.14 mm
Lens diameter	9 mm
Lens weight	174 mg
Volume of the vitreous humor	$4 \text{ cm}^3$
Weight of vitreous humor	4 g
Thickness of retina at retinal equator	0.18 mm
Retinal thickness at yellow spot (macula lutea)	0.1 mm
Diameter of yellow spot (horizontal)	2 mm
Diameter of yellow spot (vertical)	0.88 mm
Number of visual cells in the retina	132,000,000
Number of rods	125,000,000
Number of cones	7,000,000
Number of interneurons	2,000,000
Number of nerve fibers in the optic nerve	1,000,000
Number of ciliary processes in ciliary body	70–80

(Cont.) →

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Length of a ciliary process	2 mm
Thickness of a ciliary process	0.5 mm
Refractive power of the cornea	43 diopters
Refractive power of the lens	19-33 diopters
Resolving power of the eye	$\frac{1}{120}$ arc degree

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**Table 4.6.7: Changes in the Binocular Horizontal Visual Field of Humans with Age**

Figures from ALTMAN and DITTMER 1973

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Age (years)	Visual field (degrees)	
	♂	♀
16-19	174.5	176.4
20-29	174.8	176.2
30-39	173.8	175.3
40-49	171.7	172.7
50-59	167.1	170.1
60-69	160.1	162.3
70-79	151.2	155.5
80 and older	139.8	138.5

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**Table 4.6.8: Changes in the Near Point of the Human Eye with Age**

The near point describes the closest point in front of the eyes at which an object may still be seen clearly given maximum accommodation.

After REIN and SCHNEIDER 1971, SIEBECK 1977

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Age (years)	Distance of the near point
10	7 cm
20	9 cm
30	12 cm
40	22 cm
50	40 cm
60	100 cm
70	up to 400 cm
75	$\infty$

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**Table 4.6.9: Numbers on the Human Ear**

See also Table 4.6.10 and, on hearing in animals, see Table 1.11.13.

Figures from BERTELSMANN 1979, MEYER 1964, RUCKER 1976

Diameter of the eardrum	10 mm
Thickness of the eardrum	0.1 mm
Diameter of the <i>fenestra vestibuli</i> (oval window)	4 mm
Length of the basilar membrane	3.35 mm
Width of the basilar membrane at its beginning	0.04 mm
Width of the basilar membrane at its end	0.495 mm
Number of hair cells on the basilar membrane	14,000
Number of coils in the cochlea	2.5
Spatial resolution of the ear	8.4°

**Table 4.6.10: Age Dependency of Upper Hearing Limits**

The most important pitches (frequencies) of human language lie between ca. 80 and 600 Hz; consonants of the S and T groups lie between ca. 1 and 3 kHz. For animals, see Table 1.11.13.

Figures from REIN and SCHNEIDER 1971

Age	Upper limit (kHz)
Child	21
35 years	15
59 years	12
Elderly man	5

**Table 4.6.11: Sound Levels of Selected Sounds**

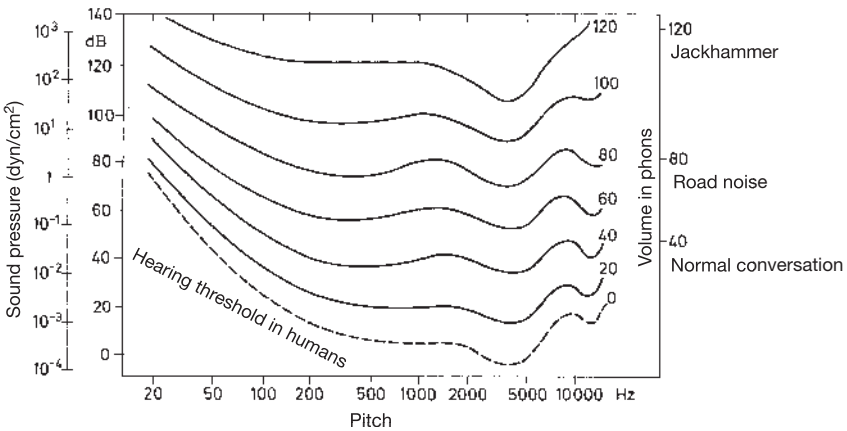
Figures given in A-weighted decibels [dB(A)]. dB(A) describes the intensity of the frequency-dependent perception of the human ear. At a frequency of 1,000 Hz, dB(A) values coincide with phon values. Since decibel [dB(a)] values represent logarithmic units, a sound that increases by 10 dB(A) is sensed to be twice as loud.

