Basic calculations for feeding animals

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Emmen 2022

University of Zurich[UZH]

Clinic of Zoo Animals, Exotic Pets and Wildlife

from Spielberg et al. (1993)

Judicophagy

from Spielberg et al. (1993)

How many lawyers does a T. rex need per year?

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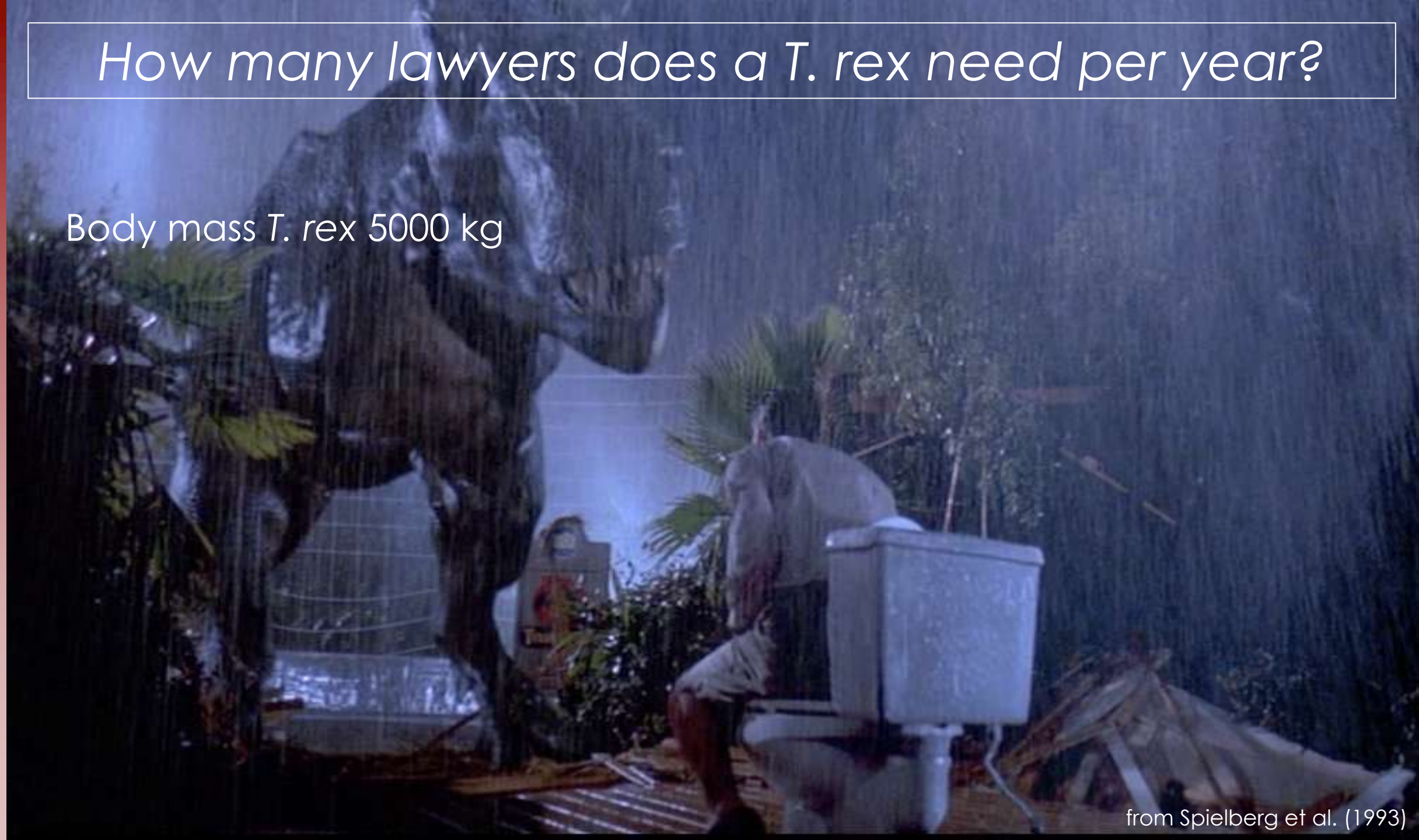
Body mass *T. rex*

from Spielberg et al. (1993)

How many lawyers does a T. rex need per year?

Body mass *T. rex* 5000 kg



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Energy requirement ‘

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Energy requirement 'endotherm' basal metabolic rate 293 kJ/$BM^{0.75}$/d

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		basal metabolic rate
Energy requirement	'endotherm'	293 kJ/$BM^{0.75}$/d
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How many lawyers does a T. rex need per year?

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Energy requirement	'endotherm'	293 kJ/BM$^{0.75}$/d	*	2
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as fed

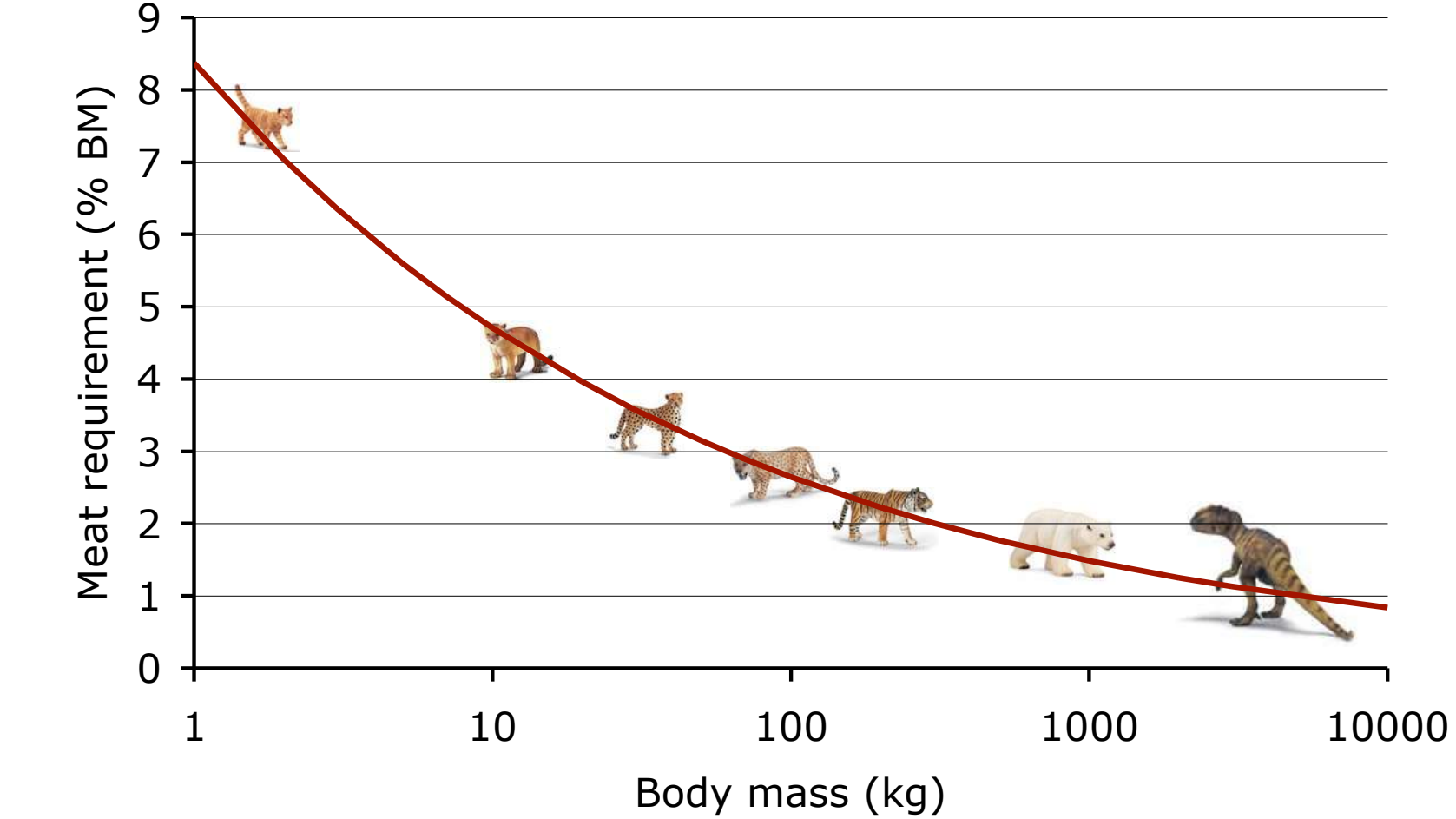
~ 0.3 % BM

~ 0.03 % BM

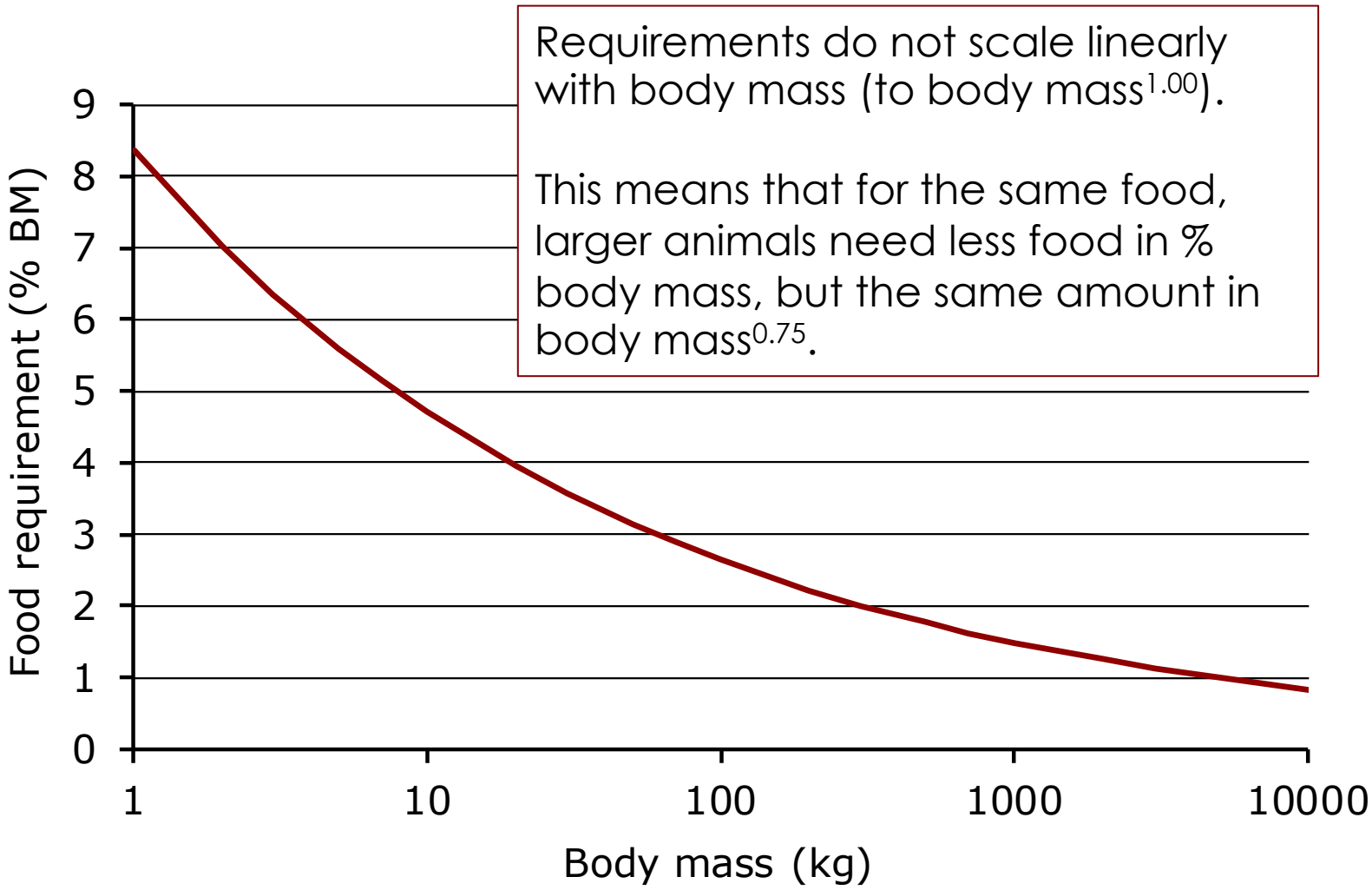
dry matter

from Spielberg et al. (1993)

Food requirements of carnivores



Food requirements of … anything



Allometries

Morphological, physiological and life history variables scale with body mass.

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If scaling is not linear, you need "another measure" = allo-metry

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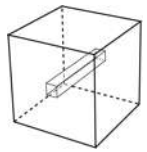

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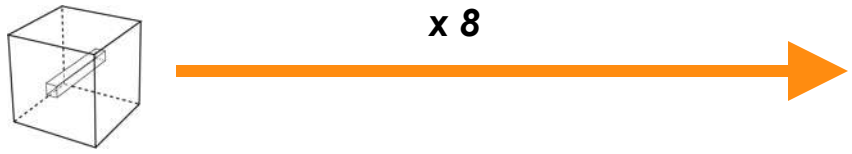

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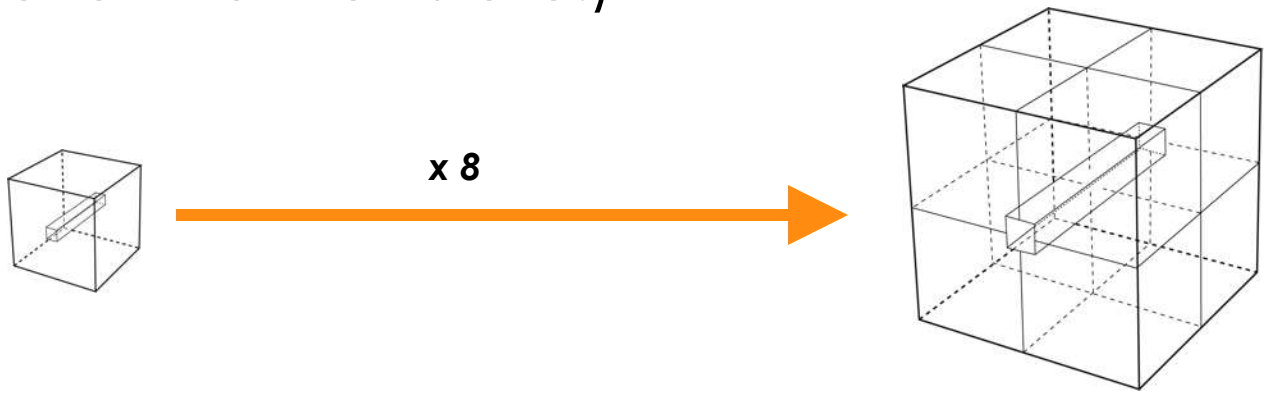

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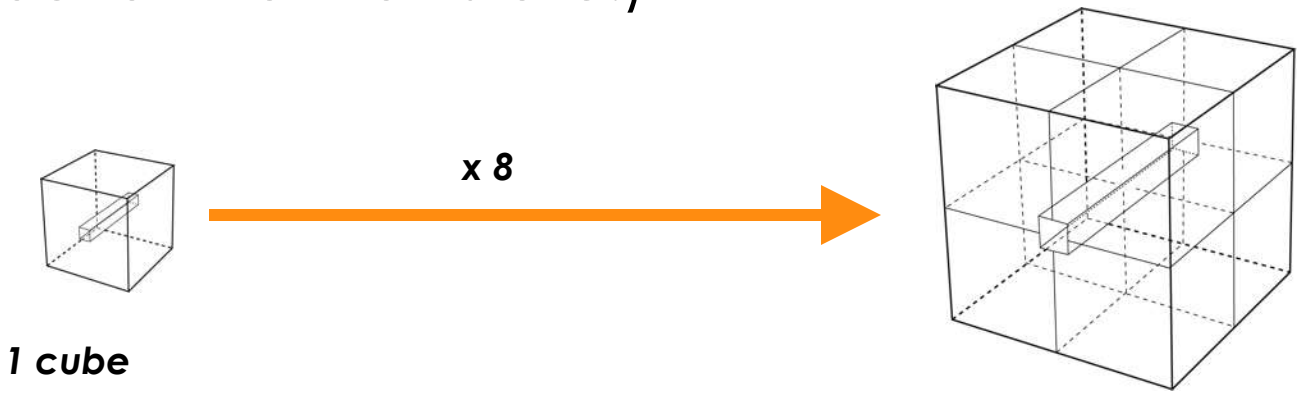

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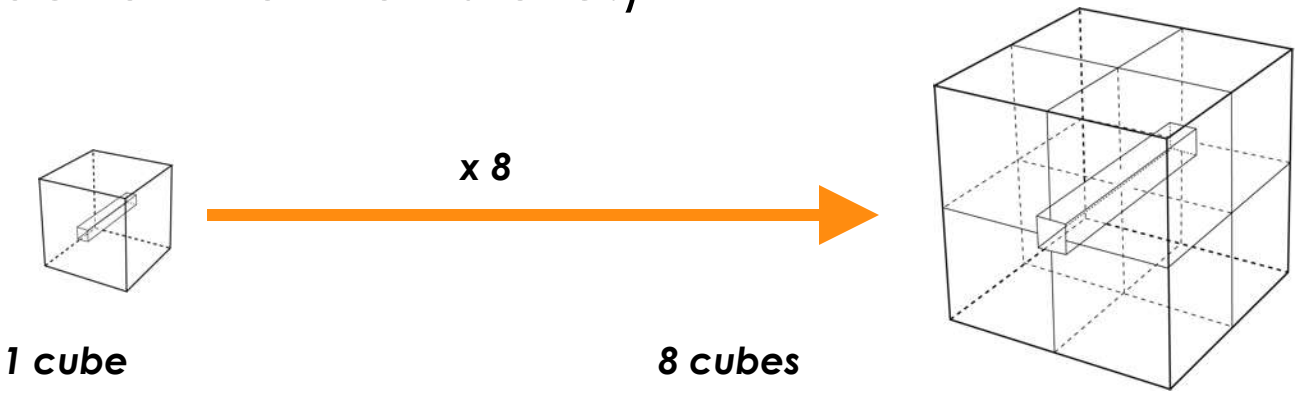

