Biophysics for Gamers

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When assigning values to a creature's attributes there is no substitute for thorough research but some facts are too hard to find or nobody knows. Luckily some basic physics came to the rescue. All the rules upon which everything else was built had already been discovered all I had to do was work out were to look. Anyway here are these simple foundations unearthed and laid bare.

This discussion assumes a game system that rates humans at about 50 and uses a linear range, i.e. 100 strength could lift twice as much as 50. You will need to adjust the scale of the attributes to the game system you are using. For example if in your system a typical human is STR10 simply divide the results of the formula by five.

Also assumed is that the animals are from some version of Earth or a very Earth-like world that implausibly uses pretty much the same biochemistry as Earth life. This assumption is true for most fantasy settings and most science fiction (which is written by engineers and arts students). However, some well-researched modern science fiction has realized that different worlds and different molecules (life does not have to use DNA based hereditary and 'animals' don't have to be mostly protein and water) can produce very different ranges to those generated by the formulae presented here. For realistic aliens any of the values discussed here could be very different perhaps even by orders of magnitude! Such realistic aliens would be the topic of a whole other article. However I have included a note on alien life in the discussion of metabolic rates.

Basic facts about the average human.

Mechanics are usually based on the human range of abilities tap into our self-interest that makes Homo sapiens the species about which the most is known and readily accessible. The below rough averages were rendered down during the process.

Mass 60kg

Height 17dm

Volume 59L

Surface area 2m^2

Longevity 75years

Food / day 1.2kg

Water / day 3.0litres

Sleep Period 8hours

Finally some attributes common to most settings were set arbitrarily at a convenient value, 50, for typical humans these are given below.

Strength

Reflexes

Body/Wounds

Basic Relationships

A few basic biophysical relationships hold true for most real living organisms. They are the key to educated guesses of the unknown and placing values for statistics and scores of organisms. All of these are given in terms of mass (kg) except mass itself. In each the first number after the '=' is a constant calculated from the human averages above.

Mass (kg) = 0.013 x hieght^3

Height/Length (dm) = 4.3 x mass$^{1/3}$

Surface Area (m^2)= 0.13 x $mass^{2/3}$

Also 0.0069xhieght^2

Volume (l)= 0.98 x mass

Strength*= 3.3 x $mass^{2/3}$

A more detailed formula is =7.2 x ($Mass^{2/3}$ x F)-mass

Body (Wounds, hits etc.)= 3.3 x $mass^{2/3}$

Metabolic Factor = 0.046 x $mass^{3/4}$

Reflexes = (1/metabolic factor) x 50

Longevity = 12 x $mass^{1/4}$

As all of these formulae are based on the human values they provide only rules of thumb, other considerations are discussed below.

Mass and Height/Length are based on human values and will be completely wrong for most non-humanoids. Fortunately these statistics are usually easy to find or invent. Mass can also be derived from a volume guestimate as the two are roughly equal in Earthly animals.

Surface Area is very variable for different body shapes and the formula given is very rough even for humanoids. Use an average of the two formulae. For winged beasts use wingspan rather than height. Alternatively, for non-humanoids workout roughly using formulae for basic shapes; a snake is almost a cylinder. Surface area is most often used for worn items so ignore the effects of huge ears or other flat or wrinkly organs or hair and other body coverings.

Volume is for land animals for aquatic animals the constant will usually be close to one. Other stranger types must be dealt with on a case by case basis. However for most circumstances I assume for animals that,

Mass (kg) = Volume (l).

This allows easy calculation and allows enough room for comfort in enclosed spaces.

The remaining formulae are for scores and assume that the creature being described obeys the rules of physics as we understand them to apply to living creatures. In some settings these formula should be tossed out of the window. For example in the world of Gulliver's Travels the inhabitants of Lilliput and Brobdingbag are directly scaled versions of normal people surrounded by similarly scaled up objects so strength, body and metabolic factor must be multiplied by the same number as mass.

