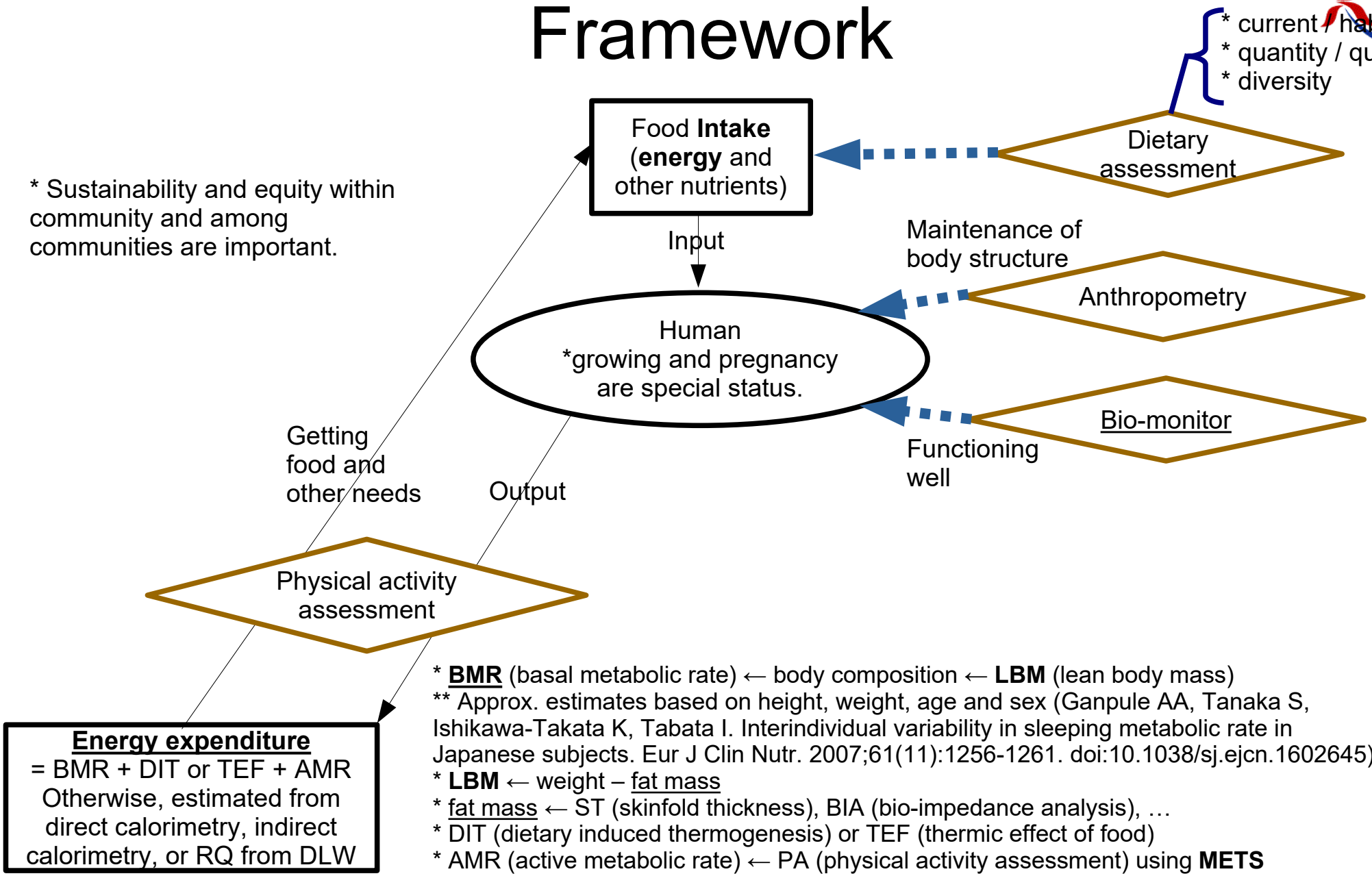
Models of food intake and energy

- Human-being needs energy/nutrient intake for survival
  - As counteraction (input): Food (energy and nutrients) intake, …
    - Individual level: BMR (basal metabolic rate) + AMR (active metabolic rate) (+growth in children, adolescents), micronutrients (vitamin, mineral, ...)
    - Community level: Sharing, Storage, … (esp. pre-harvest season)
  - As action (output): Food gathering, hunting, fishing, agricultural labor, …
    - Optimal foraging theory
    - Energy expenditure for subsistence
- Input-Output analysis
  - Developed in economics in the 1930s and 1940s by Wassily Wassilyovich Leontief
    - An adaptation of the neo-classical theory of general equilibrium to the empirical study of the quantitative interdependence between interrelated economic activities. All industries, households, government are connected through buy-sell relationships, which is measurable

    https://support.implan.com/hc/en-us/articles/18943229883675-History-of-Input-Output
  - Application to sociology https://doi.org/10.1016/S1053-5357(01)00120-2
  - Application to anthropology
    - Dobe !Kung San (Lee RB, 1969), Mezquiral valley farmer (Finkler K, 1979), Jamaican fishermen (Edel M, 1967), … as Economic Anthropology study
      https://www.jstor.org/stable/643563
      https://www.jstor.org/stable/27856295
    - Dobe !Kung San (Howell N, 2010), Oriomo Papuans (Ohtsuka R, 1983), … as Ecological Anthropology study
      https://doi.org/10.1007/BF01531422
      https://doi.org/10.1017/S002193200021477

Framework



* Sustainability and equity within community and among communities are important.

* **BMR** (basal metabolic rate) ← body composition ← **LBM** (lean body mass)
** Approx. estimates based on height, weight, age and sex (Ganpule AA, Tanaka S, Ishikawa-Takata K, Tabata I. Interindividual variability in sleeping metabolic rate in Japanese subjects. Eur J Clin Nutr. 2007;61(11):1256-1261. doi:10.1038/sj.ejcn.1602645)
* **LBM** ← weight – fat mass
