Table 3. Molecular motors. (No, line number; Ab, abbreviated motor name; Ty, motor type: M1 = single molecule, M2 = molecular assembly, including myofibrils and myocytes; U, organism: U = unicellular, Z = multicellular; C, S = swimming; T = terrestrial, solid surface; F = flying; N = non-locomotory; group, taxonomic group, see list of abbreviations; motor: m. = muscle; *M*, cell or body mass (kg); *I*, mass indicated in the cited article : Y = Yes, N = No; *A*, molecular area (nm^2); *F*, force (pN) or torque (pN nm)/lever arm (nm) of rotary motors; *f*, specific tension (kPa); T, temperature (°C), R = room temperature; Comment, f. = force.)

no.	Ab	Ty	U	C	species	group	motor	*M* (kg)	*I*	*A* (nm^2)	*F* (pN)	*f* (kPa)	*T* (°C)	comment	reference
linear motors															
1	RN	M1	U	N	*Escherichia coli*	Ba	RNA polymerase	1.3×10^{-15}	N	99	25	253	—	stall force	Wang *et al.* [17]
2	DC	M1	U	N	*Saccharomyces cerevisiae* (yeast)	Fu	dynein (cytoplasmic)	3×10^{-13}	N	67	7	104	25	stall force	Gennerich *et al.* [16]
3	DC	M1	Z	N	*Drosophila melanogaster* (fruit fly)	In	dynein (cytoplasmic, early embryo)	0.9×10^{-13}	N	67	1.10	16	—	estimate per single dynein	Gross *et al.* [32]
4	DC	M1	Z	N	*Sus scrofa domesticus* (pig)	Ma	dynein (cytoplasmic, brain)	1.6×10^{-13}	N	67	7.50	112	25	active dynein stall force	Toba *et al.* [33]
5	DC	M1	Z	N	*Bos taurus* (bull)	Ma	dynein (cytoplasmic, brain)	10^{-13}	N	67	1.10	16	24	stall force	Mallik *et al.* [34]
6	DA	M1	Z	S	*Tetrahymena thermophile*	Pr	dynein (axonemal, cilia)	3×10^{-11}	N	67	4.70	70	26	single molecule	Hirakawa *et al.* [35]
7	DA	M1	Z	S	*Chlamydomonas reinhardtii*	Al	dynein (axonemal, flagellum)	5×10^{-13}	N	67	1.20	18	—	trap force	Sakakibara *et al.* [36]
8	DA	M1	U	S	*Hemicentrotus pulcherrimus*	Ec	dynein (axonemal, sperm)	10^{-13}	N	67	6	90	25	isolated arms	Shingyoji *et al.* [37]
9	DA	M1	U	S	*Bos taurus* (bull)	Ma	dynein (axonemal, flagellum sperm)	10^{-13}	N	67	5	75	—	isometric stall force, indirect	Schmitz *et al.* [14] (*M* in Holcomb-Wygle *et al.* [38])
10	KI	M1	Z	N	*Loligo pealeii* (squid)	Mo	kinesin (optic lobe)	10^{-12}	N	34	5.50	162	R	stall force	Svoboda & Block [39]
11	KI	M1	Z	N	*Loligo pealeii* (squid)	Mo	kinesin	10^{-12}	N	34	6.50	191	—	maximum stall force	Visscher *et al.* [40], Schnitzer *et al.* [15]
12	KI	M1	Z	N	*Bos taurus* (cow)	Ma	kinesin (brain)	10^{-11}	N	34	6.70	197	26	uniform stall force	Higushi *et al.* [41]
13	KI	M1	Z	N	*Bos taurus* (cow)	Ma	kinesin (brain)	10^{-11}	N	34	4.50	132	30	near isometric	Hunt *et al.* [42]
14	KI	M1	Z	N	*Bos taurus* (cow)	Ma	kinesin (brain)	10^{-11}	N	34	5.40	159	25	force to stop single molecule	Meyhöfer & Howard [43]
15	KI	M1	Z	N	*Bos taurus* (cow)	Ma	kinesin (brain)	10^{-11}	N	34	7	206	26	stall force	Kojima *et al.* [44]
16	KI	M1	Z	N	*Homo sapiens* (man)	Ma	kinesin-1 (recombinant)	10^{-11}	N	34	7.60	224	—	single-kinesin maximum force	Jamison *et al.* [45]

(*Continued*.)