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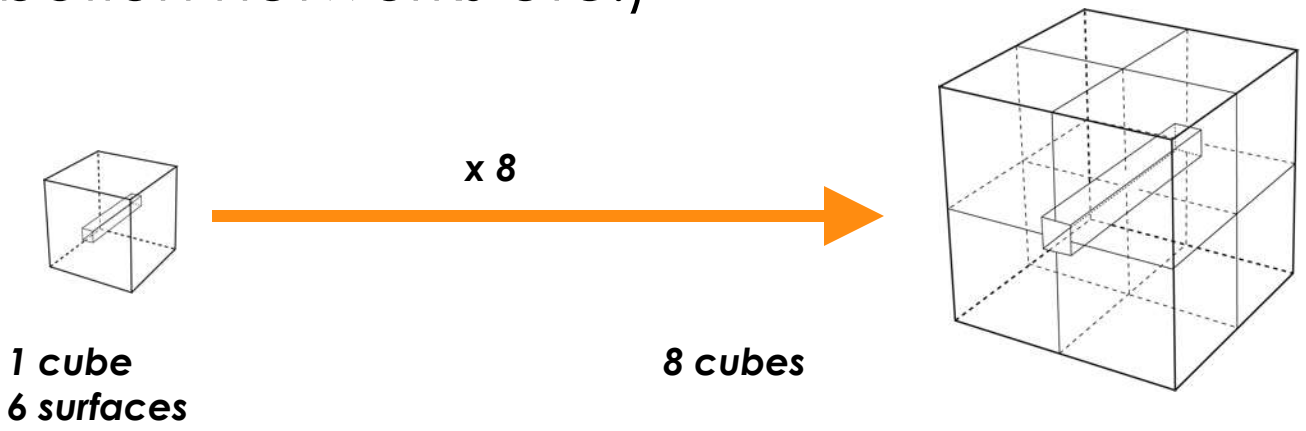

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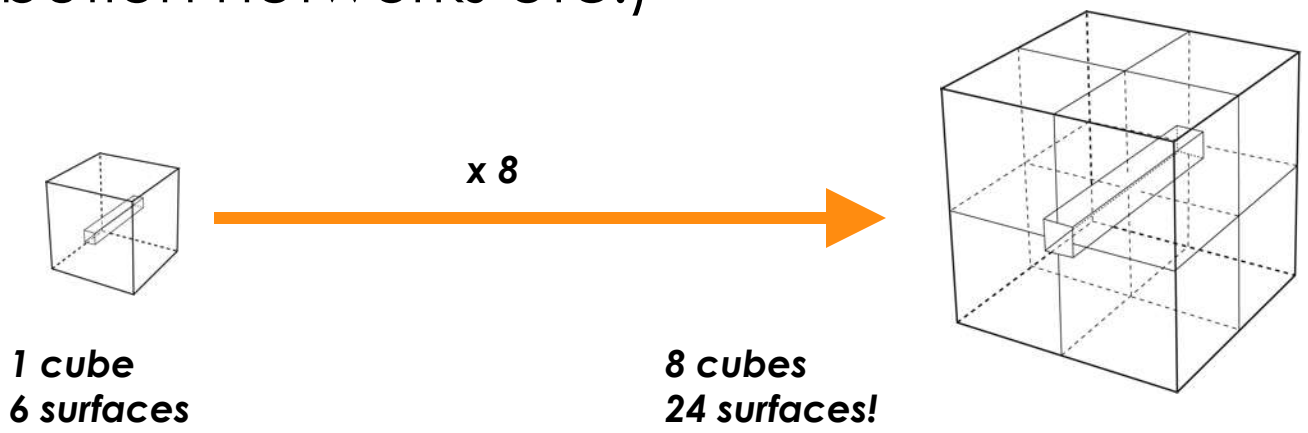

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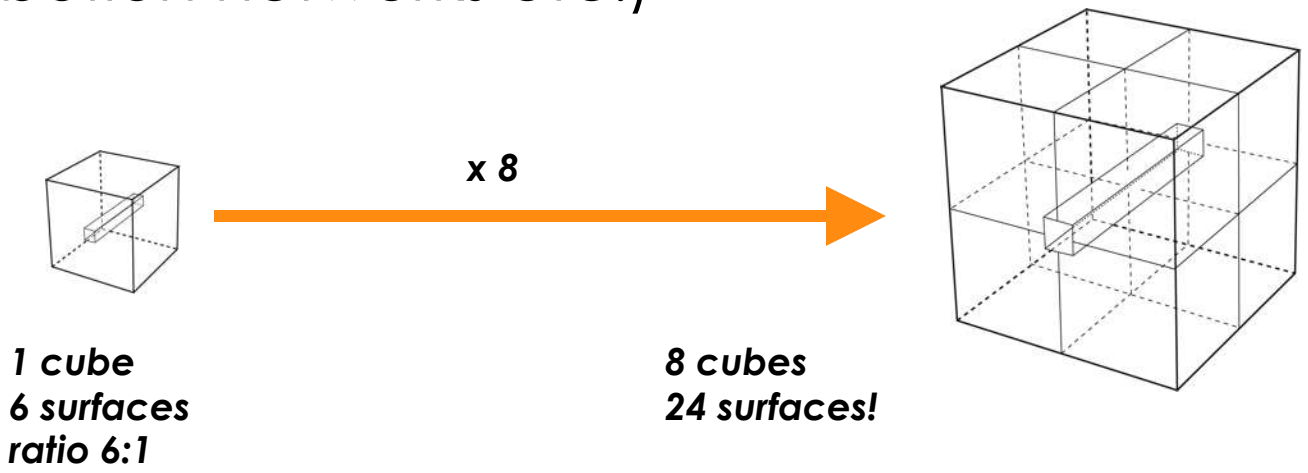

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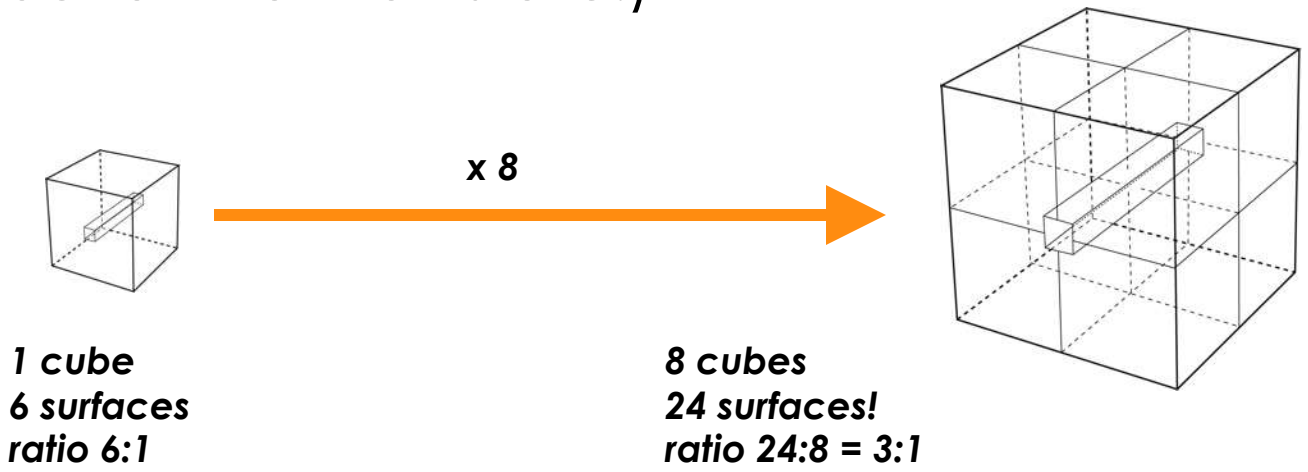

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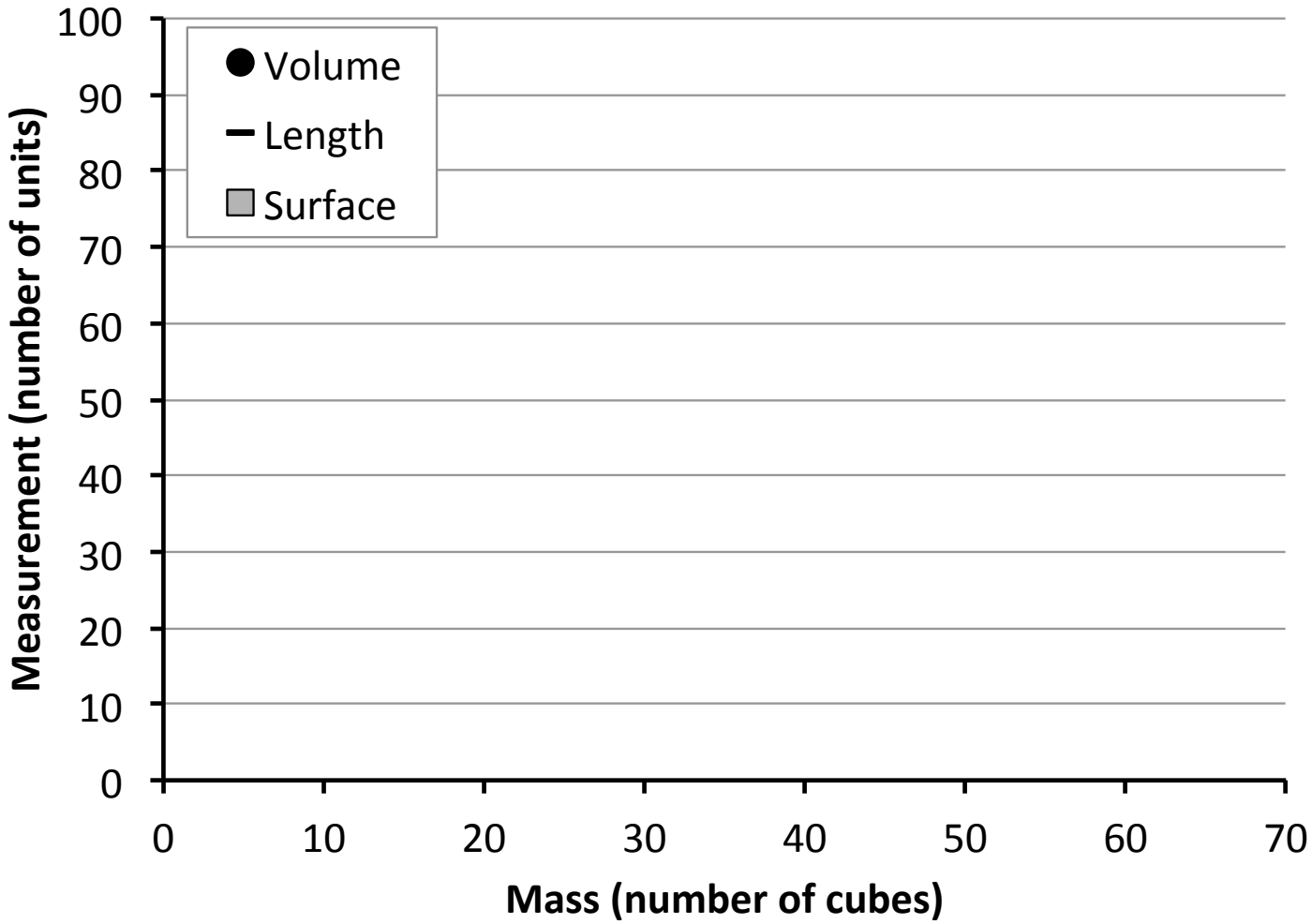

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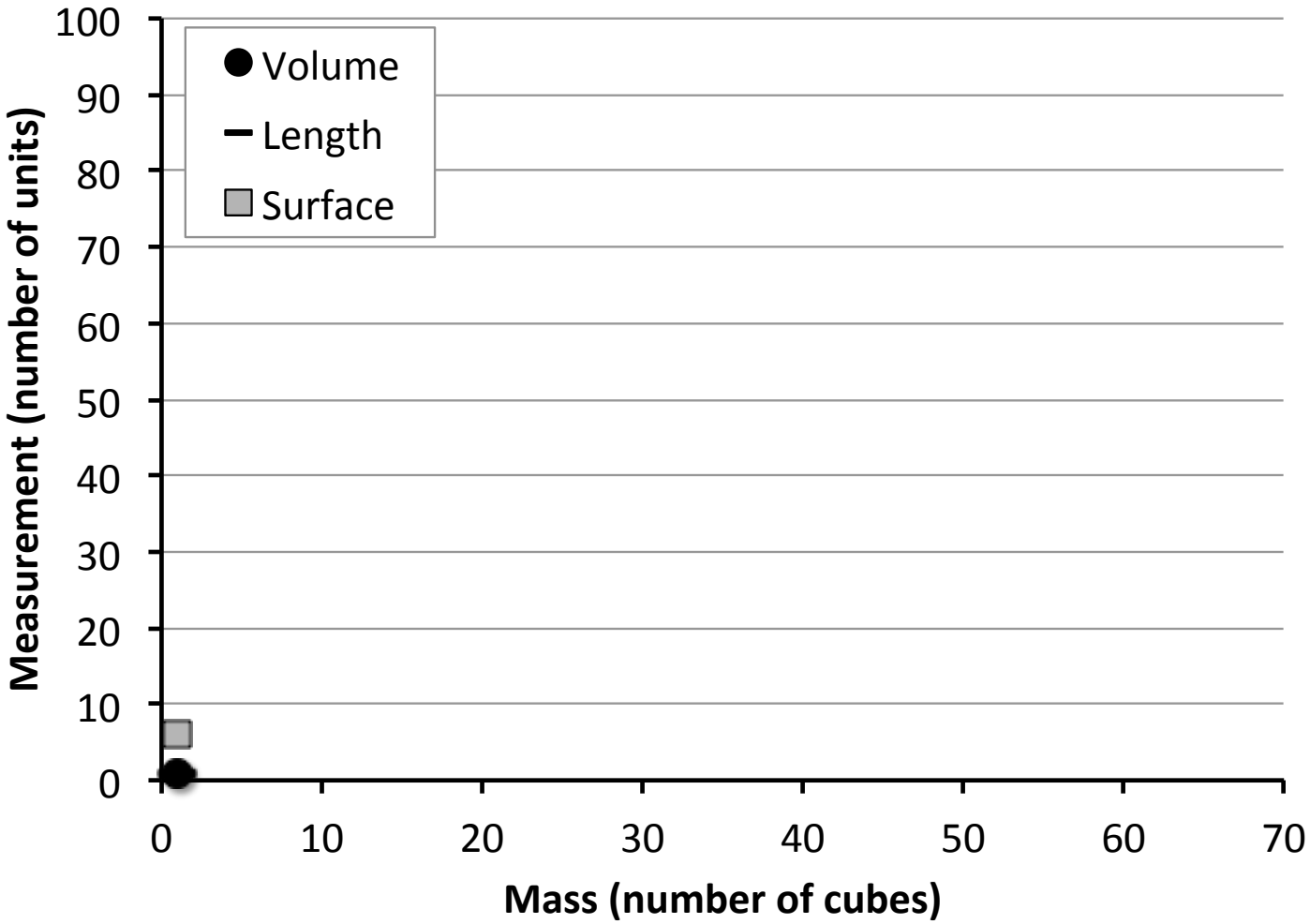

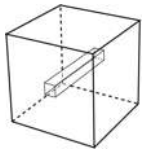

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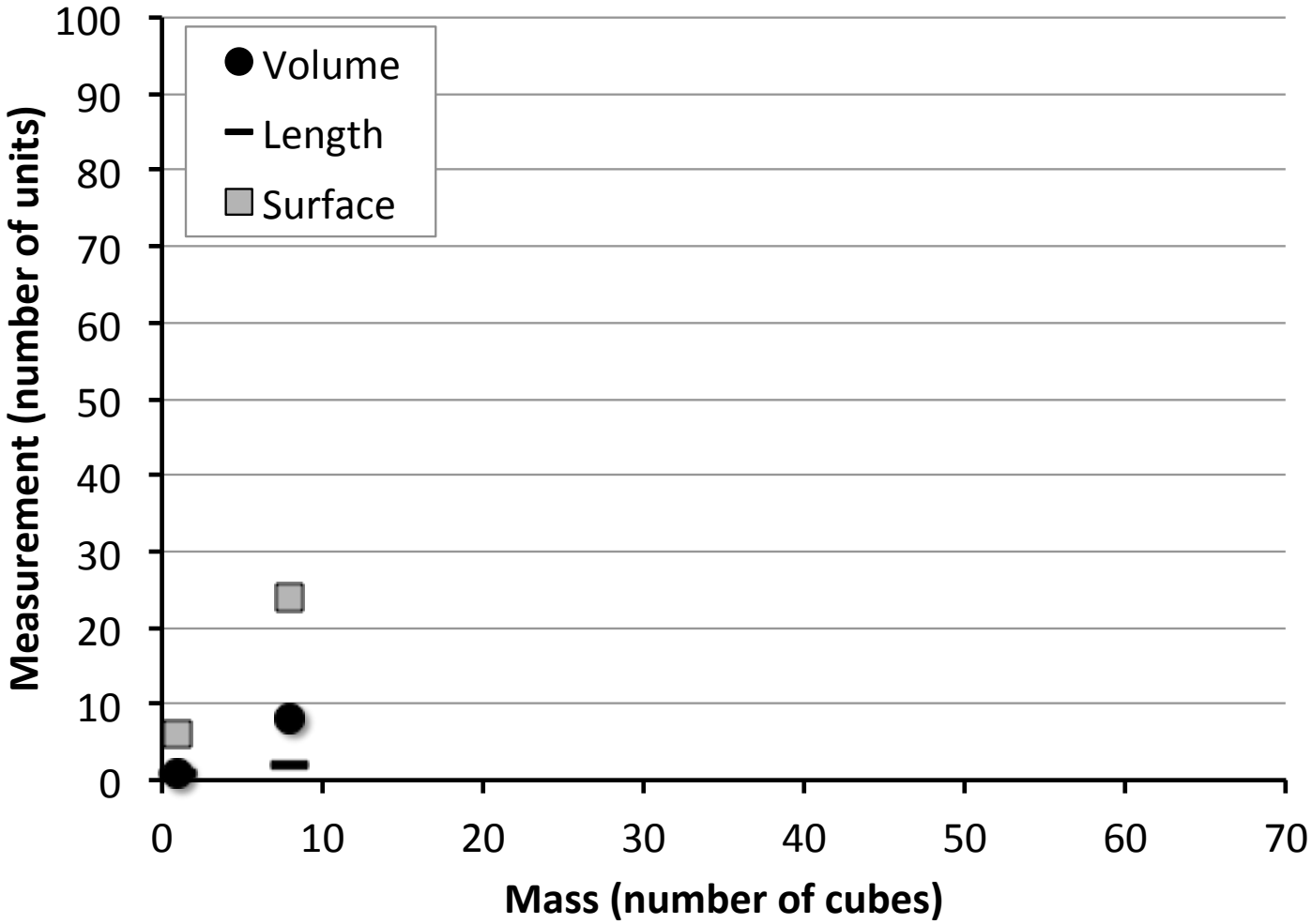