Figures after BELTZ 1974, FAHRENBERGER and MÜLLER 1972, REIN and SCHNEIDER 1971

	dB(A)
Hearing threshold	0
Quiet whispering, ticking of a pocket watch, breathing in an echo-free space	10
Whispered dialogue (from a film recording studio)	20
Alarm clock, residential area at night	30

(Cont.) →

	dB(A)
Quiet conversation, quiet apartment	40
Normal conversation, loudspeaker set at room volume	50
Conversation	60
Office typewriter	70
Vacuum cleaner, road traffic	80
Motorcycle, automobile, heavy road traffic	90
Jackhammer, a nearby car horn	100
Textile factory	110
Propeller airplane, rock 'n' roll band	120
Pain threshold, noise in a boiler shop	130
Jet fighter at takeoff	140
Jet engine with afterburners at 25 meters	160
Space rocket at blastoff, heard from nearby	170



**Fig. 4.6.11:** Relationship between the objectively measurable, frequency-independent sound pressure (dB) and the subjectively perceived, frequency-dependent sound level (phon).  
 From REMANE, STORCH and WELSH 1974

**Table 4.6.12: Spatial Discrimination Threshold of Selected Sites on the Human Body**

The spatial discrimination threshold (or spatial resolution) represents the distance separating two equally strong pressure stimuli (e.g., with a pair of compasses) at which they can still be perceived as two separate stimuli.

From CZIHAK et al. 1976, MEYER 1964, OPPENHEIMER and PINCUSSEN 1925

Body site	Spatial threshold (mm)	Body site	Spatial threshold (mm)
Tip of the tongue	1.1	Buttocks	45.0
Border of the tongue	9.0	Fingertip	2.3
Lip	4.0	Back of the finger	6.8
Hard palate	13.6	Palm of the hand	11.3
Tip of the nose	6.8	Back of the hand	31.6
Cheek	11.3	Forearm, underside	15.0
Eyelid	11.3	Forearm, back	40.0
Forehead	22.6	Upper arm	68.0
Chin	33.8	Kneecap	36.0
Sternum	45.0	Thigh	68.0
Nape of the neck	67.7	Lower leg	40.6
Back	68.0	Heel	22.6

**Table 4.6.13: Number and Distribution of Hot and Cold Spots in Human Skin**

nr = not resolvable into spots.

From GAUER et al. 1972

Body region	Number of cold spots per cm <sup>2</sup>	Number of hot spots per cm <sup>2</sup>
Forehead	5.5– 8	2
Nose	8 –13	1
Mouth	16 –19	nr
Rest of face	8.5– 9	1.7
Breast	9 –10.2	0.3
Forearm	6 – 7.5	0.3–0.4
Palms of the hands	1 – 5	0.4
Backs of fingers	7 – 9	1.7
Finger, underside	2 – 4	1.6
Thigh	4.5– 5.2	0.4

**Table 4.6.14: Odor Threshold in Humans for Selected Distinctive Substances**Data after GANONG 1972, KEIDEL 1971, *Lexikon der Biologie*, REIN and SCHNEIDER 1971

Substance	Olfactory threshold (mg/l air)
Pyrazine	300
Ethanol	100
Ethyl ether	5.83
Chloroform	3.30
Naphthalene	0.04
Pyridine	0.03
Peppermint oil	0.02
Iodoform	0.02
Propyl mercaptan	0.006
Acetic acid	0.001
Vanilla	0.00005
Synthetic musk	0.00004
Butyric acid	0.00001
Skatole	0.0000035
$\alpha$ -Ionone	0.0000005
Methyl mercaptan	0.0000004

**Table 4.6.15: Taste Thresholds in Humans**

Figures represent the minimum amount of the substance in question in grams per liter of water.

Figures from KEIDEL 1971

Taste quality	Substance	Threshold (g/l)
Sweet	Saccharin	0.001
Sour	Hydrochloric acid	0.01
Salty	Common salt	1.0
Bitter	Quinine	0.004

## Part 5: Comparative Data

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**Table 5.1: Composition of Animal and Plant Organisms from the Elements**

Figures represent the percentage of total weight. Please note that just the four elements of carbon, hydrogen, oxygen, and nitrogen account for 99.77% of the weight of plants and 96.54 % of animals. See also Table 4.1.3, for the specific figures on the human organism.

