Supporting Information

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SI Methods

Metabolic rates of 3,006 species across life's major domains were analyzed in the article, as listed in the accompanying Datasets S1–S11. Here, we report additional information on data conversions used in our analyses.

Mass Units Conversions. To make the data reported on either wet or dry mass bases across different groups studied comparable, we chose the ratio of DM/WM = 0.3 for converting dry-mass based q_{DM} to wet-mass-based metabolic rates q, $q = q_{DM} \times 0.3$. The value 0.3 was chosen as a crude mean for the DM/WM ratio of the nongelatinous groups where metabolic rates were reported on wet mass basis (letter W in the U column of Table 1).

Note that applying a single DM/WM = 0.3 ratio is conservative with respect to the main conclusion of the article about the narrow range of the observed mass-specific metabolic rates between the studied groups. Using a lower DM/WM (e.g., DM/WM = 0.15–0.20) for heterotrophic unicells or a DM/WM > 0.3 ratio for vascular plants would have left the observed range of mean taxonomic mass-specific metabolic rates (Table 1) essentially unchanged. Given the scarce information on DM/WM ratio across the groups, it seems unjustified to be very specific here, so a universal DM/WM = 0.3 ratio was applied.

Further Details on Temperature Conversions: Information on Q_{10} Determination in Macroalgae seen in Dataset S9. All nonendothermic data were adjusted to 25°C before analyses. No temperature adjustments of metabolic rates were performed for endothermic vertebrates. Endotherms do not live at body temperatures of 25°C, and very few ectotherms live at ambient temperatures in the vicinity of 40°C. Therefore, expression of endothermic and ectothermic metabolic rates at one and the same temperature (White *et al.*, 2006), which is fully relevant for testing recent models of metabolic rate dependence on body size and temperature, does not conform to the goal of the present study, which is to explore and describe the realistic range of metabolic rates. Noteworthy, the temperature of 25°C is representative of tropical forest habitats where the diversity of life forms is the greatest.

On the Question of Minimal Metabolic Rates in Aquatic Organisms. Because the buoyancy of the living matter is not precisely zero, to sustain their position in space aquatic organisms (unless they are bottom-dwellers) need to swim, i.e., they make periodical mechanical movements to adjust the position of their bodies in the water column. Terrestrial animals, helped by gravity, can remain in a given point of the Earth surface without locomotive energy expenditures.

The theoretical issue on what is the true "standard metabolism" in aquatic animals and how it compares with that of terrestrial animals is a big and important one. Metabolic rate measurements are characterized by some duration, i.e., the period during which metabolic rate is measured. For example, during a many hours' measurement the completely motionless state can be found as being unnatural or even health-detrimental for many terrestrial animals, especially the metabolically active ones like shrews. For such animals, too, locomotion can be thought of as an essential part of maintenance expenditures. At the other extreme, during short-term measurements in the order of several minutes many aquatic animals (otherwise periodically performing swimming movements) can be found motionless, similar to terrestrial animals during standard metabolic rate measurements.

On a practical basis, with the advent of measurement facilities that allow for a long-term, high-resolution, real-time monitoring of metabolic rates, it became possible to discriminate such periods of minimal activity in aquatic animals; accordingly, these were sometimes thought of as representing the true standard metabolic rate or "minimal" metabolic rate (e.g., Steffensen 2002). For example, Kawall *et al.* (2001) studied Antarctic copepods making dozens of sequential 30-min runs of metabolic rate measurements for each individual. Mean minimum 30-min values were found to be approximately one-third at high as the mean—i.e., "routine"—metabolic rate in the studied species.

However, a great deal of data that are available in the literature (and which we make use of in our article) was obtained by standard techniques. Such data pertain to routine metabolic rate, i.e., the one that accounts for some swimming. Here, in the following paragraph we compare the existing data on "minimal" metabolic rate from the direct long-term, high-resolution measurements described above with the averages we obtained for the same aquatic taxa (see Table 1).

It is important to note that in our dataset we took the minimal (after temperature correction) value available in the literature for each species. When the directly measured minimum data of Kawall *et al.* (2001) were corrected for temperature and body size, these values appeared on average to be 50% lower than the copepod mean values we used in our study (see Table S1). Similarly, using data of Steffensen (2002) as "etalons" for minimal metabolic rate in fish, we found even better agreement with the established taxonomic mean from Table 1 (≈10% lower on average). These data indicate that the elevation of the reported taxonomic means of metabolic rate in aquatic animals (Table 1) above the "minimal" metabolic rate is within several dozens of percent, i.e., it is significant, but is significantly smaller than the severalfold range of mean values among taxa and taxon groups discussed in the article.