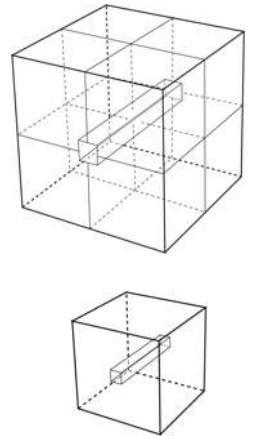

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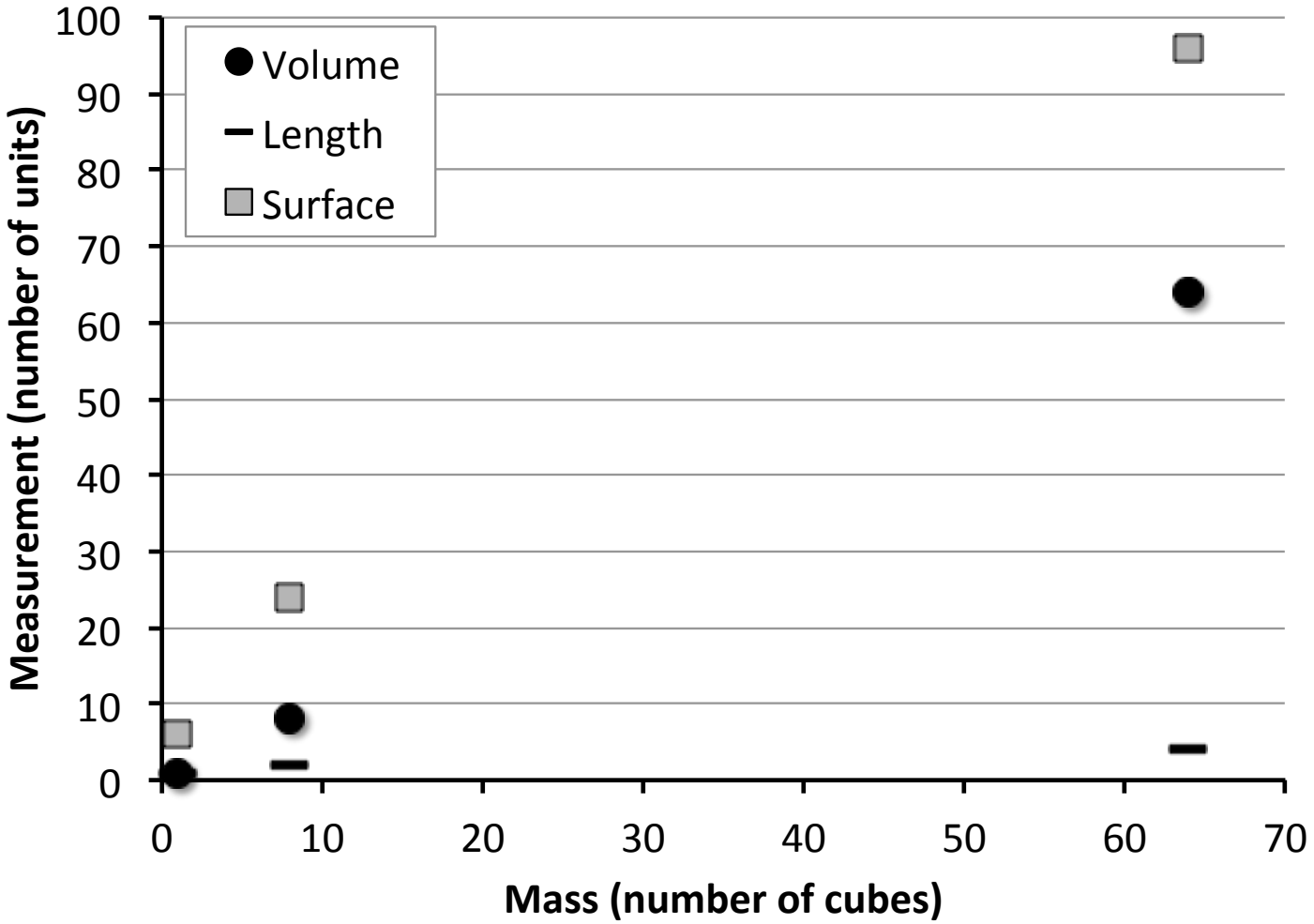

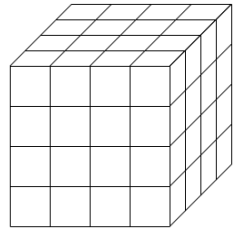

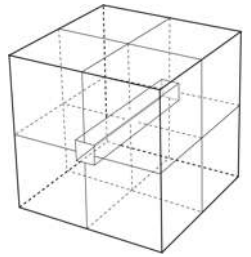

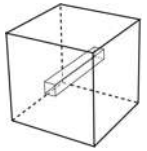

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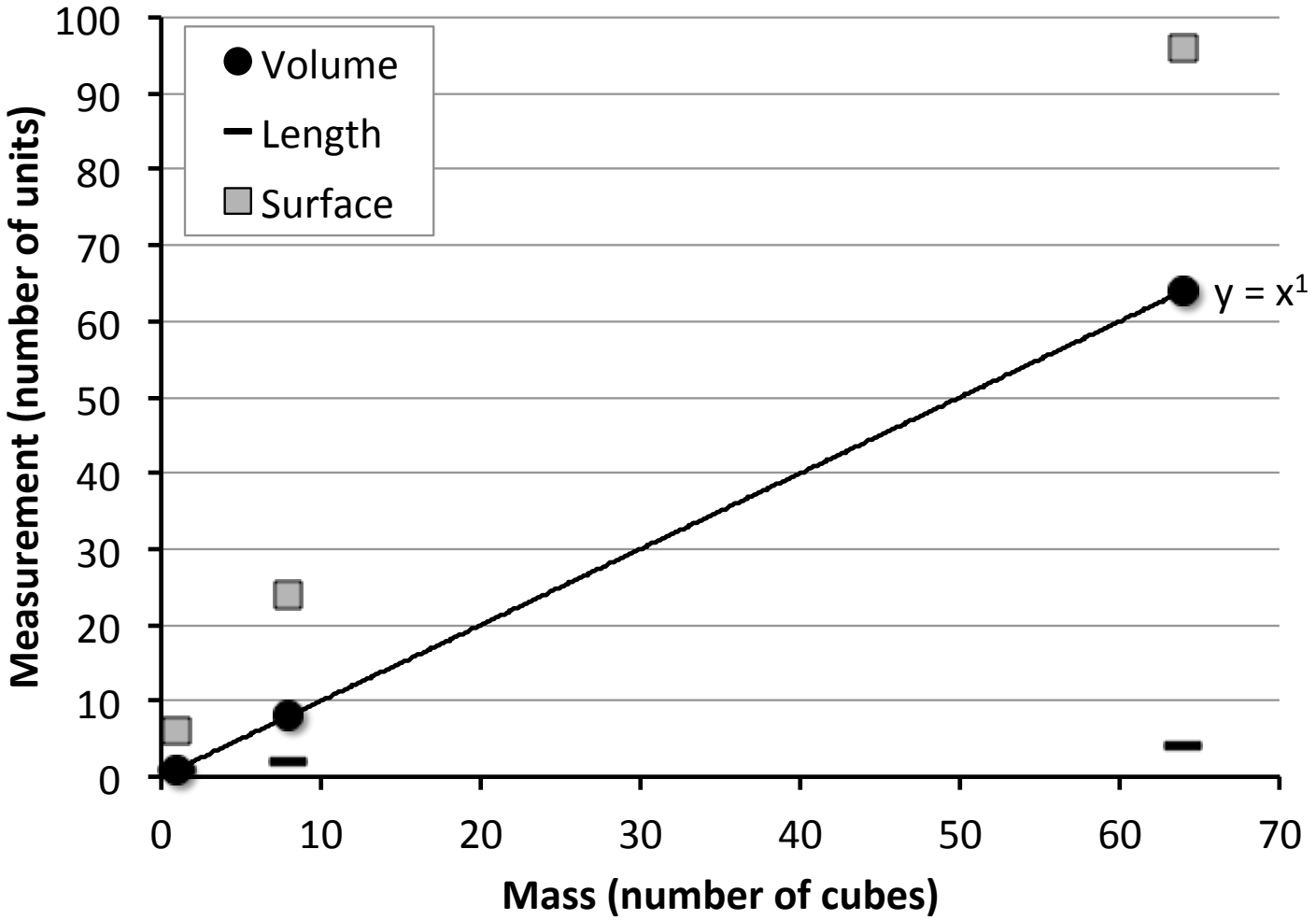

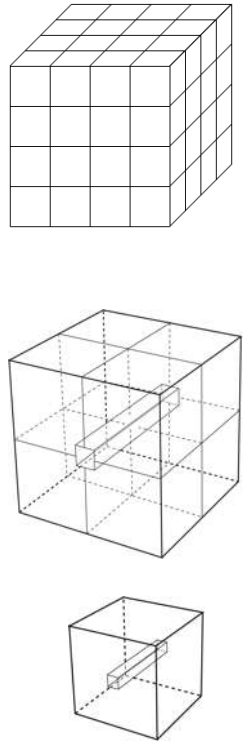

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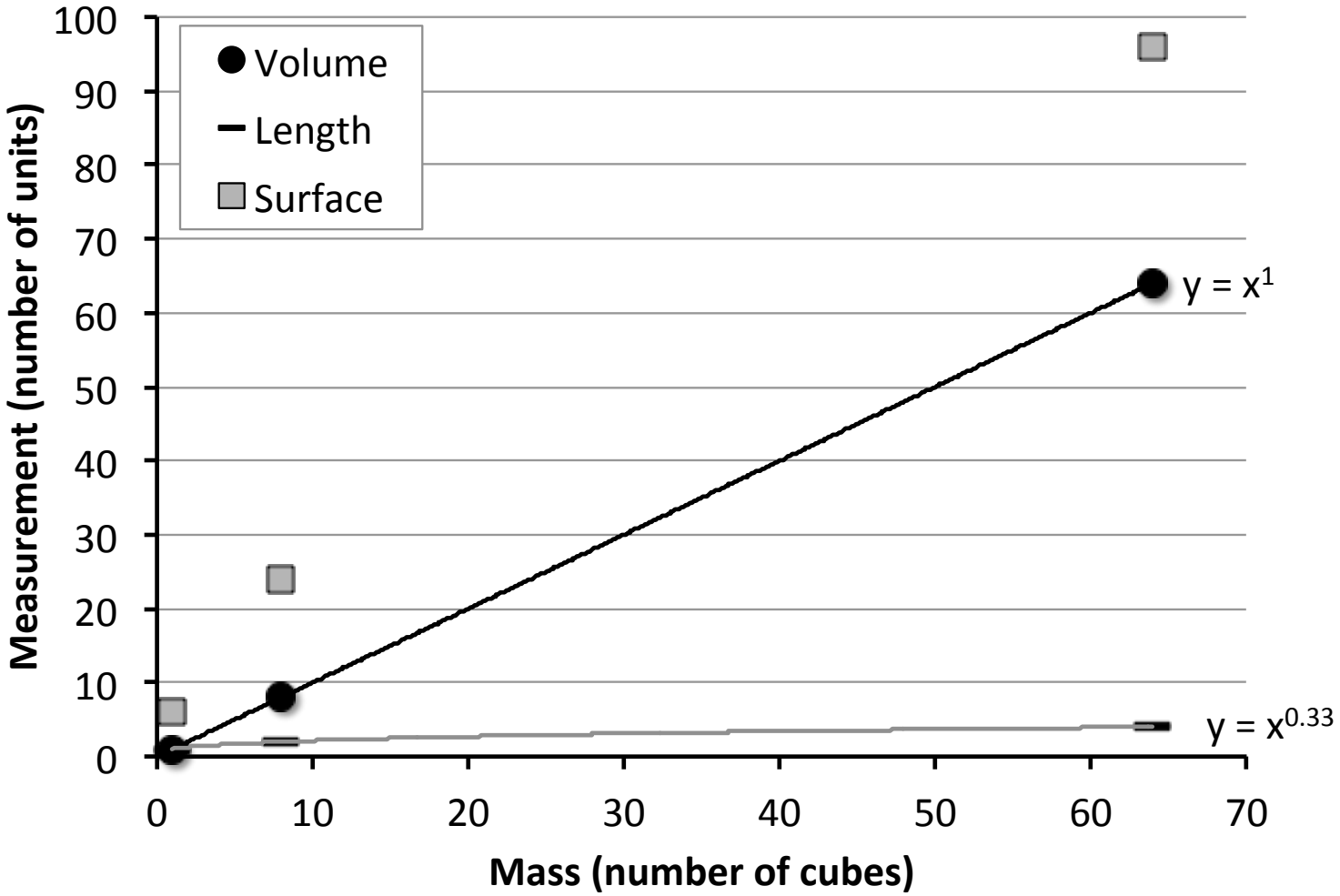

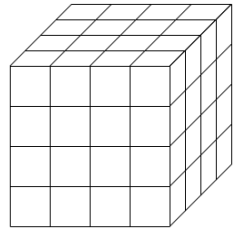

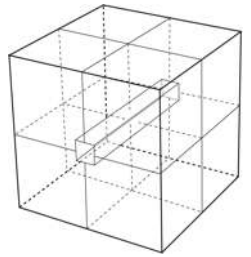

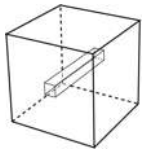

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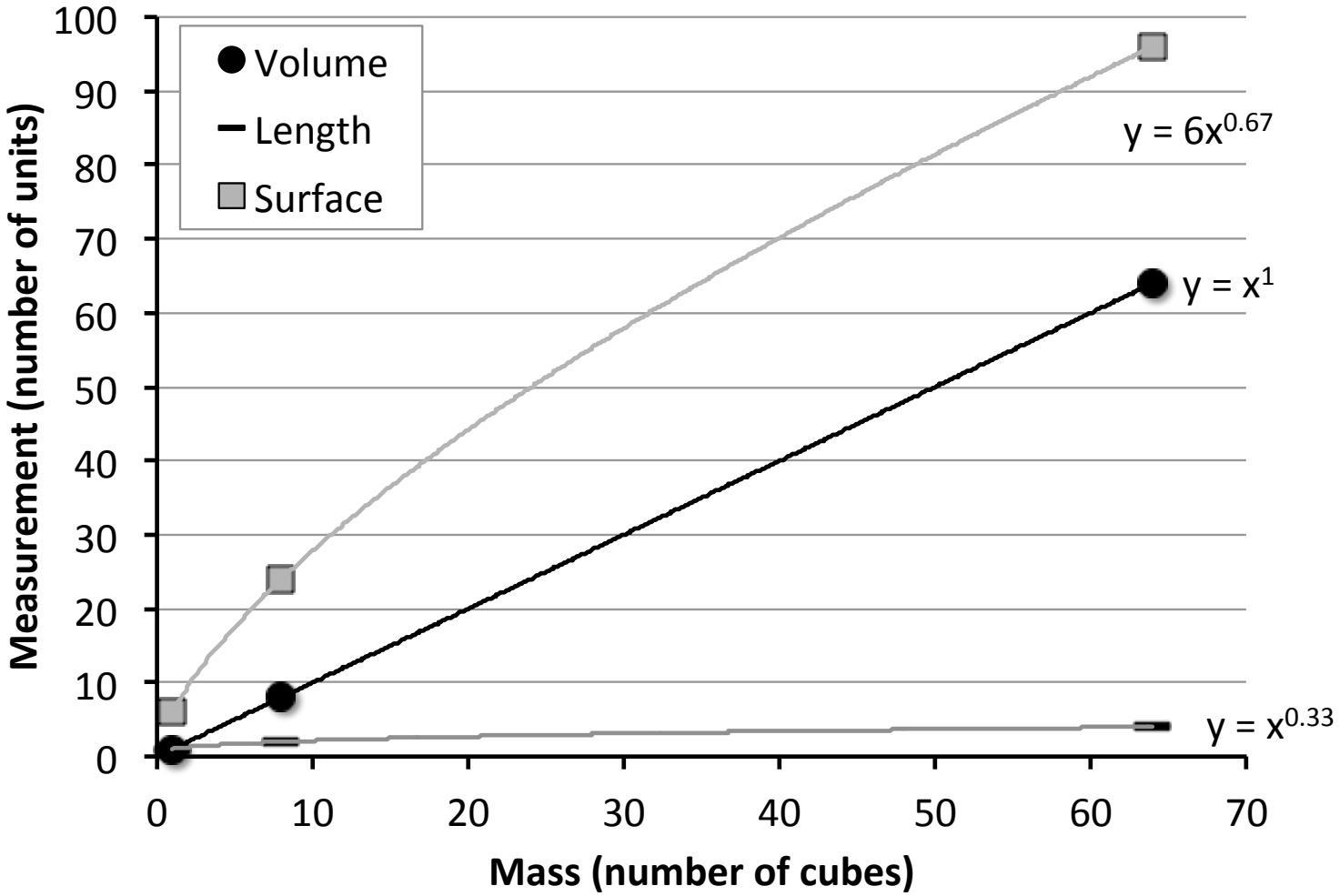