no.	Ab	Ty	U	C	species	group	motor	*M* (kg)	*I*	*A* (nm^2)	*F* (pN)	*F* (kPa)	*T* (°C)	comment	reference
17	MY	M1	Z	S	*Rana esculenta* (frog)	Am	myosin (tibialis anterior muscle)	5×10^{-8}	N	36	3.60	100	4	isometric, indirect	Linari *et al.* [46]
18	MY	M1	Z	S	*Rana esculenta* (frog)	Am	Actomyosin (tibialis anterior m.)	5×10^{-8}	N	36	10	278	4	indirect isometric (indep. n)	Piazzesi *et al.* [47]
19	MY	M1	Z	S	*Rana esculenta* (frog)	Am	myosin (tibialis anterior muscles)	5×10^{-8}	N	36	5.70	158	4	indirect isometric (dep. on n)	Piazzesi *et al.* [48]
20	MY	M1	Z	T	*Oryctolagus cuniculus* (rabbit)	Ma	myosin (heavy meromyosin, ske. m.)	5×10^{-8}	N	36	3.50	97	—	average isometric force	Finer *et al.* [49]
21	MY	M1	Z	T	*Oryctolagus cuniculus* (rabbit)	Ma	myosin (skeletal muscle)	5×10^{-8}	N	36	5.70	158	27	peak isometric	Ishijima *et al.* [50]
22	MY	M1	Z	T	*Oryctolagus cuniculus* (rabbit)	Ma	myosin (heavy meromyosin, ske. m.)	5×10^{-8}	N	36	3.30	92	R	direct (not isometric)	Miyata *et al.* [51]
23	MY	M1	Z	T	*Oryctolagus cuniculus* (rabbit)	Ma	myosin (psoas, fast skeletal m.)	5×10^{-8}	N	36	6.30	175	32	indirect	Tsaturyan *et al.* [52]
24	MY	M1	Z	T	*Oryctolagus cuniculus* (rabbit)	Ma	myosin (skeletal white muscle)	5×10^{-8}	N	36	6.50	181	R	direct (sliding not isometric)	Nishizaka *et al.* [53]
25	MY	M1	Z	T	*Oryctolagus cuniculus* (rabbit)	Ma	myosin (skeletal white muscle)	5×10^{-8}	N	36	9.20	256	R	single molecule unbinding force	Nishizaka *et al.* [54]
26	MY	M1	Z	T	*Oryctolagus cuniculus* (rabbit)	Ma	Actomyosin (skeletal muscle)	5×10^{-8}	N	36	9	250	—	direct isometric	Takagi *et al.* [55]
27	MY	M1	Z	T	*Oryctolagus cuniculus* (rabbit)	Ma	myosin (psoas)	5×10^{-8}	N	36	6.30	175	32	indirect	
28	SP	M2	U	T	*Vorticella convallaria*	Pr	spasmoneme	6.8×10^{-11}	N	1.2×10^{6}	4×10^{4}	33	—	maximum isometric tension	Moriyama *et al.* [56]
29	SP	M2	U	T	*Vorticella convallaria*	Pr	spasmoneme	6.8×10^{-11}	N	2.0×10^{6}	7×10^{4}	35	—	not isometric tension	Upadhyaya *et al.* [12]
30	SP	M2	U	T	*Vorticella convallaria*	Pr	spasmoneme	6.8×10^{-11}	N	2.0×10^{6}	2.5×10^{5}	125	—	isometric tension	Ryu *et al.* [57]
31	PI	M2	U	T	*Escherichia coli*	Ba	pili type P	10^{-15}	N	46	27	587	—	optical tweezers, unfolding f.	Jass *et al.* [58]

(*Continued*.)