From HEIDERMANNS 1957, modified

	Animal (here: mammal)	Plant (here: stone pine)
Carbon (C)	21.15	53.960
Hydrogen (H)	9.86	7.130
Oxygen (O)	62.43	38.650
Nitrogen (N)	3.10	0.030
Calcium (Ca)	1.90	0.007
Phosphorus (P)	0.95	0.005
Potassium (K)	0.23	0.006
Sulphur (S)	0.16	0.052
Chlorine (Cl)	0.08	0.001
Magnesium (Mg)	0.027	0.003
Iodine (I)	0.002	0.002
Iron (Fe)	0.005	0.030
Fluorine (F)	0.003	0.001
Aluminum (Al)	0.001	0.065
Silicon (Si)	0.001	0.057
Manganese (Mn)	0.0005	0.001

**Table 5.2: Water Content of Organisms**

Figures as percentage of total weight. See also Tables 1.1.19 and 2.1.10.

Data after BUDDENBROCK 1956, HEIDERMANNS 1957, STRASBURGER 1978

Species	Water content (%)
<b>Plants</b>	
Algae	up to 98.0
Slime molds	70–94.0
Leaves, higher-order plants	80–90.0
Cucumber	up to 95.0
Wood	50.0
Dry seeds	13–14.0
<b>Animals</b>	
Moon jelly	98.2
Leech ( <i>Herpobdella</i> )	86.3
Ascaris worm	79.3
Edible snail (without shell)	84.4

(Cont.) →

Species	Water content (%)
Terrestrial nematodes ( <i>Planorbis</i> )	88.3
Water flea	73.9
Caterpillar of the small white (butterfly)	83.0
Colorado potato beetle	62–66.0
Grain weevil	40–44.0
Tench	80.0
Frog	77.0
Sheep	57.0
Pig	55.0
Rabbit	69.0
<b>Human</b>	
Adult	60.0
Embryo, 15 weeks	91.5
Fetus, 24 weeks	85.0
Fetus, 30 weeks	79.0
Newborn	66.0

**Table 5.3: Size and Molecular Weight of Selected Important Biological Molecules**

Data after CZIHAK et al. 1976, HARTMANN 1953, HEIDERMANNS 1957, KARLSON 1974, MEYER 1964

	Size	Mol. wt.
Myoglobin	0.07 $\mu\text{m}$	17,500
Myosin		468,000
Fibrinogen	0.68 $\mu\text{m}$	400,000
Serum albumin (horse)	0.28 $\mu\text{m}$	66,900
Serum globulin (horse)	0.56 $\mu\text{m}$	150,000
Pepsin	0.14 $\mu\text{m}$	35,500
Urease	1.68 $\mu\text{m}$	483,000
Insulin	0.14 $\mu\text{m}$	35,500
Catalase	1.12 $\mu\text{m}$	281,600
Hemoglobin (human)	2.8 $\mu\text{m}$	66,800
Hemocyanin	up to 26.88 $\mu\text{m}$	up to 6,300,000
Glycogen		$1-16 \times 10^6$
Cellulose	8.3 $\mu\text{m}$	2,400,000
Glucose	0.7 nm	180
Chlorophyll	3.5 nm	approx. 900
Amino acid glycine	7 $\text{\AA}$	75
Amino acid leucine	12 $\text{\AA}$	131

**Table 5.4: Redox Potentials of Selected Organic Compounds**

Since the redox potential depends upon the given pH value, the latter is also indicated.

After *Enzyklopädie* 1979, HIRSCH 1966

	pH value	Potential $E_0$ (volt)
Cytochrome a	7.4	+ 0.29
Cytochrome c	5–8	+ 0.26
Cytochrome b	7.4	– 0.04
Hemoglobin	7.0	+ 0.152
Ascorbic acid	4.59	+ 0.136
Methylene blue	7.0	+ 0.011
Pyocyanin	7.0	– 0.034
Flavoprotein	7.0	– 0.059
Hemin	6.99	– 0.114
Lactate/pyruvate	7.01	– 0.186
Riboflavin	7.0	– 0.208
Cystine/cysteine	7.15	– 0.227
Gluthathione	7.15	– 0.233
Coenzyme I	7.4	– 0.325