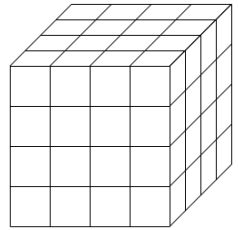

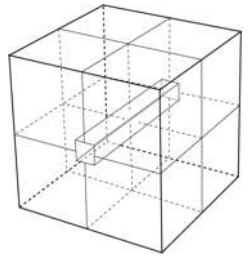

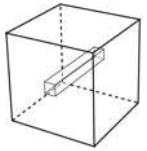

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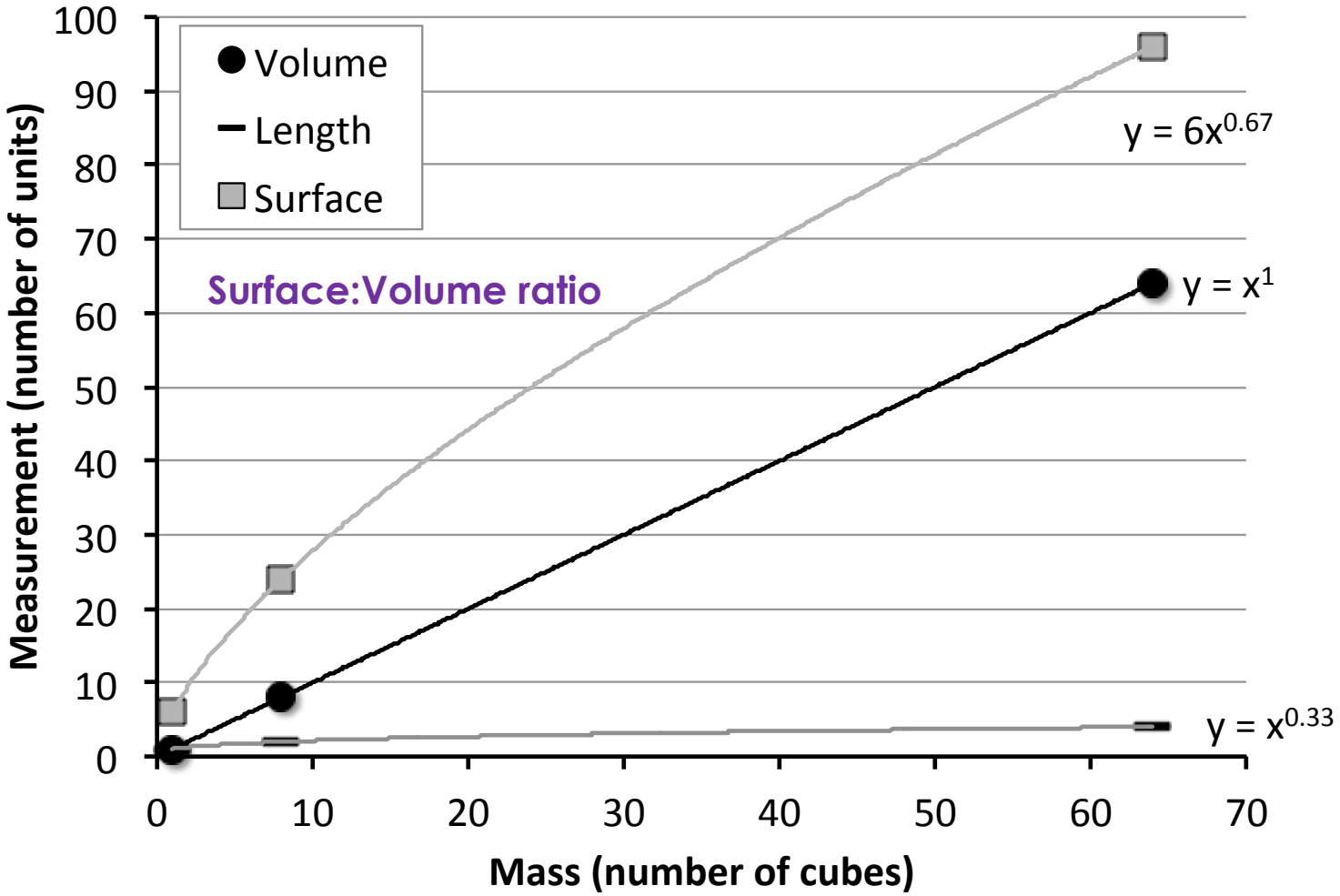

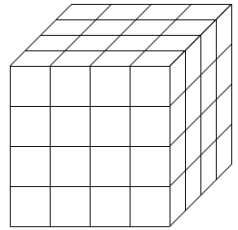

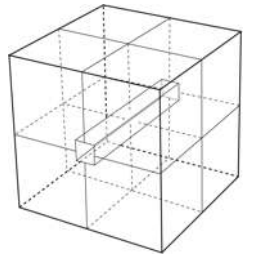

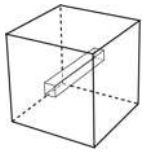

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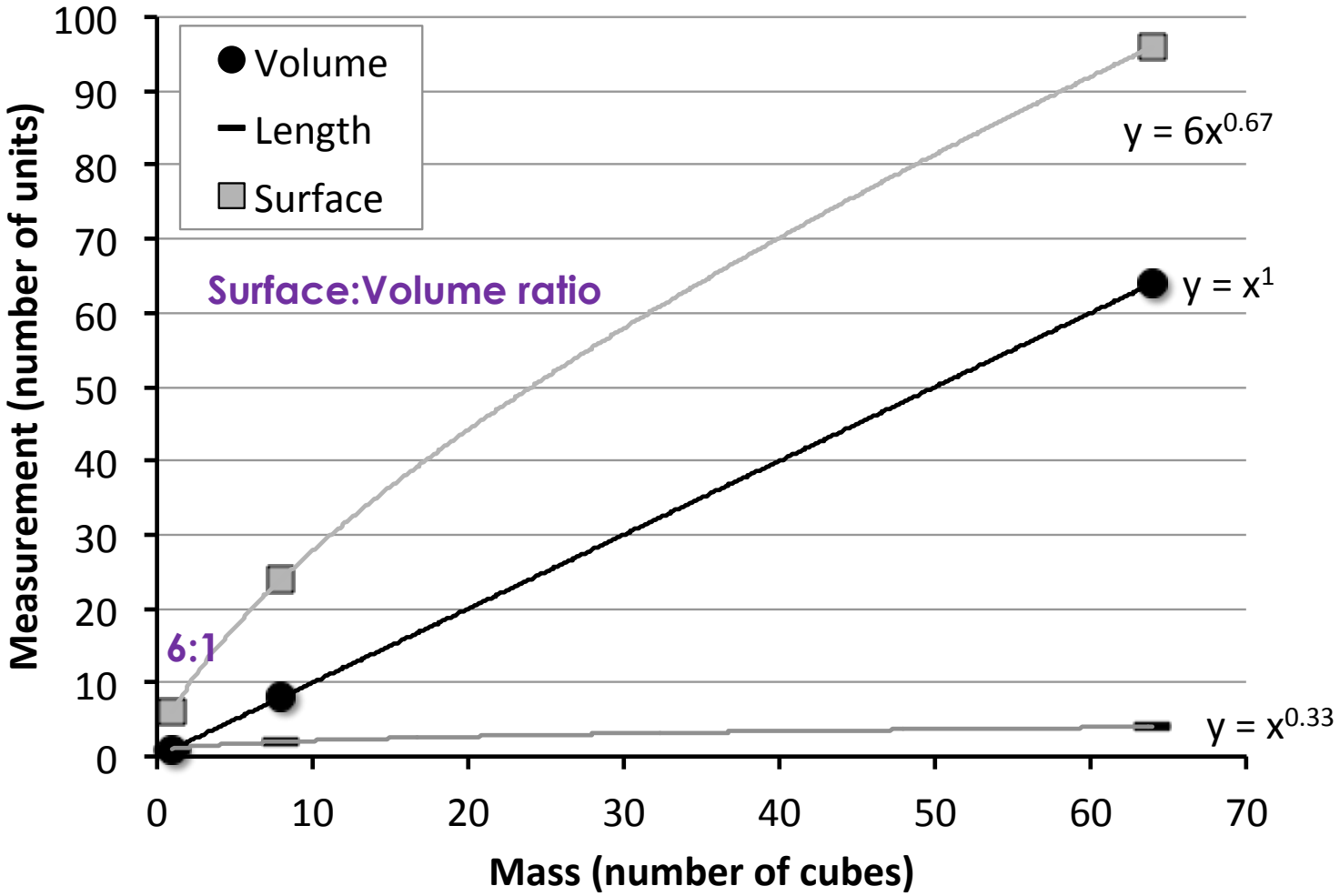

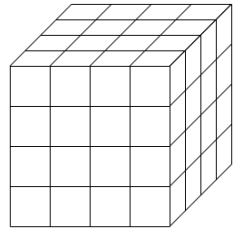

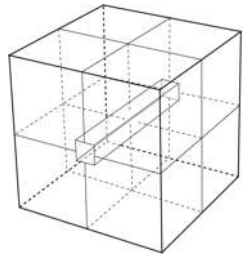

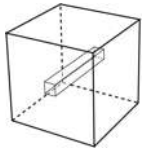

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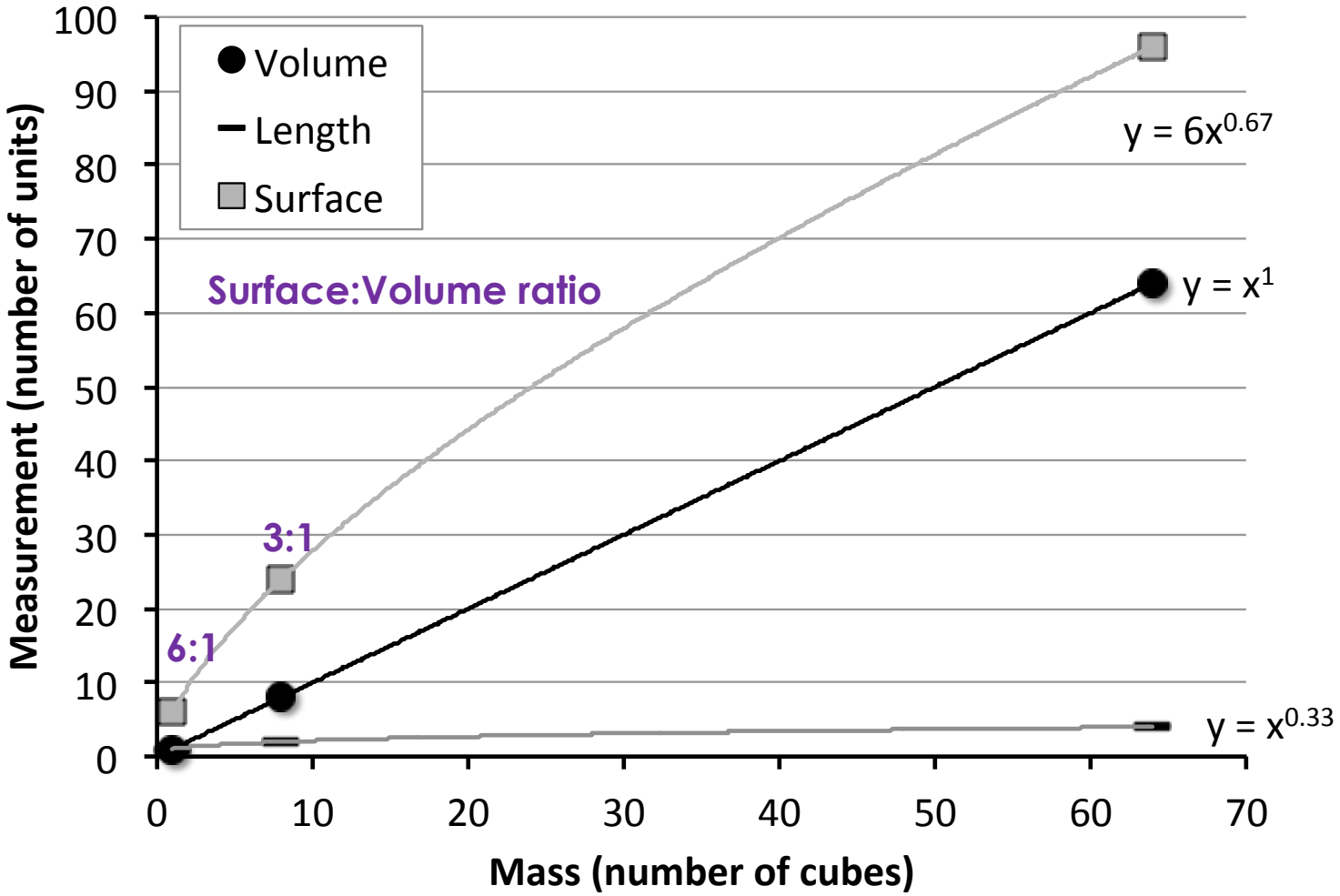

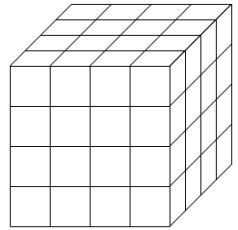

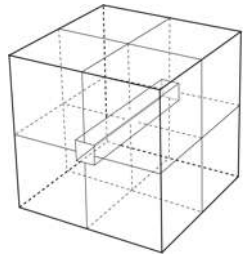

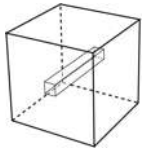

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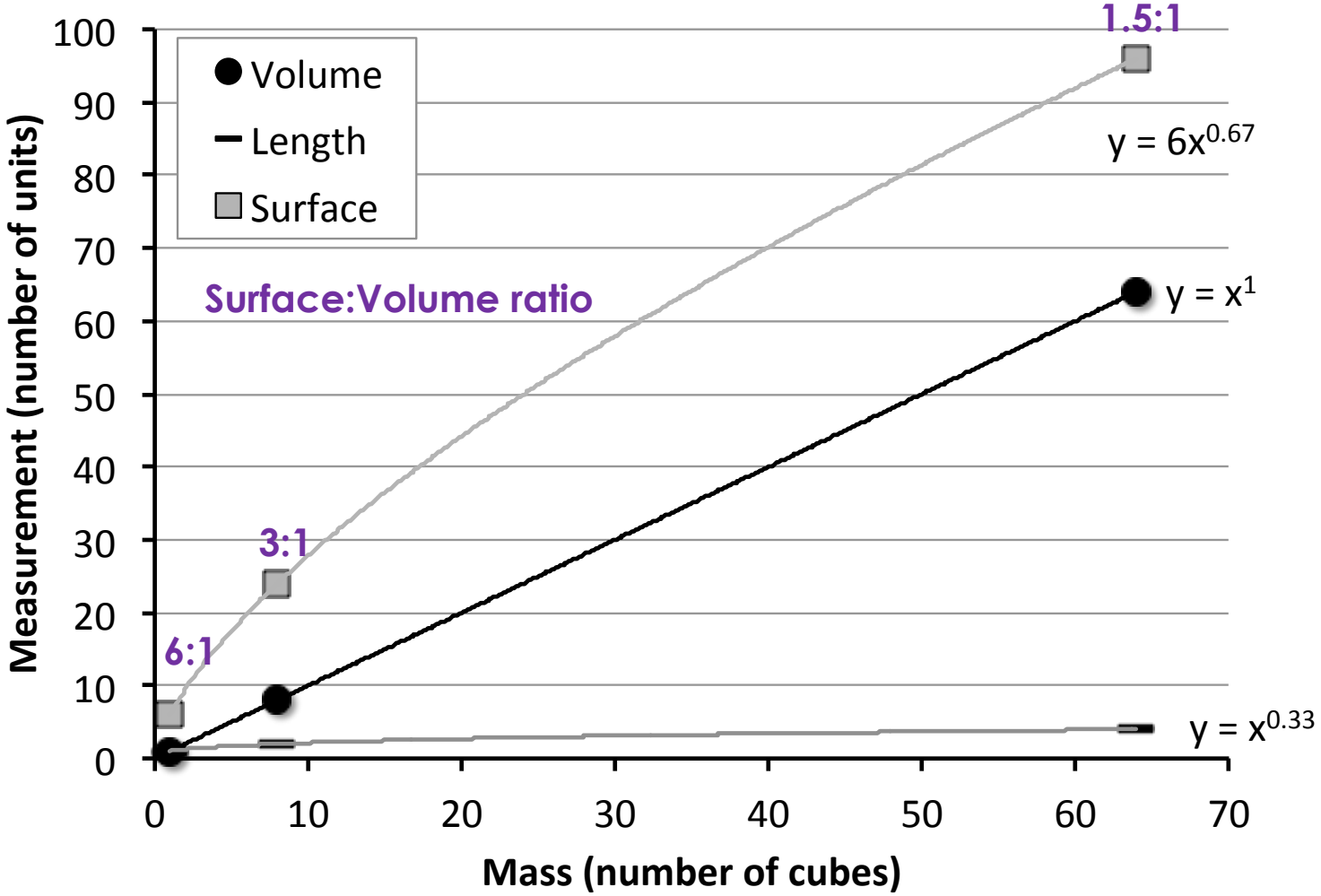