no.	Ab	Ty	U	C	species	group	motor	*M* (kg)	*I*	*A* (nm^2)	*F* (pN)	*F* (kPa)	*T* (°C)	comment	reference
32	PI	M2	U	T	*Escherichia coli*	Ba	pili type P	10^{-15}	N	46	27	587	—	optical tweezers	Fällman *et al.* [59]
33	PI	M2	U	T	*Escherichia coli*	Ba	pili type P	10^{-15}	N	46	28	609	—	isometric force	Andersson *et al.* [60]
34	PI	M2	U	T	*Escherichia coli*	Ba	pili type P	10^{-15}	N	46	35	761	—	atomic f. microscopy, plateau	Miller *et al.* [11]
35	PI	M2	U	T	*Escherichia coli*	Ba	pili type I	10^{-15}	N	48	60	1250	—	atomic force microscopy	Miller *et al.* [11]
36	PI	M2	U	T	*Neisseria gonorrhoeae*	Ba	pili type IV	10^{-15}	Y	36	70	1944	—	detachment force	Biais *et al.* [10] (*M* in Kaiser [61], Merz *et al.* [62])
rotary motors															
37	FA	M2	U	N	*Escherichia coli*	Ba	F0 ATPase (ionic pump)	1.3×10^{-15}	N	46	40/3.5	248	—		Noji *et al.* [63], Sambongi *et al.* [7]
38	FA	M2	U	N	*Bacillus*	Ba	F1 ATPase	3×10^{-15}	N	74	40/4.5	120	23		Yasuda *et al.* [8]
39	FL	M2	U	S	*Escherichia coli*	Ba	flagellum (basal + hook)	1.6×10^{-15}	Y	650	4500/20	346	—	stall (or slow rotation)	Berry and Berg [64] (*M* in Berg [9,65])
40	FL	M2	U	S	*Vibrio alginolyticus*	Ba	flagellum	1.3×10^{-15}	N	650	2100/20	162	—	stall torque	Sowa *et al.* [66]
41	FL	M2	U	S	*Salmonella*	Ba	flagellum	4×10^{-15}	N	650	2100/20	162	23	torque at zero speed	Nakamura *et al.* [67]
42	FL	M2	U	S	*Streptococcus*	Ba	flagellum	2×10^{-16}	N	650	2500/20	192	22	torque at zero speed	Lowe *et al.* [68]
myofibrils															
43	MF	M2	Z	T	*Mus musculus* (mouse)	Ma	psoas (fast skeletal m.)	10^{-11}	N	—	—	91	20	single myofibril not stretched	Powers *et al.* [69]
44	MF	M2	Z	T	*Oryctolagus cuniculus* (rabbit)	Ma	psoas (fast skeletal m.)	5×10^{-8}	N	—	—	265	5	not skinned, single or few	Tesi *et al.* [5]
45	MF	M2	Z	T	*Oryctolagus cuniculus* (rabbit)	Ma	psoas (fast skeletal m.)	5×10^{-8}	N	—	—	186	10	bundle (1–3 myofibrils)	Telley *et al.* [70]
46	MF	M2	Z	T	*Oryctolagus cuniculus* (rabbit)	Ma	psoas (fast skeletal m.)	5×10^{-8}	N	—	—	250	23	single or 2–3 myofibrils	Shimamoto *et al.* [71]
47	MF	M2	Z	S	*Rana* sp. (frog)	Am	tibialis anterior & sartorius	5×10^{-8}	N	—	—	376	15	single myofibril	Colomo *et al.* [72]
48	MF	M2	Z	N	*Rana* sp.(frog)	Am	heart atrial myocyte	1.8×10^{-12}	N	—	—	149	15	single myocyte (1–5 myofibrils)	Colomo *et al.* [72] (*M* in Brandt *et al.* [73])

(*Continued.*)

Table 3. (*Continued.*)

no.	Ab	Ty	U	C	species	group	motor	*M* (kg)	*I*	*A* (nm^2)	*F* (pN)	*F* (kPa)	*T* (°C)	comment	reference
49	MF	M2	Z	N	*Rana esculenta* (frog)	Am	heart atrial	1.8×10^{-12}	Y	—	—	120	20	single myocyte (1–5 myofibrils)	Brandt *et al.* [73]