**Table 5.5: Dimensions of Cells and Organelles**

Data after CZIHAK et al. 1976, DAVID 1977, METZNER 1966, MEYER 1964, SCHARF and WEBER 1976, STRASBURGER 1978

	Length	Diameter
Foot-and-mouth disease virus		10 nm
Influenza virus		120 nm
Tobacco mosaic virus	28 nm	
<i>Micrococcus</i> (bacterium)		0.2 $\mu\text{m}$
<i>Escherichia coli</i>	3 $\mu\text{m}$	
<i>Thiospirillum</i> (bacterium)	80 $\mu\text{m}$	
Yeast cells		6– 8 $\mu\text{m}$
<i>Chlamydomonas</i> (flagellate alga)		20 $\mu\text{m}$
Diatoms, pennate	180 $\mu\text{m}$	
Diatoms, centric		35 $\mu\text{m}$
Red blood cells, human		7.5 $\mu\text{m}$
Spermatozoon, human	50 $\mu\text{m}$	2 $\mu\text{m}$
Egg cell, human		100 $\mu\text{m}$
Ostrich egg cell	150 mm	
Epidermis, oak		28 $\mu\text{m}$
Pith, elder		200 $\mu\text{m}$
Epidermis, onion		400 $\mu\text{m}$

(Cont.) →

	Length	Diameter
Fiber cell, flax	40–65 mm	
Fiber cell, nettle	50–75 mm	
Internodal cell, <i>Chara</i>	40–80 mm	
Fiber cell, ramie	400 mm	
Oral mucosa cell, human		60–80 $\mu\text{m}$
Mitochondria		0.5– 0.8 $\mu\text{m}$
Dictyosomes	0.2– 5.5 $\mu\text{m}$	
Chloroplasts		4– 8 $\mu\text{m}$
Ribosomes		10–15 nm
Simple membrane, plants		6– 8 nm
Double membrane, endoplasmatic reticulum, plants		25–30 nm
Cell membrane, human, oral mucosa		7.67 nm
Cell membrane, human, erythrocyte		8.5 nm

### Table 5.6: Speed of Movement of Cells and Organelles

Figures from CZIHAK et al. 1976, *Documenta Geigy* 1975, HERTEL 1963, KÄSTNER 1973, OPPENHEIMER and PINCUSSEN 1927, PROSSER 1973

Cell or organelle	Speed ( $\mu\text{m/s}$ )
<i>Bacillus subtilis</i>	10
<i>Bacillus megatherium</i>	200
<i>Euglena</i>	130– 200
Amoeba ( <i>A. limax</i> )	1
Diatom	7
Paramecium	2,000–3,000
Zoospore from sea lettuce	150
Spermatozoids of the liverwort <i>Marchantia</i>	20– 27
Migrating plasmodia	14– 17
Spermatozoa, cattle	200
Spermatozoa, human	1,300–2,600
White blood cells, human	4– 24
Lymphocytes in tissue culture	0.55
Chromosomes during cell division	0.01– 0.03
Golgi vesicle (plant cell)	0.1– 0.3
Vesicle transport down the neuronal axon	1– 10
Plasma flow in root hairs	2– 16
Plasma flow in <i>Nitella</i>	80–1,000

**Table 5.7: Times of Cell Division in Selected Cells**

Data after BERKALOFF et al. 1973, HIRSCH 1966, KUHL 1964, NOUGARÈDE 1969, OPPENHEIMER and PINCUSSEN 1930

Species and cell	Prophase	Metaphase	Anaphase	Telophase	Overall time
Heliozoa	12 min	3–6 min	4 min		30 min
Broad bean, meristem	90 min	31 min	34 min	34 min	189 min
Pea, endosperm	40 min	20 min	12 min	110 min	182 min
Iris, endosperm	40–60 min	10–30 min	12–22 min	40–75 min	140 min
Grasses, stomata cells	36–45 min	7–10 min	15–20 min	20–35 min	78–110 min
Newt, fibroblasts	18 min	38 min	26 min	28 min	110 min
Chicken, fibroblasts	45 min	6 min	2 min	10 min	63 min
Chicken, mesenchyme	30–60 min	2–10 min	2–3 min	3–12 min	37–82 min
Rat, hepatocytes	4 h	10 min	30 min	30 min	5 h 10 min
Sea urchin eggs, furrow formation					30–40 min
<i>Drosophila</i> eggs, furrow formation	4 min	30 s	1 min	50 s	6 min 20 s