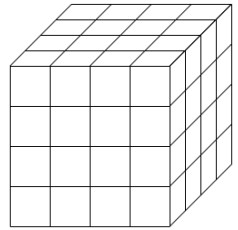

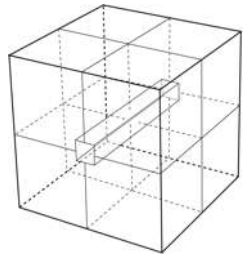

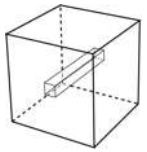

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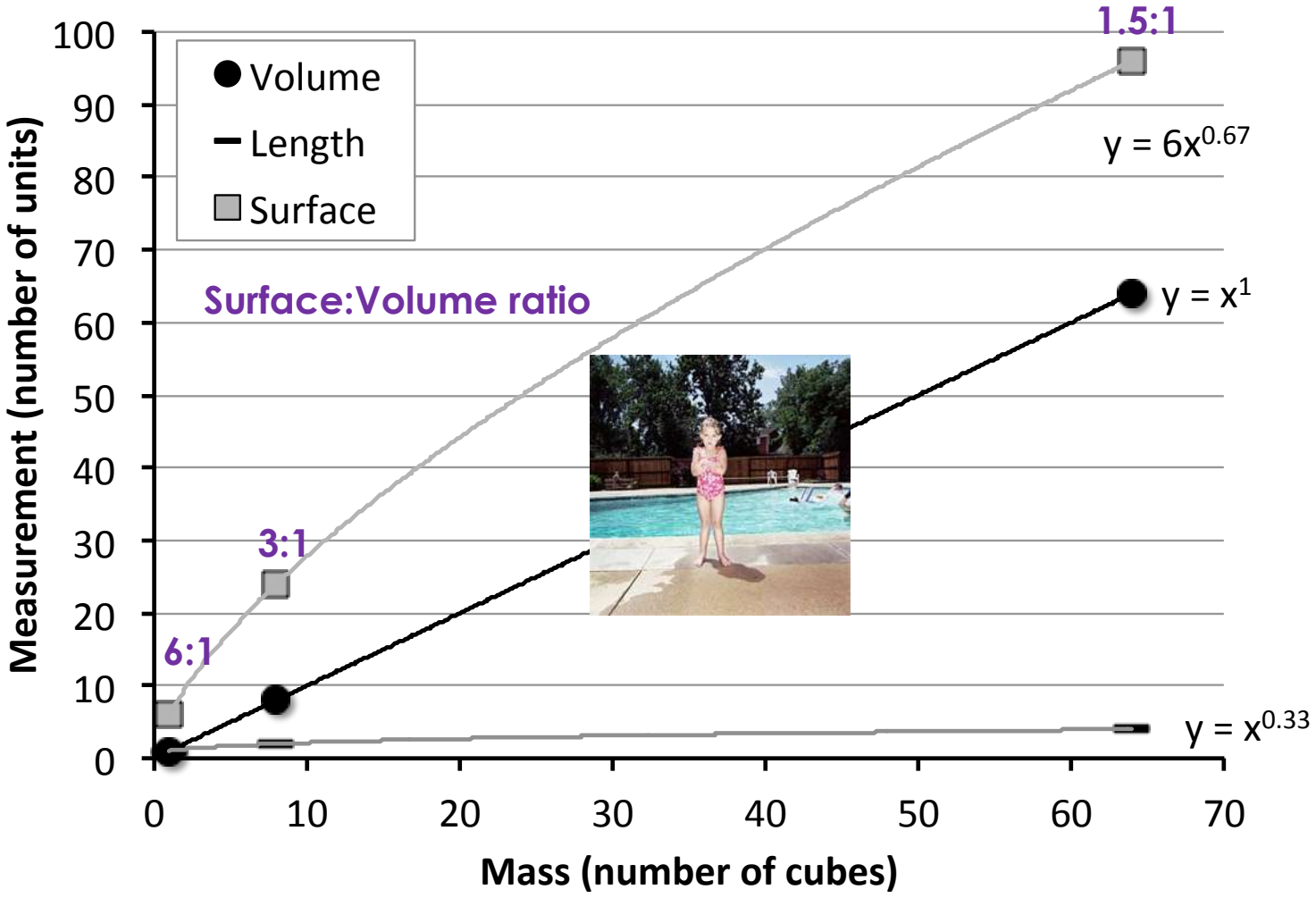

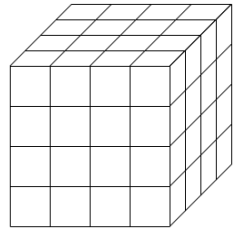

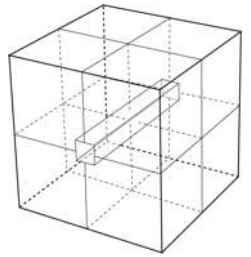

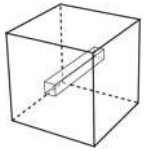

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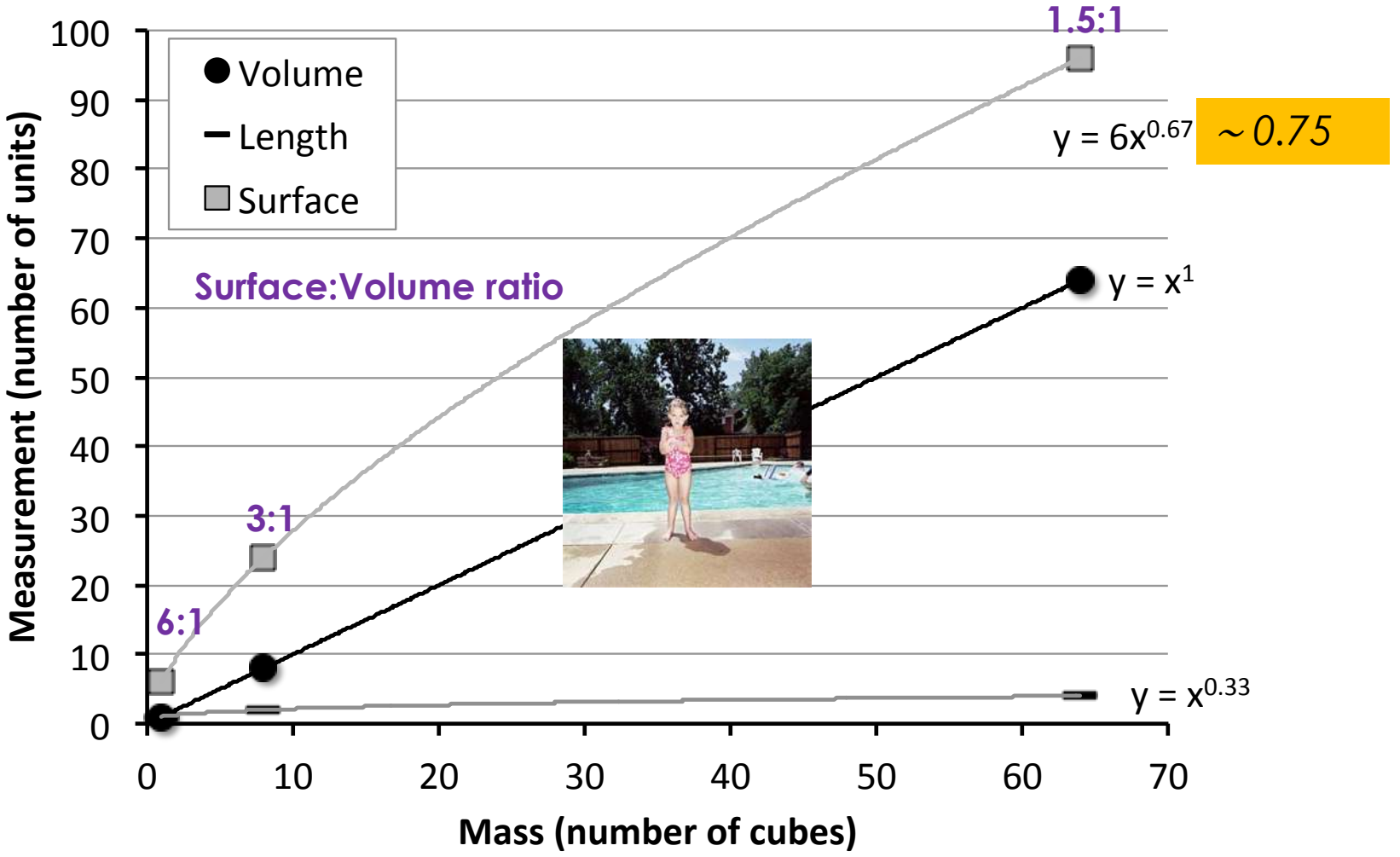

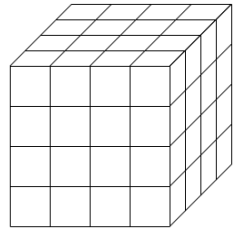

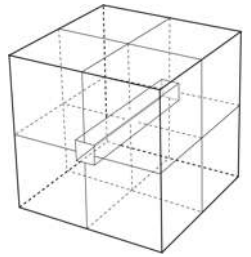

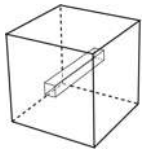

Nutrition of Captive and Free-Living Wild Animals

James K. Kirkwood

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    - estimate (or weigh) body mass
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	Taxonomic group	Equation	Source
BMR	Reptiles (30°C)	$6.7\ W^{0.77}$	Bennett and Dawson, 1976
	Reptiles (20°C)	$2.5\ W^{0.80}$	Bennett and Dawson, 1976
	Birds	$80\ W^{0.67}$	Bennett and Harvey, 1987
	Eutherian mammals	$70\ W^{0.75}$	Kleiber, 1961
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Table 23.1: Allometric equations describing basal metabolic rate (BMR), maintenance energy requirements (MER), and free-living average daily (ADMR) metabolic rates (kcal/day) for a variety of taxonomic groups in relation to body weight (W, kg).

1kcal = 4.184kJ.

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Remember: BMR is a requirement in ME (metabolizable energy). Not GE (gross energy)! Not DE (digestible energy)!

Nutrition of Captive and Free-Living Wild Animals

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1. Requirement estimate
    - estimate (or weigh) body mass
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    - from tables, using various equations (e.g., dog & cat NRC)

Food	Carnivore	Omnivore	Herbivore
lean meat	1.5	1.5	-
fat	9	9	9
whole animals	1.5	1.5	-
grass	-	0.5	0.5
hay	-	-	1.8
cereals/grains	-	3.5	3.0
green vegetables	-	0.2	0.3
roots	-	0.4	0.4
fresh fruit	-	0.4	0.4

Table 23.3: Approximate metabolisable energy densities of some foods

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!

dry matter of hay: 90% of fresh weight
dry matter of grass: 25% of fresh weight

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4. Monitor and adjust continuously !

What about diets with several components ?






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all items must be part of the calculation & weighing/counting





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all items must be part of the calculation & weighing/counting

no problem if you really monitor and adjust continuously

if animals must be fed as a group, the least-preferred item should be given first, when all are hungry and will eat it, before more preferred items are offered

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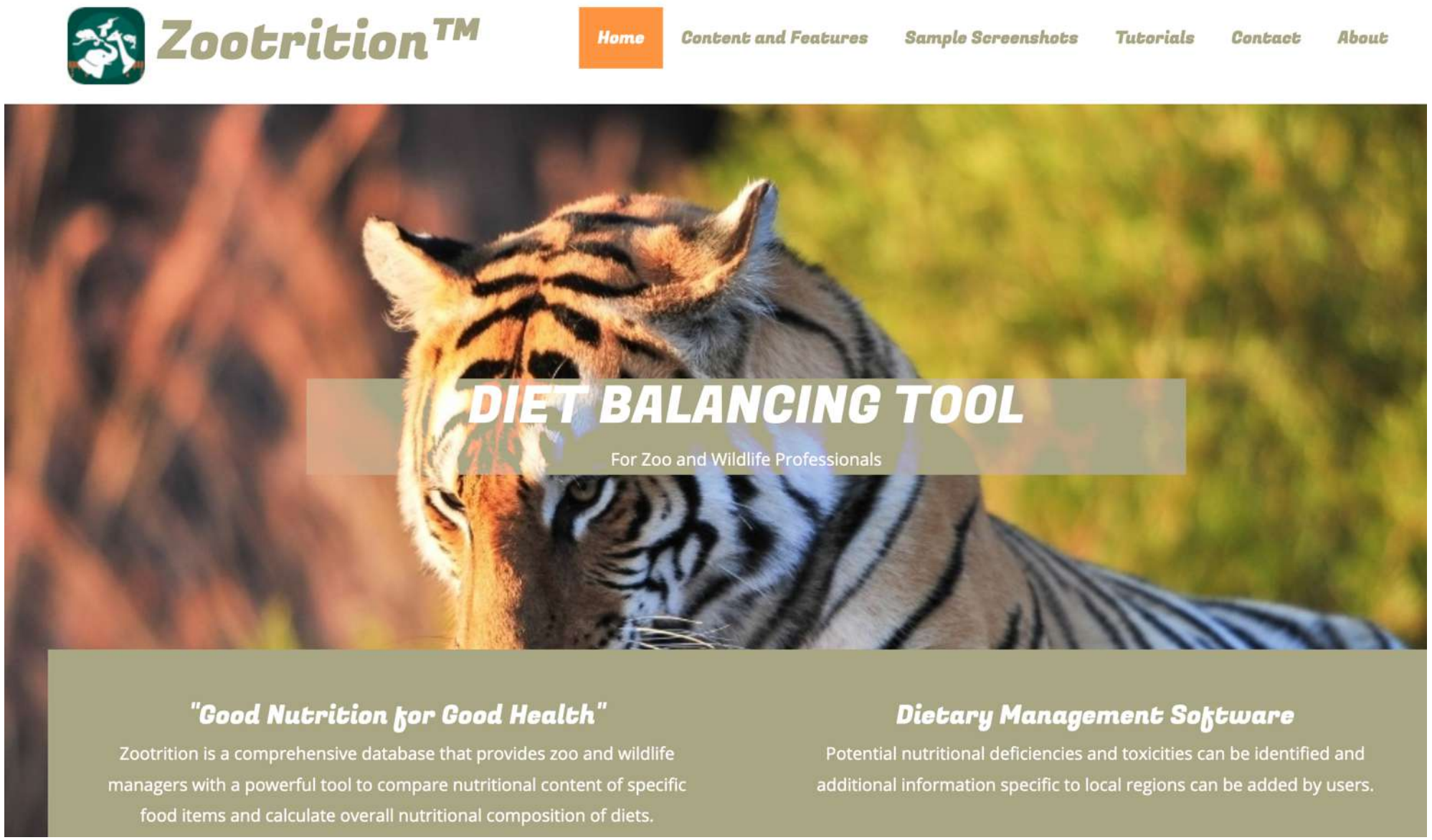
Calculation software



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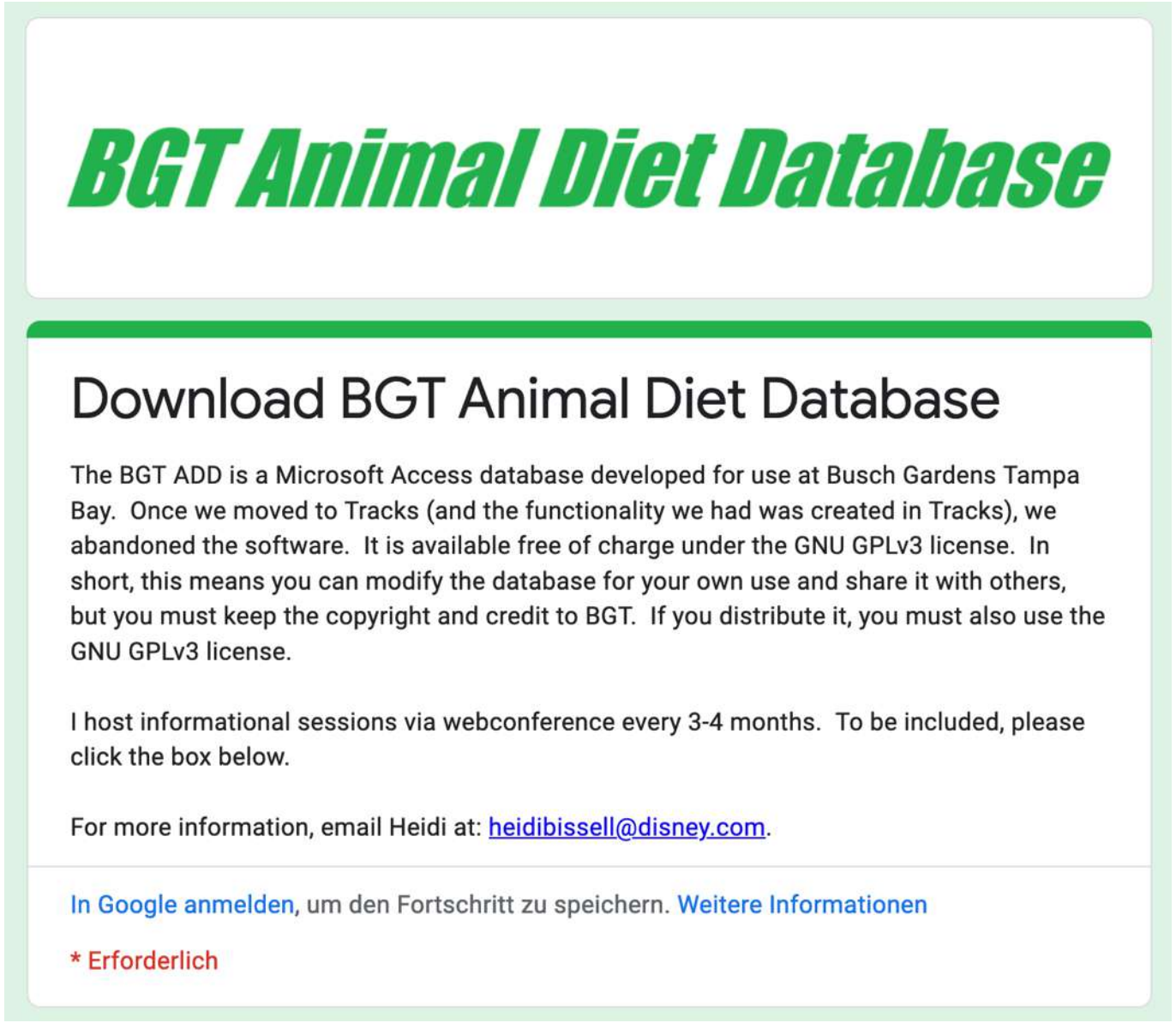

BGT Animal Diet Database

Download BGT Animal Diet Database

The BGT ADD is a Microsoft Access database developed for use at Busch Gardens Tampa Bay. Once we moved to Tracks (and the functionality we had was created in Tracks), we abandoned the software. It is available free of charge under the GNU GPLv3 license. In short, this means you can modify the database for your own use and share it with others, but you must keep the copyright and credit to BGT. If you distribute it, you must also use the GNU GPLv3 license.