50	MF	M2	Z	N	*Rana esculenta* (frog)	Am	heart ventricle	3.5×10^{-12}	Y	—	—	124	20	single myocyte (1–5 myofibrils)	Brandt *et al.* [73]
51	MF	M2	Z	N	*Mus musculus* (mouse)	Ma	heart left ventricle	10^{-11}	N	—	—	119	10	bundle (2–6 myofibrils)	Kruger *et al.* [74]
52	MF	M2	Z	N	*Mus musculus* (mouse)	Ma	heart left ventricle	10^{-11}	N	—	—	138	10	bundle (2–6 myofibrils)	Stehle *et al.* [75]
53	MF	M2	Z	N	*Cavia porcellus* (guinea pig)	Ma	heart left ventricle	10^{-11}	N	—	—	161	10	bundle (2–6 myofibrils)	Stehle *et al.* [75]
54	MF	M2	Z	N	*Cavia porcellus* (guinea pig)	Ma	heart left ventricle	10^{-11}	N	—	—	149	10	bundle (2–6 myofibrils)	Stehle *et al.* [76]
55	MF	M2	Z	N	*Cavia porcellus* (guinea pig)	Ma	heart left ventricular trabeculae	10^{-11}	N	—	—	141	10	bundle (1–3 myofibrils)	Telley *et al.* [70]
56	MF	M2	Z	N	*Cavia porcellus* (guinea pig)	Ma	heart left ventricle	10^{-11}	N	—	—	196	10	bundle (2–6 myofibrils)	Stehle *et al.* [77]
57	MF	M2	Z	N	*Oryctolagus cuniculus* (rabbit)	Ma	heart right ventricle	10^{-11}	N	—	—	145	21	single myofibril	Linke *et al.* [78]
58	MF	M2	Z	N	*Homo sapiens* (human)	Ma	heart left ventricle	10^{-11}	N	—	—	151	10	bundle (2–6 myofibrils)	Stehle *et al.* [75]

5. Tesi C, Colomo F, Nencini S, Piroddi N, Poggesi C. 2000 The effect of inorganic phosphate on force generation in single myofibrils from rabbit skeletal muscle. *Biophys. J.* **78**, 3081–3092. (doi:10.1016/S0006-3495(00)76845-7)
7. Sambongi Y, Iko Y, Tanabe M, Omote H, Iwamoto-Kihara A, Ueda I, Yanagida T, Wada Y, Futai M. 1999 Mechanical rotation of the c subunit oligomer in ATP synthase (F_0F_1): direct observation. *Science* **286**, 1722–1724. (doi:10.1126/science.286.5445.1722)
8. Yasuda R, Noji H, Kinosita , Jr K, Yoshida M. 1998 F1-ATPase is a highly efficient molecular motor that rotates with discrete 120° steps. *Cell* **93**, 1117–1124. (doi:10.1016/S0092-8674(00)81456-7)
9. Berg HC. 2003 The rotary motor of bacterial flagella. *Annu. Rev. Biochem.* **72**, 19–54. (doi:10.1146/annurev.biochem.72.121801.161737)
10. Biais N, Ladoux B, Higashi D, So M, Sheetz M. 2008 Cooperative retraction of bundled type IV pili enables nanonewton force generation. *PLoS Biol.* **6**, e87. (doi:10.1371/journal.pbio.0060087)
11. Miller E, Garcia T, Hultgren S, Oberhauser AF. 2006 The mechanical properties of *E. coli* type 1 pili measured by atomic force microscopy techniques. *Biophys. J.* **91**, 3848–3856. (doi:10.1529/biophysj.106.088989)
12. Upadhyaya A, Baraban M, Wong J, Matsudaira P, van Oudenaarden A, Mahadevan L. 2008 Power-limited contraction dynamics of *Vorticella convallaria*: an ultrafast biological spring. *Biophys. J.* **93**, 265–272. (doi:10.1529/biophysj.107.108852)