Comparing terrestrial versus aquatic vertebrates, e.g., reptiles versus fish, as suggested by an anonymous referee, is a very interesting idea. For reptiles the mean taxonomic q (AMR) from Table 1 is 0.30 W kg^{-1} at mean body mass of 700 g, whereas for fish it is 0.38 W kg^{-1} at 400 g (data for 25°C). Using the established mass scaling coefficient $\beta = -0.22$ for reptiles (Table 1), we calculate that at body mass of $M = 400$ g the average reptile would have 0.34 W kg^{-1}, which is statistically indistinguishable from the fish mean.

As follows from Table S1, our data for fish are very close to minimal rather than routine metabolic rates. This coincidence between reptile and fish average values hints that namely the minimal (rather than routine) metabolic rates of aquatic ectothermic vertebrates might be the relevant metabolic analogy of standard metabolic rate measured in motionless terrestrial ectothermic vertebrates. But clearly much more analysis is needed to reach a definitive conclusion here.

Miscellaneous. Out of 245 measurements of endogenous metabolic rates in heterotrophic prokaryotes, that were analyzed in this study, only 14 (5.7%) were accompanied by some information on cell size. In all other cases this information had to be found elsewhere.

Data on basal metabolic rates of mammals were taken from appendix 1 of the work of Savage *et al.* (2004). Minimal mass-specific values for each species were taken. Note that using,

for each species, mean species values given by Savage *et al.* (2004) in their appendix 1 instead of minimum values changes the geometric mean of the sample by 7%, from 4.4 W kg^{-1} (Table 1) to 4.7 W kg^{-1}.

All other information can be found in the corresponding files for taxonomic groups. As specified in *Methods*, we used the conversion factor of 20 J per 1 ml of O_2 consumed to convert oxygen consumption rates to energy consumption rates. While in plants, bacteria and fungi O_2 uptake may or may not be coupled to ATP synthesis (where the so-called cyanide-resistant respiration can indeed constitute a substantial portion of total respiration), this does not affect the energetic conversion factor, which only depends on the products of chemical reaction.

That is, if a carbohydrate molecule $(CH_2O)_n$ is oxidized to produce water and carbon dioxide, $(CH_2O)n + nO_2 = nCO_2 + nH_2O$, the energy released will not depend on the chemical pathway, i.e., whether ATP synthesis was involved or not. For this reason, for example, the caloric equivalent of organic food (i.e., how much energy is released after its oxidation) can be measured (and originally was in the first food measurements made for military troops, fodder for cattle, etc.) by simply burning the food in the oven, where apparently no ATP synthesis occurs.

To summarize, the particular biochemical pathway provided the reaction products are the same does not influence the energetic equivalent of oxygen. The value of 20 J per 1 ml of O_2 that we use is representative of the main biochemical substrates oxidized by aerobic life, proteins (≈19 J per ml of O_2), lipids (≈20 J per ml of O_2) and carbohydrates (≈21 J per ml of O_2), to the accuracy of 5%.

References for *SI Methods* and Tables S1–S3

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Table S1. Comparison of minimal metabolic rates with taxonomic means from Table 1 in fish and copepods

Species	Body mass, g	Temp, °C	MMR, W kg^{-1}	MMR adjusted to 25°C and to the mean taxonomic body mass from Table 1	AMR, W kg^{-1}	MMR/AMR
			Fish			
Onchorhynchus mykiss	392	10	0.19	0.40	0.38	1.1
Trematomus hansoni	100	−1	0.11	0.32	0.38	0.8
Pagothenia borchgrevinki	100	−1	0.11	0.32	0.38	0.8
Mean for fish						0.9
			Copepods			
Calanoides acutus	0.0033	0			3.0	0.4
Calanus propinquus	0.0047	0			3.0	0.7
Metridia gerlachei	0.0014	0			3.0	0.7
Gaetanus tenuispinus	0.0036	0			3.0	0.1
Rhincalanus gigas	0.0117	0		1.	3.0	0.3
Paraeuchaeta antarctica	0.0196	0			3.0	0.5
Heterohabdus farrani	0.0032	0			3.0	0.8
Mean for copepods						0.5

MMR, minimal metabolic rate; AMR, average taxonomic metabolic rate from Table 1. Data for fish are from Steffensen (2002), and for copepods are from Kawall *et al.* (2001). Note: for temperature and body mass adjustments of MMR Q_{10} values of 1.65 and 2.0 (*Methods*) and scaling exponents $\beta = -0.15$ and -0.30 (Table 1) were used for fish and copepods, respectively.