I host informational sessions via webconference every 3-4 months. To be included, please click the box below.

For more information, email Heidi at: heidibissell@disney.com.

In Google anmelden, um den Fortschritt zu speichern. Weitere Informationen

* Erforderlich

What is your level of accuracy ?

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Try to get data on the nutritent composition of every item you are using?

- very labour-intensive

*How do you account for **natural variation** due to geographic region, season, subspecies …. ?*

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Always analyse all diet items so that you can do a correct ration composition calculation?

- very expensive (and logistically challenging)

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Try to get species-specific data on the energy and nutrient requirements?

- labour intensive (incl. correct literature interpretation)

*How do you account for **individual differences** in requirements?*

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*How do you account for **individual differences** in requirements?*

*How do you account for **variable ingestion**, leftovers, variation due to group feeding?*

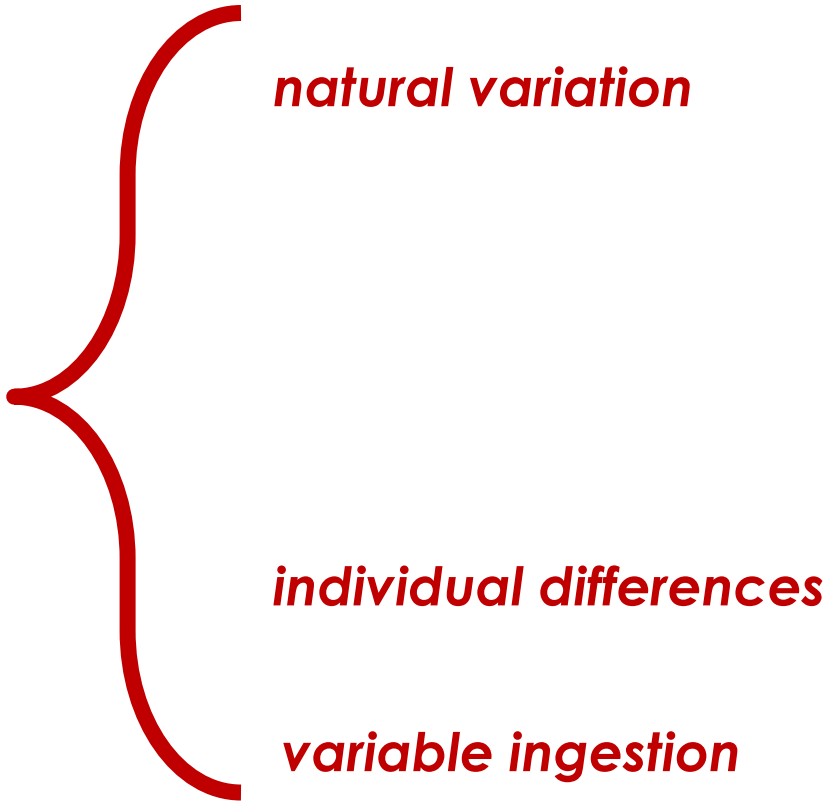
Try to regularly get precise intake data?

- very labour intensive

-

What is your level of accuracy ?

you want safety, not meaningless accuracy



What do we need to achieve our aims ?

We feed zoo animals and we need …

to meet energy requirements → *info on what others did* → *old school*

to meet nutrient requirements / avoid toxicity → *calculate /estimate amounts requirement and composition data* → *nutrition expert*

Nutrient	Quality Prime[a] Alfalfa	Quality 1[a] Alfalfa	Quality 3-4[a,b] Grass	Low Fiber Herbivore Pellet
Moisture, %	9.0-10.7	8.2-9.6	7.4-10.0	10.6
Crude protein, %	18.0-21.8	15.9-17.0	9.8-11.2	17.4
Neutral detergent fiber, %	29.1-36.5	37.2-42.8	51.0-67.4	29.3
Acid detergent fiber, %	24.6-27.3	25.3-33.5	31.2-36.3	17.3
Vitamin A, IU/g[c]	*	*	*	5
Vitamin D, IU/g[c]	*	*	*	1.2
Vitamin E, IU/kg[c]	*	*	*	400
Calcium, %	1.13-1.33	1.2-1.5	0.41-0.67	0.88
Phosphorus, %	0.26-0.27	0.26-0.27	0.19-0.38	0.64
Sodium, %	0.057-0.53	0.014-0.08	0.003-0.03	0.4
Magnesium, %	0.27-0.28	0.24-0.31	0.15-0.21	0.29
Potassium, %	2.1-2.2	1.4-1.7	1.9-2.4	1.5
Copper, mg/kg	7-12	5-9	5-11	23
Iron, mg/kg	166-240	106-138	69-85	394
Manganese, mg/kg	28-38	25-33	25-36	120
Zinc, mg/kg	25-29	17-20	15-31	136

[a] These are classifications of the Hay Market Task Force of the American Forage and Grassland Council (see NAG Fact Sheet 001).
[b] Grasses include timothy, coastal bermudagrass, and sudan.
[c] The vitamin levels in hays are variable; values in pellets were specified concentrations.
* Value not determined.

Body Size	Concentrate Selectors	Medium/Large Browsers		Medium Intermediate Browsers	Medium Intermediate Grazers	Medium/Large Grazers	
Ruminant/Nonrum.	Ruminant	Ruminant	Nonrum.	Ruminant		Ruminant	Nonrum.
Species	Bongo, Klipspringer	Giraffe, Kudu, Sitatunga, Gerenuk, Reindeer, Okapi	Tapir, Blk Rhino, Pigmy Hippo	Goats, Ibex, Eland, Springbok, Dama Gazelle	Sheep, Addax, Pere David's Deer	Waterbuck, Topi, Llama, Camel, Cape Buffalo, Banteng	Zebra, White Rhino	Nile Hippo
Suggested Diet, %[a]	50-75P 25-50AHP	30-40P 60-70AHP	30P 40-50AHQ1 20-30GH	30-40P 60-70AHQ1	30-40P 40-50AHQ1 20GH	30-40P 60-70GH	25-40P 60-75GH	25-30P 20AHQ1 50-55GH
Intake as %BM	3-4%	2%	1.5%	2-3.5%	2-3.5%	1.5-2.5%	1.5-3.0%	1.5%
Nutrient	Nutrient Profiles							
Protein, %	15-18	15-19	13-18	15-19	14-17	12-13	12-14	12-15
NDF, %	23-33	25-34	31-37	25-36	30-33	37-49	37-51	38-44
Vitamin A, IU/g	2.5-3.8	1.5-2.2	1.5	1.5-2.0	1.5-2.0	1.5-2.0	1.2-2.0	1.2-1.5
Vitamin D, IU/g	0.6-0.9	0.4-0.5	0.4	0.4-0.5	0.4-0.5	0.4-0.5	0.3-0.5	0.3-0.4
Vitamin E, IU/kg	200-300	120-178	120	120-160	120-160	120-160	100-160	100-120
Thiamin, mg/kg	-	-	2.4	-	-	-	2.0-3.2	2.0-2.4
Riboflavin, mg/kg	-	-	2.7	-	-	-	2.2-3.6	2.2-2.7
Calcium, %	0.65-0.87	0.70-0.97	0.80-0.90	0.90-1.10	0.80-1.00	0.56-0.63	0.55-0.63	0.68-0.72
Phosphorus, %	0.44-0.54	0.36-0.40	0.35-0.40	0.36-0.41	0.35-0.40	0.32-0.38	0.30-0.38	0.31-0.35
Magnesium, %	0.18-0.22	0.18-0.24	0.20-0.22	0.22-0.24	0.21-0.22	0.16-0.19	0.16-0.19	0.18-0.20
Potassium, %	1.3-1.5	1.6-1.8	1.5-1.7	1.2-1.8	1.3-1.7	1.4-1.8	1.4-1.8	1.6-1.7
Sodium, %	0.16-0.39	0.10-0.44	0.09-0.36	0.10-0.44	0.09-0.36	0.09-0.12	0.07-0.12	0.08-0.20
Iron, mg/kg	107-125	126-139	82-126	98-139	93-126	75-84	73-84	77-99
Zinc, mg/kg	77-106	54-68	52-58	51-67	51-68	50-84	44-71	45-60
Copper, mg/kg	13-16	10-12	10-12	11-13	11-12	9-14	8-14	9-12
Manganese, mg/kg	57-75	54-57	45-51	44-57	43-56	43-55	40-55	41-50
Selenium, mg/kg	0.20-0.30	0.12-0.18	0.12	0.12-0.16	0.12-0.16	0.12-0.16	0.10-0.16	0.10-0.12
Iodine, mg/kg	0.5-0.8	0.3-0.4	0.3	0.3-0.4	0.3-0.4	0.3-0.4	0.2-0.4	0.2-0.3

[a] P = Low Fiber Pellets; AHP = alfalfa hay quality prime; AHQ1 = alfalfa hay quality grade 1; GH = grass hay.

We feed zoo animals and we need …

to meet energy requirements → *info on what others did* → *old school*

to meet nutrient requirements / avoid toxicity → *calculate /estimate amounts requirement and composition data* → *nutrition expert*

to meet physiological requirements

Nutrient	Quality Prime[a] Alfalfa	Quality 1[a] Alfalfa	Quality 3-4[a,b] Grass	Low Fiber Herbivore Pellet
Moisture, %	9.0-10.7	8.2-9.6	7.4-10.0	10.6
Crude protein, %	18.0-21.8	15.9-17.0	9.8-11.2	17.4
Neutral detergent fiber, %	29.1-36.5	37.2-42.8	51.0-67.4	29.3
Acid detergent fiber, %	24.6-27.3	25.3-33.5	31.2-36.3	17.3
Vitamin A, IU/g[c]	*	*	*	5
Vitamin D, IU/g[c]	*	*	*	1.2
Vitamin E, IU/kg[c]	*	*	*	400
Calcium, %	1.13-1.33	1.2-1.5	0.41-0.67	0.88
Phosphorus, %	0.26-0.27	0.26-0.27	0.19-0.38	0.64
Sodium, %	0.057-0.53	0.014-0.08	0.003-0.03	0.4
Magnesium, %	0.27-0.28	0.24-0.31	0.15-0.21	0.29
Potassium, %	2.1-2.2	1.4-1.7	1.9-2.4	1.5
Copper, mg/kg	7-12	5-9	5-11	23
Iron, mg/kg	166-240	106-138	69-85	394
Manganese, mg/kg	28-38	25-33	25-36	120
Zinc, mg/kg	25-29	17-20	15-31	136

[a] These are classifications of the Hay Market Task Force of the American Forage and Grassland Council (see NAG Fact Sheet 001).
[b] Grasses include timothy, coastal bermudagrass, and sudan.
[c] The vitamin levels in hays are variable; values in pellets were specified concentrations.
* Value not determined.

Body Size	Concentrate Selectors	Medium/Large Browsers		Medium Intermediate Browsers	Medium Intermediate Grazers	Medium/Large Grazers	
Ruminant/Nonrum.	Ruminant	Ruminant	Nonrum.	Ruminant		Ruminant	Nonrum.
Species	Bongo, Klipspringer	Giraffe, Kudu, Sitatunga, Gerenuk, Reindeer, Okapi	Tapir, Blk Rhino, Pygmy Hippo	Goats, Ibex, Eland, Springbok, Dama Gazelle	Sheep, Addax, Pere David's Deer	Waterbuck, Topi, Llama, Camel, Cape Buffalo, Banteng	Zebra, White Rhino	Nile Hippo
Suggested Diet, %[a]	50-75P 25-50AHP	30-40P 60-70AHP	30P 40-50AHQ1 20-30GH	30-40P 60-70AHQ1	30-40P 40-50AHQ1 20GH	30-40P 60-70GH	25-40P 60-75GH	25-30P 20AHQ1 50-55GH
Intake as %BM	3-4%	2%	1.5%	2-3.5%	2-3.5%	1.5-2.5%	1.5-3.0%	1.5%
Nutrient	Nutrient Profiles							
Protein, %	15-18	15-19	13-18	15-19	14-17	12-13	12-14	12-15
NDF, %	23-33	25-34	31-37	25-36	30-33	37-49	37-51	38-44
Vitamin A, IU/g	2.5-3.8	1.5-2.2	1.5	1.5-2.0	1.5-2.0	1.5-2.0	1.2-2.0	1.2-1.5
Vitamin D, IU/g	0.6-0.9	0.4-0.5	0.4	0.4-0.5	0.4-0.5	0.4-0.5	0.3-0.5	0.3-0.4
Vitamin E, IU/kg	200-300	120-178	120	120-160	120-160	120-160	100-160	100-120
Thiamin, mg/kg	-	-	2.4	-	-	-	2.0-3.2	2.0-2.4
Riboflavin, mg/kg	-	-	2.7	-	-	-	2.2-3.6	2.2-2.7
Calcium, %	0.65-0.87	0.70-0.97	0.80-0.90	0.90-1.10	0.80-1.00	0.56-0.63	0.55-0.63	0.68-0.72
Phosphorus, %	0.44-0.54	0.36-0.40	0.35-0.40	0.36-0.41	0.35-0.40	0.32-0.38	0.30-0.38	0.31-0.35
Magnesium, %	0.18-0.22	0.18-0.24	0.20-0.22	0.22-0.24	0.21-0.22	0.16-0.19	0.16-0.19	0.18-0.20
Potassium, %	1.3-1.5	1.6-1.8	1.5-1.7	1.2-1.8	1.3-1.7	1.4-1.8	1.4-1.8	1.6-1.7
Sodium, %	0.16-0.39	0.10-0.44	0.09-0.36	0.10-0.44	0.09-0.36	0.09-0.12	0.07-0.12	0.08-0.20
Iron, mg/kg	107-125	126-139	82-126	98-139	93-126	75-84	73-84	77-99
Zinc, mg/kg	77-106	54-68	52-58	51-67	51-68	50-84	44-71	45-60
Copper, mg/kg	13-16	10-12	10-12	11-13	11-12	9-14	8-14	9-12
Manganese, mg/kg	57-75	54-57	45-51	44-57	43-56	43-55	40-55	41-50
Selenium, mg/kg	0.20-0.30	0.12-0.18	0.12	0.12-0.16	0.12-0.16	0.12-0.16	0.10-0.16	0.10-0.12
Iodine, mg/kg	0.5-0.8	0.3-0.4	0.3	0.3-0.4	0.3-0.4	0.3-0.4	0.2-0.4	0.2-0.3

[a] P = Low Fiber Pellets; AHP = alfalfa hay quality prime; AHQ1 = alfalfa hay quality grade 1; GH = grass hay.

We feed zoo animals and we need …

to meet energy requirements → *info on what others did* → *old school*

to meet nutrient requirements / avoid toxicity → *calculate /estimate amounts requirement and composition data* → *nutrition expert*

to meet physiological requirements → *calculate /estimate amounts knowledge on natural diets*
incl. composition, and composition of available replacements

Nutrient	Quality Prime[a] Alfalfa	Quality 1[a] Alfalfa	Quality 3-4[a,b] Grass	Low Fiber Herbivore Pellet
Moisture, %	9.0-10.7	8.2-9.6	7.4-10.0	10.6
Crude protein, %	18.0-21.8	15.9-17.0	9.8-11.2	17.4
Neutral detergent fiber, %	29.1-36.5	37.2-42.8	51.0-67.4	29.3
Acid detergent fiber, %	24.6-27.3	25.3-33.5	31.2-36.3	17.3
Vitamin A, IU/g[c]	*	*	*	5
Vitamin D, IU/g[c]	*	*	*	1.2
Vitamin E, IU/kg[c]	*	*	*	400
Calcium, %	1.13-1.33	1.2-1.5	0.41-0.67	0.88
Phosphorus, %	0.26-0.27	0.26-0.27	0.19-0.38	0.64
Sodium, %	0.057-0.53	0.014-0.08	0.003-0.03	0.4
Magnesium, %	0.27-0.28	0.24-0.31	0.15-0.21	0.29
Potassium, %	2.1-2.2	1.4-1.7	1.9-2.4	1.5
Copper, mg/kg	7-12	5-9	5-11	23
Iron, mg/kg	166-240	106-138	69-85	394
Manganese, mg/kg	28-38	25-33	25-36	120
Zinc, mg/kg	25-29	17-20	15-31	136

[a] These are classifications of the Hay Market Task Force of the American Forage and Grassland Council (see NAG Fact Sheet 001).
[b] Grasses include timothy, coastal bermudagrass, and sudan.
[c] The vitamin levels in hays are variable; values in pellets were specified concentrations.
* Value not determined.