14. Schmitz KA, Holcomb-Wygle DL, Oberski DJ, Lindemann CB. 2000 Measurement of the force produced by an intact bull sperm flagellum in isometric arrest and estimation of the dynein stall force. *Biophys. J.* **79**, 468–478. (doi:10.1016/S0006-3495(00)76308-9)
15. Schnitzer MJ, Visscher K, Block SM. 2000 Force production by single kinesin motors. *Nat. Cell Biol.* **2**, 718–723. (doi:10.1038/35036345)

16. Gennerich A, Carter AP, Reck-Peterson SL, Vale RD. 2007 Force-induced bidirectional stepping of cytoplasmic dynein. *Cell* **131**, 952–965. (doi:10.1016/j.cell.2007.10.016)
17. Wang MD, Schnitzer MJ, Yin H, Landick R, Gelles J, Block SM. 1998 Force and velocity measured for single molecules of RNA polymerase. *Science* **282**, 902–907. (doi:10.1126/science.282.5390.902)
32. Gross SP, Welte MA, Block SM, Wieschaus EF. 2000 Dynein-mediated cargo transport *in vivo*: a switch controls travel distance. *J. Cell Biol.* **148**, 945–955. (doi:10.1083/jcb.148.5.945)
33. Toba S, Watanabe TM, Yamaguchi-Okimoto L, Toyoshima YY, Higuchi H. 2006 Overlapping hand-over-hand mechanism of single molecular motility of cytoplasmic dynein. *Proc. Natl Acad. Sci. USA* **103**, 5741–5745. (doi:10.1073/pnas.0508511103)
34. Mallik R, Carter BC, Lex SA, King SJ, Gross SP. 2004 Cytoplasmic dynein functions as a gear in response to load. *Nature* **427**, 649–652. (doi:10.1038/nature02293)
35. Hirakawa E, Higuchi H, Toyoshima YY. 2000 Processive movement of single 22S dynein molecules occurs only at low ATP concentrations. *Proc. Natl Acad. Sci. USA* **97**, 2533–2537. (doi:10.1073/pnas.050585297)
36. Sakakibara H, Kojima H, Sakai Y, Katayama E, Oiwa K. 1999 Inner-arm dynein c of *Chlamydomonas* flagella is a single-headed processive motor. *Nature* **400**, 586–590. (doi:10.1038/23066)
37. Shingyoji C, Higuchi H, Yoshimura M, Katayama E, Yanagida T. 1998 Dynein arms are oscillating force generators. *Nature* (*Lond.*) **393**, 711–714. (doi:10.1038/31520)
38. Holcomb-Wygle DL, Schmitz KA, Lindemann CB. 1999 Flagellar arrest behavior predicted by the geometric clutch model is confirmed experimentally by micromanipulation experiments on reactivated bull sperm. *Cell Motil. Cytoskeleton* **44**, 177–189. (doi:10.1002/(SICI)1097-0169(199911)44:3<177::AID-CM3>3.0.CO;2-W)
39. Svoboda K, Block SM. 1994 Force and velocity measured for single kinesin molecules. *Cell* **77**, 773–784. (doi:10.1016/0092-8674(94)90060-4)
40. Visscher K, Schnitzer MJ, Block SM. 1999 Single kinesin molecules studied with a molecular force clamp. *Nature* **400**, 184–189. (doi:10.1038/22146)
41. Higushi H, Muto E, Inoue Y, Yanagida T. 1997 Kinetics of force generation by single kinesin molecules activated by laser photolysis of caged ATP. *Proc. Natl Acad. Sci. USA* **94**, 4395–4400. (doi:10.1073/pnas.94.9.4395)