* fat mass ← ST (skinfold thickness), BIA (bio-impedance analysis), …
* DIT (dietary induced thermogenesis) or TEF (thermic effect of food)
* AMR (active metabolic rate) ← PA (physical activity assessment) using **METS**
** Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc. 2000;32(9 Suppl):S498-S504. doi:10.1097/00005768-200009001-00009

Dietary Intake Research

- Sources
  - https://www.nutritools.org/tools
  - https://openknowledge.fao.org/server/api/core/bitstreams/3dc75cfc-9128-4f29-9d76-8d1f792078f0/content
  - https://www.measurement-toolkit.org/ (DAPA toolkit)
- Dietary Diversity
  - FAO's DD (2012) https://www.fao.org/4/i1983e/i1983e00.htm
    - Minimum DD For Women (2021) https://doi.org/10.4060/cb3434en
  - FDSK-11 (2008) http://yumik-fn.sakura.ne.jp/whats-fn/
- FFQ (Food Frequency Questionnaire) https://doi.org/10.1136/bmjopen-2021-058831
  - NHANES (USA) https://epi.grants.cancer.gov/diet/usualintakes/ffq.html
  - BDHQ/DHQ (Japan) http://www.nutrepi.m.u-tokyo.ac.jp/dhq/summary.html (in Japanese) https://webpark1505.sakura.ne.jp/english/dhq/dhq.html
- 24 hours dietary recall https://www.measurement-toolkit.org/diet/subjective-methods/24-hour-dietary-recall
  - ASA24 https://epi.grants.cancer.gov/asa24/
    - (For research) https://asa24.nci.nih.gov/researchersite/
    - (Demonstration) https://asa24.nci.nih.gov/demo/
- Food diary
  - Weighed diary https://www.measurement-toolkit.org/diet/subjective-methods/weighed-food-diaries
  - Estimated diary https://www.measurement-toolkit.org/diet/subjective-methods/estimated-food-diaries
- Technology-assisted methods https://www.measurement-toolkit.org/diet/subjective-methods/technology-assisted
- Direct observation https://www.measurement-toolkit.org/diet/objective-methods/direct-observation
- Duplicated diets https://www.measurement-toolkit.org/diet/objective-methods/duplicate-diets