Body Size	Concentrate Selectors	Medium/Large Browsers		Medium Intermediate Browsers	Medium Intermediate Grazers	Medium/Large Grazers	
Ruminant/Nonrum.	Ruminant	Ruminant	Nonrum.	Ruminant		Ruminant	Nonrum.
Species	Bongo, Klipspringer	Giraffe, Kudu, Sitatunga, Gerenuk, Reindeer, Okapi	Tapir, Blk Rhino, Pygmy Hippo	Goats, Ibex, Eland, Springbok, Dama Gazelle	Sheep, Addax, Pere David's Deer	Waterbuck, Topi, Llama, Camel, Cape Buffalo, Banteng	Zebra, White Rhino	Nile Hippo
Suggested Diet, %[a]	50-75P 25-50AHP	30-40P 60-70AHP	30P 40-50AHQ1 20-30GH	30-40P 60-70AHQ1	30-40P 40-50AHQ1 20GH	30-40P 60-70GH	25-40P 60-75GH	25-30P 20AHQ1 50-55GH
Intake as %BM	3-4%	2%	1.5%	2-3.5%	2-3.5%	1.5-2.5%	1.5-3.0%	1.5%
Nutrient	Nutrient Profiles							
Protein, %	15-18	15-19	13-18	15-19	14-17	12-13	12-14	12-15
NDF, %	23-33	25-34	31-37	25-36	30-33	37-49	37-51	38-44
Vitamin A, IU/g	2.5-3.8	1.5-2.2	1.5	1.5-2.0	1.5-2.0	1.5-2.0	1.2-2.0	1.2-1.5
Vitamin D, IU/g	0.6-0.9	0.4-0.5	0.4	0.4-0.5	0.4-0.5	0.4-0.5	0.3-0.5	0.3-0.4
Vitamin E, IU/kg	200-300	120-178	120	120-160	120-160	120-160	100-160	100-120
Thiamin, mg/kg	-	-	2.4	-	-	-	2.0-3.2	2.0-2.4
Riboflavin, mg/kg	-	-	2.7	-	-	-	2.2-3.6	2.2-2.7
Calcium, %	0.65-0.87	0.70-0.97	0.80-0.90	0.90-1.10	0.80-1.00	0.56-0.63	0.55-0.63	0.68-0.72
Phosphorus, %	0.44-0.54	0.36-0.40	0.35-0.40	0.36-0.41	0.35-0.40	0.32-0.38	0.30-0.38	0.31-0.35
Magnesium, %	0.18-0.22	0.18-0.24	0.20-0.22	0.22-0.24	0.21-0.22	0.16-0.19	0.16-0.19	0.18-0.20
Potassium, %	1.3-1.5	1.6-1.8	1.5-1.7	1.2-1.8	1.3-1.7	1.4-1.8	1.4-1.8	1.6-1.7
Sodium, %	0.16-0.39	0.10-0.44	0.09-0.36	0.10-0.44	0.09-0.36	0.09-0.12	0.07-0.12	0.08-0.20
Iron, mg/kg	107-125	126-139	82-126	98-139	93-126	75-84	73-84	77-99
Zinc, mg/kg	77-106	54-68	52-58	51-67	51-68	50-84	44-71	45-60
Copper, mg/kg	13-16	10-12	10-12	11-13	11-12	9-14	8-14	9-12
Manganese, mg/kg	57-75	54-57	45-51	44-57	43-56	43-55	40-55	41-50
Selenium, mg/kg	0.20-0.30	0.12-0.18	0.12	0.12-0.16	0.12-0.16	0.12-0.16	0.10-0.16	0.10-0.12
Iodine, mg/kg	0.5-0.8	0.3-0.4	0.3	0.3-0.4	0.3-0.4	0.3-0.4	0.2-0.4	0.2-0.3

[a] P = Low Fiber Pellets; AHP = alfalfa hay quality prime; AHQ1 = alfalfa hay quality grade 1; GH = grass hay.

We feed zoo animals and we need …

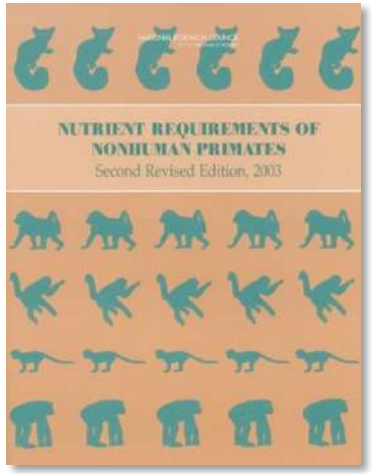
to meet energy requirements → *info on what others did* → *old school*

to meet nutrient requirements / avoid toxicity → *calculate /estimate amounts requirement and composition data* →

to meet physiological requirements → *calculate /estimate amounts knowledge on natural diets*
incl. composition, and composition of available replacements →

nutrition expert

zoology expert



Nutrient	Quality Prime[a] Alfalfa	Quality 1[a] Alfalfa	Quality 3-4[a,b] Grass	Low Fiber Herbivore Pellet
Moisture, %	9.0-10.7	8.2-9.6	7.4-10.0	10.6
Crude protein, %	18.0-21.8	15.9-17.0	9.8-11.2	17.4
Neutral detergent fiber, %	29.1-36.5	37.2-42.8	51.0-67.4	29.3
Acid detergent fiber, %	24.6-27.3	25.3-33.5	31.2-36.3	17.3
Vitamin A, IU/g[c]	*	*	*	5
Vitamin D, IU/g[c]	*	*	*	1.2
Vitamin E, IU/kg[c]	*	*	*	400
Calcium, %	1.13-1.33	1.2-1.5	0.41-0.67	0.88
Phosphorus, %	0.26-0.27	0.26-0.27	0.19-0.38	0.64
Sodium, %	0.057-0.53	0.014-0.08	0.003-0.03	0.4
Magnesium, %	0.27-0.28	0.24-0.31	0.15-0.21	0.29
Potassium, %	2.1-2.2	1.4-1.7	1.9-2.4	1.5
Copper, mg/kg	7-12	5-9	5-11	23
Iron, mg/kg	166-240	106-138	69-85	394
Manganese, mg/kg	28-38	25-33	25-36	120
Zinc, mg/kg	25-29	17-20	15-31	136

[a] These are classifications of the Hay Market Task Force of the American Forage and Grassland Council (see NAG Fact Sheet 001).
[b] Grasses include timothy, coastal bermudagrass, and sudan.
[c] The vitamin levels in hays are variable; values in pellets were specified concentrations.
* Value not determined.

Body Size	Concentrate Selectors	Medium/Large Browsers		Medium Intermediate Browsers	Medium Intermediate Grazers	Medium/Large Grazers	
Ruminant/Nonrum.	Ruminant	Ruminant	Nonrum.	Ruminant		Ruminant	Nonrum.
Species	Bongo, Klipspringer	Giraffe, Kudu, Sitatunga, Gerenuk, Reindeer, Okapi	Tapir, Blk Rhino, Pygmy Hippo	Goats, Ibex, Eland, Springbok, Dama Gazelle	Sheep, Addax, Pere David's Deer	Waterbuck, Topi, Llama, Camel, Cape Buffalo, Banteng	Zebra, White Rhino	Nile Hippo
Suggested Diet, %[a]	50-75P 25-50AHP	30-40P 60-70AHP	30P 40-50AHQ1 20-30GH	30-40P 60-70AHQ1	30-40P 40-50AHQ1 20GH	30-40P 60-70GH	25-40P 60-75GH	25-30P 20AHQ1 50-55GH
Intake as %BM	3-4%	2%	1.5%	2-3.5%	2-3.5%	1.5-2.5%	1.5-3.0%	1.5%
Nutrient	Nutrient Profiles							
Protein, %	15-18	15-19	13-18	15-19	14-17	12-13	12-14	12-15
NDF, %	23-33	25-34	31-37	25-36	30-33	37-49	37-51	36-44
Vitamin A, IU/g	2.5-3.8	1.5-2.2	1.5	1.5-2.0	1.5-2.0	1.5-2.0	1.2-2.0	1.2-1.5
Vitamin D, IU/g	0.6-0.9	0.4-0.5	0.4	0.4-0.5	0.4-0.5	0.4-0.5	0.3-0.5	0.3-0.4
Vitamin E, IU/kg	200-300	120-178	120	120-160	120-160	120-160	100-160	100-120
Thiamin, mg/kg	-	-	2.4	-	-	-	2.0-3.2	2.0-2.4
Riboflavin, mg/kg	-	-	2.7	-	-	-	2.2-3.6	2.2-2.7
Calcium, %	0.65-0.87	0.70-0.97	0.80-0.90	0.90-1.10	0.80-1.00	0.56-0.63	0.55-0.63	0.68-0.72
Phosphorus, %	0.44-0.54	0.36-0.40	0.35-0.40	0.36-0.41	0.35-0.40	0.32-0.38	0.30-0.38	0.31-0.35
Magnesium, %	0.18-0.22	0.18-0.24	0.20-0.22	0.22-0.24	0.21-0.22	0.16-0.19	0.16-0.19	0.18-0.20
Potassium, %	1.3-1.5	1.6-1.8	1.5-1.7	1.2-1.8	1.3-1.7	1.4-1.8	1.4-1.8	1.6-1.7
Sodium, %	0.16-0.39	0.10-0.44	0.09-0.36	0.10-0.44	0.09-0.36	0.09-0.12	0.07-0.12	0.08-0.20
Iron, mg/kg	107-125	126-139	82-126	98-139	93-126	75-84	73-84	77-99
Zinc, mg/kg	77-106	54-68	52-58	51-67	51-68	50-84	44-71	45-60
Copper, mg/kg	13-16	10-12	10-12	11-13	11-12	9-14	8-14	9-12
Manganese, mg/kg	57-75	54-57	45-51	44-57	43-56	43-55	40-55	41-50
Selenium, mg/kg	0.20-0.30	0.12-0.18	0.12	0.12-0.16	0.12-0.16	0.12-0.16	0.10-0.16	0.10-0.12
Iodine, mg/kg	0.5-0.8	0.3-0.4	0.3	0.3-0.4	0.3-0.4	0.3-0.4	0.2-0.4	0.2-0.3

[a] P = Low Fiber Pellets; AHP = alfalfa hay quality prime; AHQ1 = alfalfa hay quality grade 1; GH = grass hay.

We feed zoo animals and we need …

to meet energy requirements → *info on what others did* → *old school*

to meet nutrient requirements / avoid toxicity → *calculate /estimate amounts requirement and composition data* →

to meet physiological requirements → *calculate /estimate amounts knowledge on natural diets* *incl. composition, and composition of available replacements* →

to influence behaviour / meet psychological requirements

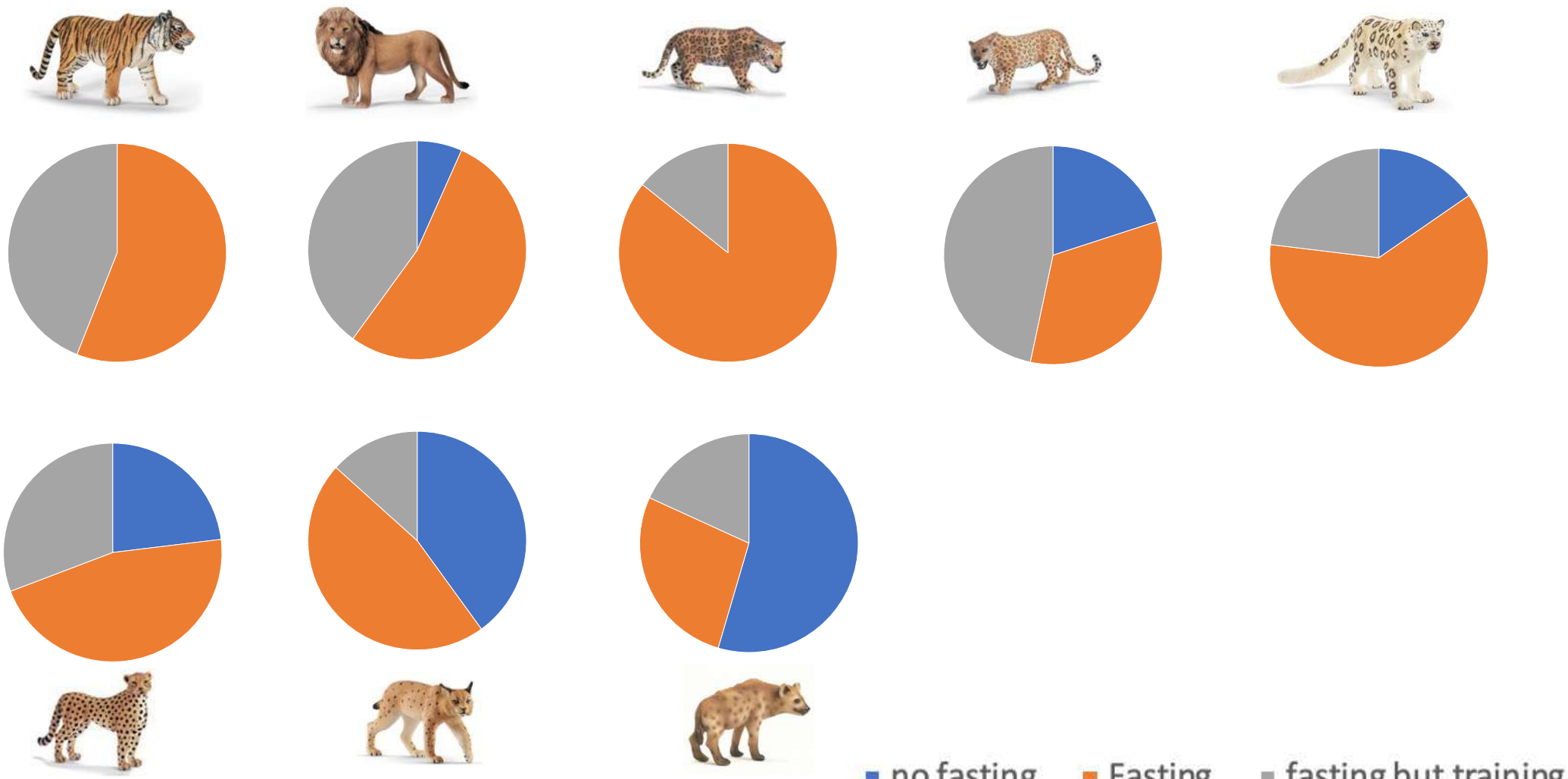
We feed zoo animals and we need …

to meet energy requirements	→	info on what others did	→ old school
to meet nutrient requirements / avoid toxicity	→	calculate /estimate amounts requirement and composition data	→ nutrition expert
to meet physiological requirements	→	calculate /estimate amounts knowledge on natural diets incl. composition, and composition of available replacements	→ zoology expert
to influence behaviour / meet psychological requirements	→	knowledge on natural (feeding) behaviour	