**Table 5.8: Dimensions of Cell Nuclei**

Figures for selected organs and animals

Figures from DAVID 1977

Species	Organ	Diameter (μm)	Volume (μm <sup>3</sup> )
Mouse	Liver	10.1	528
	Pancreas	6.4	142
	Cardiac muscle	8.8 × 2.3	
	Striated muscle	10.4 × 3.3	
	Smooth muscle	10.2 × 2.2	
Rat	Adrenal cortex	7.1	187
Guinea pig	Spinal ganglion	12.0	915
Rabbit	Spinal ganglion	14.8	1,678
Cat	Spinal ganglion	13.3	1,245
Dog	Spinal ganglion	13.9	1,415
Cattle	Spinal ganglion	16.5	2,338

(Cont.) →

Species	Organ	Diameter ( $\mu\text{m}$ )	Volume ( $\mu\text{m}^3$ )
Human	Kidney	$6.2 \times 5.5$	1,509
	Spinal ganglion	14.2	
	Lung. alveoli	$5.8 \times 3.7$	
Amphibians	Oocyte	480	

**Table 5.9: Dimensions of the Mitochondria of Selected Organs and Organisms**

After KLIMA 1967

Species, Organ	Diameter ( $\mu\text{m}$ )	Length ( $\mu\text{m}$ )
<i>Euglena</i>	0.50	10.0
Bread mold ( <i>Neurospora</i> )	0.50	3.0
Oats, coleoptiles	0.50	1.0
Migratory locust. wing muscle	1.00	8.0
Blowfly, wing muscle	1.00	3.0
Alpine newt, chorda	0.3–0.50	3.0
Sparrow, cardiac muscle	1.00	2.0
Rat, cardiac muscle	0.4–0.70	1.5
Rat, kidney, proximal tube	0.5–0.70	8.0
Rat, spinal marrow neuron	0.20	2.5
Guinea pig, ovary	0.5–0.75	1.0
Golden or Syrian hamster, small intestine	0.2–0.25	2.5
Human, small intestine	0.5–1.20	2.0
Human, retinal rods	0.18–0.25	4.0

**Table 5.10: Mitochondria: Cell Share**

Figures represent mitochondria volume as a proportion of total cell volume, given as percentage.

Figures from DAVID 1977

Species	Organ	Mitochondria (%)
Housefly	Wing muscle	28.2
Migratory locust	Wing muscle	30
Sticklebacks ( <i>Gasterosteidae</i> )	Pituitary gland	4.2
Cod (Baltic Sea)	Red muscle fiber	25.39
	White muscle fiber	1.17

Species	Organ	Mitochondria (%)
Frog	Liver	5.38
Rock dove	Liver	20.02
Hedgehog	Spinal ganglion	14.7
Mouse	Liver	16.93
	Pituitary gland	7.5
	Heart, ventricle	47.7
	Heart, atrium	34.9
	Leukocytes	3.6
Rat	Liver	18.38
	Pancreas	7.9
	Kidney	37.23
	Heart	35.8
Guinea pig	Smooth muscle cell	4.7
Rabbit	Liver	11.46
Cattle	Liver	17.75
Human	Liver	13.22
	Small intestine	13.34

**Table 5.11: DNA Content of Diploid Cell Nuclei**

Figures represent the amount of DNA per cell nucleus in picograms. For the chromosome sets of selected animals, see Table 1.9.3; for plants, see Table 2.2.9.

Data after BERKALOFF et al. 1973, BRESCH and HAUSMANN 1972, NAGL 1976

Organism	DNA per nucleus (pg)
<i>Escherichia coli</i> (bacterium)	0.0042
Pine	93.8
Fir	100.0
Wheat	36.2
Rye	17.7– 18.9
Corn (maize)	6.6– 15.4
Barley	12.8
Meadow grass ( <i>Poa annua</i> )	7.0
Onion	33.5
Tradescantie	116.0
Lesser celandine	19.6
Tobacco	13.0
Pea	9.1
Shepherd's purse	1.7
Sunflower	9.8
House cricket	12.0
Fruit fly ( <i>Drosophila</i> )	0.2

(Cont.) →

Organism	DNA per nucleus (pg)
Goldfish	4.0
Carp	3.4
Pike	1.7
Trout	4.9
Fire salamander	85.3
Edible frog	16.8
Common toad	15.0
Tree frog	11.6
Turtle	5.3
Snakes	5.0
Chicken	2.5
Goose	2.9
Sparrow	1.9
Rat	5.7
Mouse	5.0
Guinea pig	5.9
Dog	5.3
Cattle	6.4
Sheep	5.7
Human	5.8

**Table 5.12: Size of DNA in Selected Organisms**

For organisms with chromosomes, figures apply to the haploid chromosome set. For absolute quantity in picograms, see Table 5.11.