42. Hunt AJ, Gittes F, Howard J. 1994 The force exerted by a single kinesin molecule against a viscous load. *Biophys. J.* **67**, 766–781. (doi:10.1016/S0006-3495(94)80537-5)
43. Meyhöfer E, Howard J. 1995 The force exerted by a single kinesin molecule against an elastic load. *Proc. Natl Acad. Sci. USA* **92**, 574–578. (doi:10.1073/pnas.92.2.574)
44. Kojima H, Muto E, Higuchi H, Yanagida T. 1997 Mechanics of single kinesin molecules measured by optical trapping nanometry. *Biophys. J.* **73**, 2012–2022. (doi:10.1016/S0006-3495(97)7823 1-6)
45. Jamison DK, Driver JW, Rogers AR, Constantinou PE, Diehl MR. 2010 Two kinesins transport cargo primarily via the action of one motor: implications for intracellular transport. *Biophys. J.* **99**, 2967–2977. (doi:10.1016/j.bpj.2010.08.025)
46. Linari M, Dobbie I, Reconditi M, Koubassova N, Irving M, Piazzesi G, Lombardi V. 1998 The stiffness of skeletal muscle in isometric contraction and rigor: the fraction of myosin heads bound to actin. *Biophys. J.* **74**, 2459–2473. (doi:10.1016/S0006-3495(98)77954-8)
47. Piazzesi G, Reconditi M, Linari M, Lucii L, Sun Y-B, Narayanan T, Boesecke P, Lombardi V, Irving M. 2002 Mechanisms of force generation by myosin heads in skeletal muscle. *Nature* **415**, 659–662. (doi:10.1038/415659a)
48. Piazzesi G *et al.* 2007 Skeletal muscle performance determined by modulation of number of myosin motors rather than motor force or stroke. *Cell* **131**, 784–795. (doi:10.1016/j.cell.2007.09.045)
49. Finer JT, Simmons RM, Spudich JA. 1994 Single myosin molecule mechanics: piconewton forces and nanometre steps. *Nature* **368**, 113–119. (doi:10.1038/368113a0)
50. Ishijima A, Harada Y, Kojima H, Funatsu T, Higuchi H, Yanagida T. 1994 Single-molecule analysis of the actomyosin motor using nano-manipulation. *Biochem. Biophys. Res. Comm.* **199**, 1057–1063. (doi:10.1006/bbrc.1994.1336)
51. Miyata H, Yoshikawa H, Hakozaki H, Suzuki N, Furuno T, Ikegami A, Kinosita , Jr K, Nishizaka T, Ishiwata S. 1995 Mechanical measurements of single actomyosin motor force. *Biophys. J.* **68**, 286s–290s.
52. Tsaturyan AK, Bershitsky SY, Koubassova NA, Fernandez M, Narayanan T, Ferenczi MA. 2011 The fraction of myosin motors that participate in isometric contraction of rabbit muscle fibers at near-physiological temperature. *Biophys. J.* **101**, 404–410. (doi:10.1016/j.bpj.2011.06.008)
53. Nishizaka T, Miyata H, Yoshikawa H, Ishiwata S, Kinosita , Jr K. 1995 Mechanical properties of single protein motor of muscle studied by optical tweezers. *Biophys. J.* **68**, 75s.