We feed zoo animals and we need …

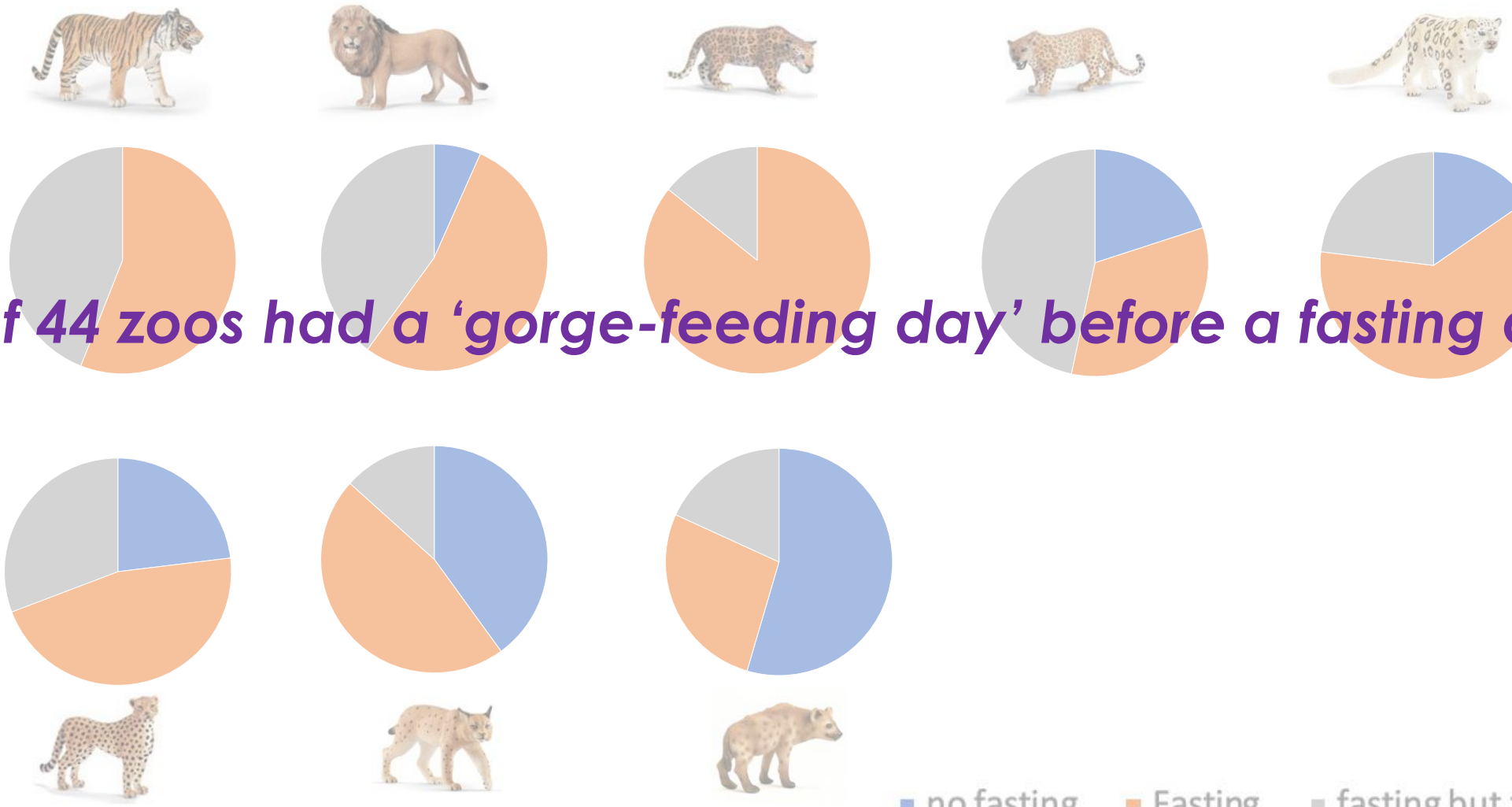
to meet energy requirements	*info on what others did*	*old school*
to meet nutrient requirements / avoid toxicity	*calculate /estimate amounts requirement and composition data*	*nutrition expert*
to meet physiological requirements	*calculate /estimate amounts knowledge on natural diets* incl. composition, and composition of available replacements	*zoology expert*
to influence behaviour / meet psychological requirements	*knowledge on natural (feeding) behaviour*	*zoology/ husbandry expert*

Example: Fasting in large carnivores



Cellina Kleinlugtenbelt (2022)

Example: Fasting in large carnivores



5 of 44 zoos had a 'gorge-feeding day' before a fasting day

Cellina Kleinlugtenbelt (2022)

We feed zoo animals and we need …

to meet energy requirements	*info on what others did*	*old school*
to meet nutrient requirements / avoid toxicity	*calculate /estimate amounts requirement and composition data*	*nutrition expert*
to meet physiological requirements	*calculate /estimate amounts knowledge on natural diets* *incl. composition, and composition of available replacements*	*zoology expert*
to influence behaviour / meet psychological requirements	*knowledge on natural (feeding) behaviour*	*zoology/ husbandry expert*

How do we monitor whether we achieve our aims ?

We monitor …

to meet energy requirements

We monitor …

to meet energy requirements → *is it alive?*

We monitor …

to meet energy requirements → *is it alive?* → *check enclosure*

We monitor …

to meet energy requirements → *is it alive?* → *check enclosure*

to meet nutrient requirements /
avoid toxicity

We monitor …

to meet energy requirements → *is it alive?* → *check enclosure*

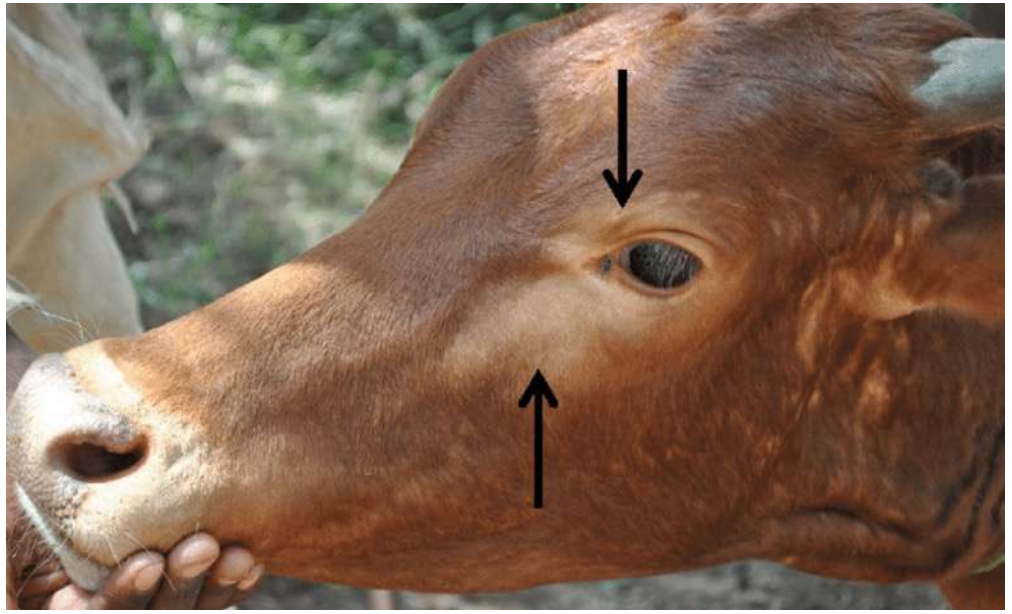
to meet nutrient requirements / avoid toxicity → *do we have deficiencies / toxicities ?*

We monitor …

to meet energy requirements →	*is it alive?* →	*check enclosure*
to meet nutrient requirements / avoid toxicity →	*do we have deficiencies / toxicities ?* →	*clinical signs (eating/defecating/urinating) blood, necropsy reports*

Some deficiency ?

Copper deficiency



Copper deficiency

Journal of Zoo Animal Medicine 19(3): 126–131, 1988

COPPER DEFICIENCY IN CAPTIVE BLESBOK ANTELOPE (*DAMILISCUS DORCAS PHILLIPSI*)

Ellen S. Dierenfeld, Ph.D., Emil P. Dolensek, D.V.M., Tracey S. McNamara, D.V.M., and James G. Doherty, B.S.

Susceptibility of yak (*Bos grunniens*) to copper deficiency

Veterinary Record (1999) 145, 436-437

M. CLAUSS, E. S. DIERENFELD

Copper deficiency and effects of copper supplementation in a herd of red deer (*Cervus elaphus*)

Kjell Handeland*[1], Aksel Bernhoft[2] and Magne S Aartun[3]

Acta Veterinaria Scandinavica 2008, **50**:8

Copper deficiency in a herd of captive muskoxen

Barry R. Blakley, Susan C. Tedesco, Peter F. Flood

Can Vet J 1998; 39: 293–295

We monitor …

to meet energy requirements → *is it alive?* → *check enclosure*

to meet nutrient requirements / avoid toxicity → *do we have deficiencies / toxicities ?* → *clinical signs (eating/defecating/urinating) blood, necropsy reports*

E. J. Flach[1], M. Clauss[2], A. Hunt[3]

Copper deficiency in yak (*Bos grunniens*) at Whipsnade Wild Animal Park

Clinical signs recorded in yak included debility, weight loss, anaemia, diarrhoea, hindleg ataxia, exercise intolerance, alopecia, depigmentation around the eyes, stillbirths and poor neonatal survival.

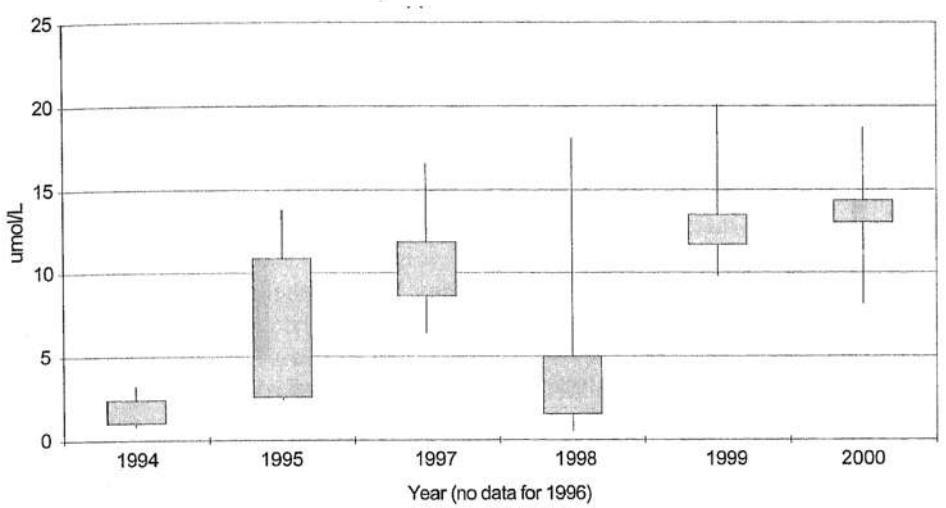


Fig. 1. Yak blood copper concentrations (1994–2000).

Mineral Concentrations in Serum/ Plasma and Liver Tissue of Captive and Free-Ranging Rhinoceros Species

Zoo Biology 24:51–72 (2005)

Ellen S. Dierenfeld,[1]* Shirley Atkinson,[2] A. Morrie Craig,[3] Karen C. Walker,[3] W. Jürgen Streich,[4] and Marcus Clauss[5]

Liver mineral concentrations (wet weight basis) in captive rhinoceros species[a]

	Cu µg/g	Fe µg/g
Adults		
Black Rhino ($n = 12$–21)	6 ± 4	4636 ± 5473
Sumatran Rhino ($n = 2$)	5 ± 0	4960 ± 6279
Indian Rhino ($n = 2$–4)	170 ± 296	833 ± 312
White Rhino ($n = 5$–6)	83 ± 88	530 ± 390
Horse Normal Ranges (this study and Puls [1994])	4.0–7.5	100–300

We monitor …

to meet energy requirements →	*is it alive?* →	*check enclosure*
to meet nutrient requirements / avoid toxicity →	*do we have deficiencies / toxicities ?* →	*clinical signs (eating/defecating/urinating) blood, necropsy reports*
to meet physiological requirements		

We monitor …

to meet energy requirements →	*is it alive?* →	*check enclosure*
to meet nutrient requirements / avoid toxicity →	*do we have deficiencies / toxicities ?* →	*clinical signs (eating/defecating/urinating) blood, necropsy reports*
to meet physiological requirements →	*is the animal physiologically healthy ?*	

We monitor …

to meet energy requirements → *is it alive?* → *check enclosure*

to meet nutrient requirements / avoid toxicity → *do we have deficiencies / toxicities ?* → *clinical signs (eating/defecating/urinating)*

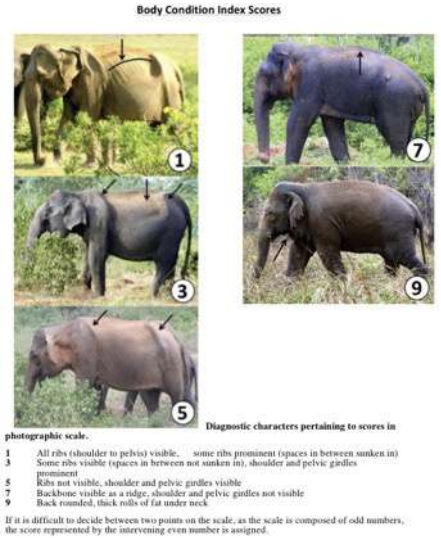
blood, necropsy reports

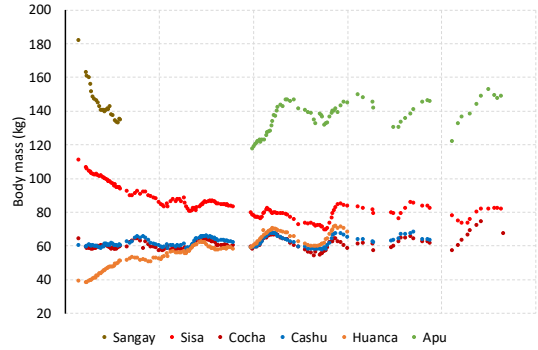
to meet physiological requirements → *is the animal physiologically healthy ?* → *body weight / BCS*

faeces consistency

intake

reproduction





Christian: Monitoring BCS

Lemur Catta Fecal Scoring Chart

Type 1

Type 2

Type 3

Type 4

Type 5

Type 6

Created by: Megan Gerowitz 2015

Type 1: Multiple firm pellets, oval or roundish in shape, may range from dry to slightly moist

Type 2: Pellets form one fecal unit that is moist with distinct segmentation.

Type 3: Soft and log-like in shape, moist dough-like consistency, segmentation is not present

Type 4: Portions may be formed but inconsistent. A mushy stool that may occur in blobs.

Type 5: Very moist, may be hummus-like in texture, found in piles or blobs

Type 6: Milkshake-like consistency, unable to maintain vertical shape, some splattering may occur

Type 7: (Not pictured) Watery, as if poured onto the ground, heavy splattering likely to occur.

akron zoo

Smithsonian
National Zoological Park

version 3.0, revised 06-Nov-05

Fecal Consistency Score for Maned Wolves

SCORE 100 Formed, very hard, dry, crumbly


SCORE 75 Formed, drier but not hard



SCORE 50 Formed, but soft, slightly moist



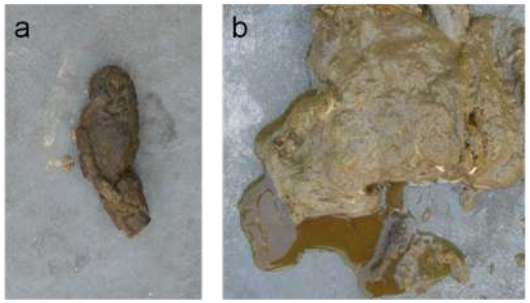
SCORE 25 Mixture of formed and poorly formed, mostly loose



SCORE 0 Very loose to liquid, no form, possibly blood


Dual consistencies

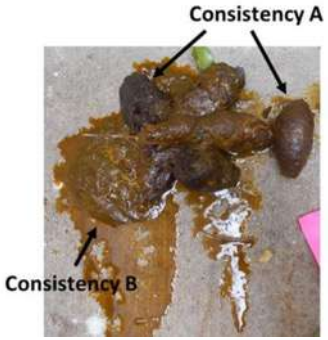
Dog



Brown

De Cuyper et al. (2021)

Tiger



Esparza et al. (2021)

Whole prey feeding

We monitor …

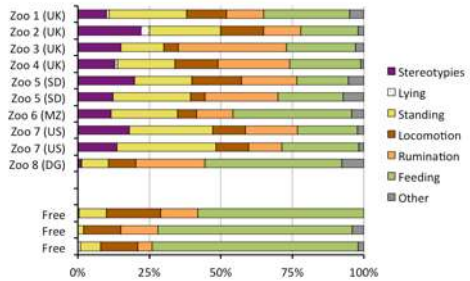
to meet energy requirements	*is it alive?*	*check enclosure*
to meet nutrient requirements / avoid toxicity	*do we have deficiencies / toxicities ?*	*clinical signs (eating/defecating/urinating)* *blood, necropsy reports*
to meet physiological requirements	*is the animal physiologically healthy ?*	*body weight / BCS* *faeces consistency* *intake* *reproduction*
to influence behaviour / meet psychological requirements		

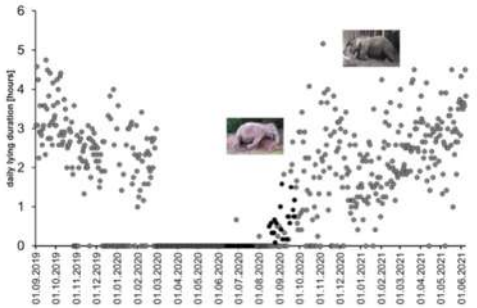
We monitor …

to meet energy requirements	→	*is it alive?*	→ *check enclosure*
to meet nutrient requirements / avoid toxicity	→	*do we have deficiencies / toxicities ?*	→ *clinical signs (eating/defecating/urinating)* *blood, necropsy reports*
to meet physiological requirements	→	*is the animal physiologically healthy ?*	→ *body weight / BCS* *faeces consistency* *intake* *reproduction*
to influence behaviour / meet psychological requirements	→	*is animal behaviour as we want it ?*	

We monitor …

to meet energy requirements	*is it alive?*	*check enclosure*
to meet nutrient requirements / avoid toxicity	*do we have deficiencies / toxicities ?*	*clinical signs (eating/defecating/urinating) bloood, necropsy reports*
to meet physiological requirements	*is the animal physiologically healthy ?*	*body weight / BCS faeces consistency intake reproduction*
to influence behaviour / meet psychological requirements	*is animal behaviour as we want it ?*	*behavioural monitoring (abnormal as well as normal ity budget)*





Imagine an interview

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"We know weighing animals is a professional way of monitoring them … but we can't do it."

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"We check the body condition / skin condition / faeces quality / food intake of our animals … but we do not document it."

Imagine an interview

"We know weighing animals is a professional way of monitoring them … but we can't do it."

"We check the body condition / skin condition / faeces quality / food intake of our animals … but we do not document it."

"We have no concrete idea how our animals should spend their day."

Where do you allocate your resources ?

Resource allocation

Nutritionist

Database generation & curation
Calculation practice (in a single zoo?)
Diet development (in a single zoo?)

Commissary manager

Food acquisition
Food breeding / harvesting
Quality control (regularly, even in a single zoo)

Monitoring of amounts used per time

Husbandry specialist

Husbandry method application (daily)
Monitoring (daily)

How to outsource with confidence