Figures from *Lexikon der Biologie*

Species	Length of DNA	Base pairs
Mitochondrial DNA, human	5.6 $\mu\text{m}$	16,569
Mitochondrial DNA, yeast	25 $\mu\text{m}$	$7.5 \times 10^3$
Chloroplast DNA corn (maize)	44 $\mu\text{m}$	$140 \times 10^3$
Bacteriophage $\lambda$	16.5 $\mu\text{m}$	48,502
<i>Escherichia coli</i>	1.36 mm	$4 \times 10^6$
Yeast ( <i>Saccharomyces cerevisiae</i> )	4.6 mm	$13.5 \times 10^6$
Fruit fly ( <i>Drosophila melanogaster</i> )	56 mm	$160 \times 10^6$
Sea urchin ( <i>Strongylocentrotus purpuratus</i> )	170 mm	$800 \times 10^6$
African clawed frog ( <i>Xenopus laevis</i> )	1 m	$3 \times 10^9$
Mammals, including humans	1 m	$3 \times 10^9$



**Table 5.13: Base Ratios in the DNA of Selected Organisms**

A = adenine, C = cytosine, G = guanine, T = thymine.

Note that there are equal quantities of each of the respective bases within a given complementary pair (thus equal quantities of adenine and thymine, on the one hand, and of guanine and cytosine, on the other).

Figures from BRESCH and HAUSMANN 1972, CZIHAK, LANGER and ZIEGLER 1976

Species	(A + T) : (G + C)
<b>Viruses</b>	
Herpes simplex virus	0.47
T2 phage	1.86
Bacteriophage $\lambda$	0.79
<b>Bacteria</b>	
<i>Sarcina lutea</i>	0.35
<i>Mycobacterium tuberculosis</i>	0.60
<i>Escherichia coli</i>	0.93–0.97
<i>Vibrio cholerae</i>	1.31
<i>Bacillus subtilis</i>	1.66
<b>Plants and Fungi</b>	
Yeast ( <i>S. cerevisiae</i> )	1.79
Black mold ( <i>Asp. niger</i> )	1.00
<i>Euglena gracilis</i> , cell nucleus	0.88
<i>Euglena gracilis</i> , plastid DNA	3.23
Wheat	1.19–1.22
<b>Animals</b>	
Migratory locust	1.41
Sea urchin ( <i>Paracentrotus</i> )	1.84
Sea urchin ( <i>Arbacia</i> )	1.58
Crab ( <i>Cancer borealis</i> )	17.50
Trout	1.34
Herring	1.23
Chicken	1.38
Sheep	1.36
Cattle	1.30
Horse	1.33
Human	1.40–1.52

**Table 5.14: Differences in the Number of Amino Acids in Humans Versus Selected Organisms as Exemplified by Cytochrome c.**

Cytochromes are among the oldest of proteins and are made up of somewhat more than 100 amino acids. For this reason, differences in amino acids allow us to draw conclusions about the degree of relatedness or the period of divergent development of the organisms being compared.

Figures from DICKERSEN and GEIS 1971

Organisms compared	Number of differing amino acids in cytochrome c
Human – rhesus monkey	1
Human – rabbit	9
Human – gray whale	10
Human – cow, sheep, pig	10
Human – kangaroo	10
Human – donkey	11
Human – dog	11
Human – Peking duck	11
Human – horse	12
Human – chicken, turkey	13
Human – penguin	13
Human – rattlesnake	14
Human – snapping turtle	15
Human – bullfrog	18
Human – tuna	21
Human – fly ( <i>Chrysomyia</i> )	27
Human – silkworm	31
Human – wheat	43
Human – baker's yeast	45
Human – sac fungus ( <i>Neurospora crassa</i> )	48
Human – yeast ( <i>Candida krusei</i> )	51

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