Strength varies greatly, even among creatures of similar shape, to fit the demands of an organism's lifestyle. Carnivores and brachiators are often very strong. A chimp for example is six times stronger than a human of the same mass. An ape is not just a human in a hairy skin the skeletons offer better leverage, they carry more muscle per mass, and the very proteins of the muscles produce more power than those of human muscles. The standard formula assumes that the creature can lift its own body. The more detailed formula has a built in upper limit were a creature of given proportions can't lift its own mass the strength is zero or less. This formula has a factor F that represents the build of the creature, for human body proportions F=1, a chimp would have F=6, a lion F=5. While more 'realistic' this more detailed version can limit creativity this formula would never allow the creation of King Kong. Strength can also be calculated from maximum carrying capacity (kg) divided by five or maximum lift divided by two. Lifting and carrying capacity for many animals can be found in records books but remember these sources list the maximum for the species so halving the figure may be in order. For flying creatures sometimes the mass the creature can lift is given, for winged flyers strength is about double this mass.

Strength is often one characteristic that game systems struggle with. Firstly, game designers set many animal strengths much too low. By human standards many animals are incredibly strong. Secondly, many games resort to a non-linear scale for strength. If this is the case in the system you are using figure out carrying capacity (x5 the strength from the formula) and use the encumbrance tables from your game to assign strength.

Body assumes that the amount of punishment an animal can take is based on structural strength, which in turn follows the 2/3 rule. Creatures that are ‘overbuilt’ for their size may have higher body scores. Armored organisms, like the tortoise or rhinoceros will not fair any better as natural armor is accounted for separately.

Metabolic Factor is used to determine all sorts of things from food required to surviving poison. A typical human has a factor of x1.0, a creature with a factor of 2.5, for example, requires two and a half times as much food, water, oxygen etc. as a human. Cold-blooded organisms have a metabolism of one tenth that of warm bloods given by the formulae. When calculating the food required vegetarians, except fruitivores, typically require ten times the amount needed by a carnivore of the same mass. Aquatic mammals, which get all their fresh water from their food, add double the water requirement for their mass to their food intake.

A reasonable starting point for guesses about aliens with unusual biochemistries, such as organisms using liquid ammonia instead of water, or operating at higher or lower temperatures for every $10^{o}C$ above $37^{o}C$ double metabolic factor and for every $10^{o}C$ below halve metabolic factor. For anaerobic organisms that do not use oxygen divide the rate by twelve.

While metabolic factor indicates the ‘how much per unit of time’ of metabolism the heart rate is only a guide to how quickly. In most instances metabolic factor is more useful.

The formula for longevity works for most mammals but not humans. For hominids double the figure. Cold-blooded animals tend to live longer, up to ten times as long if they survive. One little known fact is that your humble pond hydra seems to be immortal barring misadventure. Evolution does not overbuild, creatures that are likely to fall prey to predators or misadventure live close to the formula’s result but those that have evolved ways to avoid risk, such as wings, shells and intelligence, may have much longer life spans. There is an evolutionary hypothesis of the rise of aging inspired by our friend the immortal hydra relating reproduction timing to longevity. Species that spread the production of offspring over their lifespan and have the ability to avoid hazards select for longevity. Consider sea turtles: big tanks with few predators (when adults) that produce offspring year after year decade after decade. Sea turtles with mutations that affect them later in life end up producing less offspring. Now consider mice they produce lots of offspring every year but they are small, vulnerable and tasty. The bulk of the mouse population is born to young parents so generation after generation mutations that affect mice as they get older are passed on, the net effect is short lived rodents.

Research

Even given the above formulae I still use them as a last resort, there is no substitute for research. Other attributes can only be found by research. Some including sleep period, longevity, and speed can be derived from the description of the attribute. Speed, for example, is distance covered in a combat round, however long that is in you game. Others, such as intellect, require careful consideration of the facts and then a judgment to be made.