Table S2. Nitrogen content in the taxonomic groups studied

Taxonomic group	N/DM, %	Reference	Comment
		Heterotrophs	
Prokaryotes	6.5–8.9	*Arthrobacter globiformis*	van Veen and Paul 1979
	9.1–11.1	*Enterobacter aerogenes*	van Veen and Paul 1979
	10.0–14.1	*Bacillus cereus*	Dataset S1
	5.6–8.9	*Mycobacterium phlei*	Tepper 1968
	10	*Streptococcus agalactiae*	
	9.5	MEAN	
Protozoa	10.6	Used as a mean value for analysis of an extensive metabolic dataset	Vladimirova and Zotin 1983
	12	Used as a mean value for analysis of an extensive metabolic dataset	Fenchel and Finlay 1983
Insects	9.7 ± 0.2	119 herbivores insect species, mean ± 1 SE	Fagan *et al.* 2002
	11 ± 0.2	33 predator species, mean ± 1 SE	Fagan *et al.* 2002
Aquatic invertebrates	9–11	Crustacean zooplankton in freshwater lake	Andersen and Hessen 1991
Crustacea: copepods and krill	9–11	Sargasso Sea	Beers 1966
	9.8 ± 0.06	n = 10 species (mean ± 1 SD)	Dataset S4
Crustacea: peracarids	6.4 ± 1.9	n = 13 species (mean ± 1 SD)	Dataset S4
Crustacea: decapods	8.3 ± 1.8	n = 12 species (mean ± 1 SD)	Dataset S4
Mollusca: cephalopods	n.d.		
Gelatinous invertebrates	10	chaetognath Sagitta elegans	Ikeda and Skjoldal 1989
	4.3	medusa Aglantha digitale	Ikeda and Skjoldal 1989
Ectothermic vertebrates			
Amphibians	n.d.		
Fish	11.5	*Ictalurus punctatus*	Brugger 1993
	14.2	*Dorosoma cepedianum*	Brugger 1993
	13.7	*Lepomis cepedianum*	Brugger 1993
Reptiles	n.d.		
Endothermic vertebrates			
Birds	12–14	*Zonotrichia leucophrys*, lean dry mass	Chilgren 1985
Mammals	11.2–13.2	Various tissues of *Dugong dugong*	Yamamuro *et al.* 2002
	9.7	Rat, whole body	Truszkowski 1927
	12	Guinea-pig, whole body	Truszkowski 1927
	14.5	Horse, skeletal muscle	Truszkowski 1927
	15.2	Mean for 24 tropical bats, whole body	Studier *et al.* 1994
		Photoautotrophs	
Cyanobacteria	4–9		Fogg *et al.* 1973
	4.2–13.1	*Spirulina platensis*	Gordillo *et al.* 1999
	9.4	*Anacystis nidulans*	Kratz and Myers 1955
Eukaryotic microalgae	6.9–8.6	*Chatocerus furcellatus**	Dataset S8
	5.1–6.3	*Coscinodiscus* sp. C38B*	Dataset S8
	6.0–7.5	*Coscinodiscus* sp. CoA*	Dataset S8
	6.8–8.5	*Ditylum brightwellii**	Dataset S8
	9.1–11.4	*Dunaliella tertiolecta**	Dataset S8
	8.3–10.4	*Emiliania huxleyi**	Dataset S8
	4.8–6.0	*Gonyaulax tamarensis**	Dataset S8
	7.3–9.1	*Isochrysis galbana**	Dataset S8
	6.9–8.6	*Leptocylindrus danicus**	Dataset S8
	3.1–3.9	*Monochrysis lutheri**	Dataset S8
	5.6–6.9	*Olisthodiscus luteus**	Dataset S8
	8.2–10.2	*Phaeodactylum tricornutum**	Dataset S8
	10.8–13.5	*Prorocentrum micans**	Dataset S8
	5.9–7.4	*Skeletonema costatum**	Dataset S8
	8.7–10.9	*Stephanodiscus neoastraea**	Dataset S8
	7.5–9.4	*Thalassiosira nordenskioeldii**	Dataset S8
	5.1–6.3	*Thalassiosira pseudonana**	Dataset S8
	6.3–7.9	*Thalassiosira weissflogii**	Dataset S8
	6.3–7.9	MEAN	
Phytoplankton	5.5 ± 2.5	Mean ± 1 SD for 112 measurements	Duarte 1992
Eukaryotic macroalgae	1.9 ± 0.8	Mean ± 1 SD for 298 measurements	Duarte 1992
Vascular plants: green leaves	1.7	Geometric mean for 2,061 measurements; 95% C.I. 0.6–5	Data of Wright *et al.* 2004
Vascular plants: tree saplings	0.54	Geometric mean for 118 measurements; 95% C.I. 0.3–1	Data of Reich *et al.* 2006
Vascular plants: seedlings	2.8	Geometric mean for 198 measurements; 95% C.I. 1.6–5.0	Data of Reich *et al.* 2006