54. Nishizaka T, Miyata H, Yoshikawa H, Ishiwata S, Kinosita , Jr K. 1995 Unbinding force of a single motor molecule of muscle measured using optical tweezers. *Nature* **377**, 251–254. (doi:10.1038/377251a0)

55. Takagi Y, Homsher EE, Goldman YE, Shuman H. 2006 Force generation in single conventional actomyosin complexes under high dynamic load. *Biophys. J.* **90**, 1295–1307. (doi:10.1529/biophysj.105.068429)
56. Moriyama Y, Yasuda K, Ishiwata S, Asai H. 1996 Ca^{2+}-induced tension development in the stalks of glycerinated *Vorticella convallaria*. *Cell Motil. Cytoskeleton* **34**, 271–278. (doi:10.1002/(SICI)1097-0169(1996)34:4<271::AID-CM2>3.0.CO;2-B)
57. Ryu S, Lang MJ, Matsudaira P. 2012 Maximal force characteristics of the Ca^{2+}-powered actuator of *Vorticella convallaria*. *Biophys. J.* **103**, 860–867. (doi:10.1016/j.bpj.2012.07.038)
58. Jass J, Schedin S, Fällman E, Ohlsson J, Nilsson UJ, Uhlin BE, Axner O. 2004 Physical properties of *Escherichia coli* P Pili measured by optical tweezers. *Biophys. J.* **87**, 4271–4283. (doi:10.1529/biophysj.104.044867)
59. Fällman E, Schedin S, Jass J, Uhlin B-E, Axner O. 2005 The unfolding of the P pili quaternary structure by stretching is reversible, not plastic. *EMBO Rep.* **6**, 52–56. (doi:10.1038/sj.embor.7400310)
60. Andersson M, Fällman E, Uhlin BE, Axner O. 2006 Dynamic force spectroscopy of *E. coli* P pili. *Biophys. J.* **91**, 2717–2725. (doi:10.1529/biophysj.106.087429)
61. Kaiser D. 2000 Bacterial motility: how do pili pull? *Curr. Biol.* **10**, R777–R780. (doi:10.1016/S0960-9822(00)00764-8)
62. Merz AJ, So M, Sheetz MP. 2000 Pilus retraction powers bacterial twitching motility. *Nature* **407**, 98–102. (doi:10.1038/35024105)
63. Noji H, Yasuda R, Yoshida M, Kinosita , KJr. 1997 Direct observation of the rotation of F1-ATPase. *Nature* **386**, 299–302. (doi:10.1038/386299a0)
64. Berry RM, Berg HC. 1997 Absence of a barrier to backwards rotation of the bacterial flagellar motor demonstrated with optical tweezers. *Proc. Natl Acad. Sci. USA* **94**, 14 433–14 437. (doi:10.1073/pnas.94.26.14433)
65. Berg HC. 1995 Torque generation by the flagellar rotary motor. *Biophys. J.* **68**, 163s–167s.
66. Sowa Y, Hotta H, Homma M, Ishijima A. 2003 Torque–speed relationship of the Na^{+}-driven flagellar motor of *Vibrio alginolyticus*. *J. Mol. Biol.* **327**, 1043–1051. (doi:10.1016/S0022-2836(03)00176-1)
67. Nakamura S, Kami-Ike N, Yokota J-IP, Kudo S, Minamino T, Namba K. 2009 Effect of intracellular pH on the torque–speed relationship of bacterial proton-driven flagellar motor. *J. Mol. Biol.* **386**, 332–338. (doi:10.1016/j.jmb.2008.12.034)
68. Lowe G, Meister M, Berg HC. 1987 Rapid rotation of flagellar bundles in swimming bacteria. *Nature* **325**, 637–640. (doi:10.1038/325637a0)
69. Powers K, Schappacher-Tilp G, Jinha A, Leonard T, Nishikawa K, Herzog W. 2014 Titin force is enhanced in actively stretched skeletal muscle. *J. Exp. Biol.* **217**, 3629–3636. (doi:10.1242/jeb.105361)
70. Telley IA, Denoth J, Stüssi E, Pfitzer G, Stehle R. 2006 Half-sarcomere dynamics in myofibrils during activation and relaxation studied by tracking fluorescent markers. *Biophys. J.* **90**, 514–530. (doi:10.1529/biophysj.105.070334)
71. Shimamoto Y, Kono F, Suzuki M, Ishiwata S. 2007 Nonlinear force-length relationship in the ADP-induced contraction of skeletal myofibrils. *Biophys. J.* **93**, 4330–4341. (doi:10.1529/biophysj.107.110650)
72. Colomo F, Piroddi N, Pogegesi C, te Kronnie G, Tesi C. 1997 Active and passive forces of isolated myofibrils from cardiac and fast skeletal muscle of the frog. *J. Physiol.* **500**, 535–548. (doi:10.1113/jphysiol.1997.sp022039)
73. Brandt PW, Colomo F, Piroddi N, Poggesi C, Tesi C. 1998 Force regulation by Ca^{2+} in skinned single cardiac myocytes of frog. *Biophys. J.* **74**, 1994–2004. (doi:10.1016/S0006-3495(98)77906-8)
74. Kruger M, Zittrich S, Redwood C, Blaudeck N, James J, Robbins J, Pfitzer G, Stehle R. 2005 Effects of the mutation R145G in human cardiac troponin I on the kinetics of the contraction–relaxation cycle in isolated cardiac myofibrils. *J. Physiol.* (*Lond.*) **564**, 347–357. (doi:10.1113/jphysiol.2004.079095)
75. Stehle R, Krüger M, Pfitzer G. (2002) Force kinetics and individual sarcomere dynamics in cardiac myofibrils after rapid Ca^{2+} changes. *Biophys. J.* **83**, 2152–2161. (doi:10.1016/S0006-3495(02)73975-1)
76. Stehle R, Krüger M, Scherer P, Brixius K, Schwinger RHG, Pfitzer G. (2002) Isometric force kinetics upon rapid activation and relaxation of mouse, guinea pig and human heart muscle studied on the subcellular myofibrillar level. *Basic Res. Cardiol.* **97**(Suppl. 1), I/127–I/135.
77. Stehle R, Solzin J, Iorga B, Gomez D, Blaudeck N, Pfitzer G. 2006 Mechanical properties of sarcomeres during cardiac myofibrillar relaxation: stretch-induced cross-bridge detachment contributes to early diastolic filling. *J. Muscle Res. Cell Motil.* **27**, 423–434. (doi:10.1007/s10974-006-9072-7)
78. Linke WA, Popov V, Pollack GH. 1994 Passive and active tension in single cardiac myofibrils. *Biophys. J.* **67**, 782–792. (doi:10.1016/S0006-3495(94)80538-7)

Table 1. List of abbreviations

A	cross-sectional area of motors
F	force exerted by motors
V	volume of molecular motors
Al	algae
Am	amphibian
Ar	arachnids
Ba	bacteria
Bi	birds
Cr	crustaceans
DA	axonemal dynein
DC	cytoplasmic dynein
Ec	echinoderms
f	specific tension of motors
FA	F_0/F_1 ATPase
Fl	muscular fibre
Fi	fishes
FL	flagellum
Fly	fly locomotors
Fu	fungi
In	insects
IQR	interquartile range
KI	kinesin
m	mass of molecular motors
M	mass of organisms
M1	single molecule
M2	molecular assembly
Ma	mammals
MF	myofibril
Mo	molluscs
MU	muscle *in vitro*
MV	muscle *in vivo*
MY	myosin
non-loc	non-locomotory
PI	pili
Pr	protozoa
Re	reptiles
RN	RNA polymerase
SP	spasmoneme
Swim	swim locomotors
Terr	terrestrial locomotors