N/DM, nitrogen mass to dry mass ratio.

*N/DM calculated from the known C/N mass ratio assuming either 40% or 50% carbon in dry mass (lower and upper value of the range, respectively). The two species with known carbon/dry mass ratios were *Navicula pelliculosa* (C/DM = 0.412) and *Stephanodiscus neoastraea* (C/ODM = 0.46; ODM, organic dry matter). For each species, the N/DM ratio shown corresponds to the measurement with the lowest metabolic rate.

Table S3. Dry matter content in the taxonomic groups studied

Taxonomic group	U	DM/WM	Reference	Comment
			Heterotrophs	
Prokaryotes	D	0.16–0.40	Posch *et al.* 2001	Depends on cell size and measurement technique
Protozoa	D	0.15	Fenchel and Finlay 1983	
		0.135	Vladimirova and Zotin 1983	
Insects	W	0.2–0.6	Hadley 1994	
Aquatic invertebrates	W			
Crustacea: copepods and krill	W	0.19 ± 0.05	Dataset S4	n = 55 species (mean ± 1 SD)
Crustacea: peracarids	W	0.22 ± 0.15	Dataset S4	n = 38 species (mean ± 1 SD)
Crustacea: decapods	W	0.23 ± 0.08	Dataset S4	n = 18 species (mean ± 1 SD)
		0.29	Ivleva 1980	208 observations for eight species of tropical and temperate decapods
Mollusca: cephalopods	W	n.d.		
Gelatinous invertebrates	W	0.035–0.05	Hirst and Lucas 1998	medusae
		0.035–0.30	Hirst and Lucas 1998	chaetognaths
		0.1	Ikeda and Skjoldal 1989	chaetognaths
Ectothermic vertebrates	W			
Amphibians	W	n.d.		
Fish	W	0.26 (0.18–0.30)	Tierney *et al.* 2002	Mesopelagic Antarctic fishes
		0.29 (0.13–0.36)	Torres and Somero 1988	Mesopelagic Antarctic fishes
		0.24–0.29	Brugger 1993	3 North American fishes
Reptiles	W	n.d.		
Endothermic vertebrates	W			
Birds	W	0.30–0.38	Skadhauge 1981	
Mammals	W	0.38	Balonov and Zhesko 1989	Rats, mice, dogs, humans
			Photoautotrophs	
Cyanobacteria	D	0.42*	Fietz and Nicklisch 2002	*Planktothrix agardhii*
		0.067,0.172	Scherer *et al.* 1984	Two fully hydrated Nostoc spp.
		0.035	Li and Gao 2004	*Nostoc sphaeroides*
Eukaryotic microalgae	C	0.18–0.26*	Myers and Graham 1971	*Chlorella pyrenoidosa*
		0.27*	Fietz and Nicklisch 2002	*Stephanodiscus neoastraea*
Eukaryotic macroalgae	D	0.23 (0.12–0.54)	Weykam *et al.* 1996	35 Antarctic species
Vascular plants: green leaves	D	0.16–0.41	Vile *et al.* 2005	DM/WM increases from short-lived forbs to trees
Vascular plants: tree saplings	D	n.d.		
Vascular plants: seedlings	D	n.d.		

DM/WM, dry mass to wet mass ratio; U, dominant mass units in the original data sources: metabolic rates reported mostly per dry (D), wet (W), or carbon (C) mass basis.

*Calculated from DM/volume ratio assuming cell density of 1 g ml^{-1}.

Other Supporting Information Files

Dataset S1

Dataset S2

Dataset S3

Dataset S4

Dataset S5

Dataset S6

Dataset S7

Dataset S8

Dataset S9

Dataset S10

Dataset S11

SI Appendix