Anthropometry

- Sources
  - https://www.measurement-toolkit.org/anthropometry/introduction/anthropometry
  - https://www.fao.org/4/y4249e/y4249e0b.htm
  - https://www.fantaproject.org/tools/anthropometry-guide
- Direct measurements
  - Height: Using stadiometer (eg. Seca 213) https://www.seca.com/en_ee/products/all-products/product-details/seca213.html
  - Weight: Using digital scale (eg. TANITA HD-665) https://www.tanita.co.jp/product/bathroomscale-babyscale/3077/
  - Skinfold thickness: Using skinfold caliper (eg. Harpenden http://www.harpenden-skinfold.com/) https://doi.org/10.1017/S0007114510003727
  - Mid-Upper Arm Circumference: Using tape measure
  - Waist circumference: Using tape measure (eg. Seca 201/203) https://www.seca.com/en_ee/products/all-products/product-details/seca201.html
  - Hip circumference: Using tape measure (eg. Seca 201/203)
- Calculated indices
  - BMI (body mass index) = Weight (kg) / (Height · Height) (m^2)
  - Z scores based on **the standards (below):** (Values – Standard) / SD of Standard
    http://conflict.lshtm.ac.uk/page_125.htm
    HAZ (for stunting), WAZ (for underweight), WHZ (for wasting)
    https://www.cdc.gov/nccdphp/dnpa/growthcharts/resources/growthchart.pdf
    - CDC https://www.cdc.gov/nchs/data/series/sr_11/sr11_246.pdf
    - WHO https://www.who.int/tools/child-growth-standards/standards
  - Waist-to-hip ratio = Waist circumference / Hip circumference
  - BRI (body roundness index) = 364.2 – 365.5 * eccentricity; eccentricity = vertical ellipse around the body, as square-root of {1 – square of (Waist-to-Height ratio / pi)}
    https://doi.org/10.1002/oby.20408

Biomonitoring

- Measure nutrients and its metaborites in biological specimen
  - https://www.cdc.gov/biomonitoring/videos/Biomonitoring-teaches-about-nutrition.html
  - https://www.measurement-toolkit.org/diet/objective-methods/biomarkers
  - https://www.biomedcentral.com/collections/bfnr
  - https://academic.oup.com/jn/article/133/3/873S/4688049
  - https://dx.doi.org/10.3390%2Fnu11051092
  - http://www.ph.ucla.edu/epi/faculty/zhang/courses/epi242/reading%20week%204-2d.pdf
- Blood
  - https://magazine.baze.com/blood-testing/
  - https://ajph.aphapublications.org/doi/pdf/10.2105/AJPH.63.11_Suppl.28
- Urine (non-invasive, frequently used for salt and iodine intake)
  - https://doi.org/10.3164/jcbn.16-50
  - https://doi.org/10.1017/S136898002000097X
  - https://doi.org/10.1038/ejcn.2013.62
- Feces for gut microbiota
  - https://doi.org/10.1093/jn/nxaa285
  - https://doi.org/10.1136/bmj.k2179
- Stable isotope in hair and nail
  - https://doi.org/10.1073/pnas.1914087117
  - https://doi.org/10.1371/journal.pone.0184921

Physical Activity Assessment

- Different construct to physical fitness
- Exercise is a type of physical activity undertaken in leisure time and should not be used interchangeably with the term ‘activity’.
  - Assessing Basal Metabolic Rate (BMR)
  - Assessing Active Metabolic Rate (AMR) using Metabolic Equivalents (METs)
    - The intensity of physical activity can be expressed relative to an individual’s resting energy expenditure, referred to as MET
    - Individual activities are assigned a MET value representing their energy cost relative to this resting value
    - (eg.) A MET value of 2.0 represents a doubling of the resting rate of energy expenditure and would be indicative of light physical activity
    - A compendium of behaviors and their associated MET scores was originally published in 1993 and updated in 2011 ranging from sleep (0.9 MET) to running at 14.0 mph (23.0 METs), 2018 for youth, 2024 updates for 3 targets
      https://doi.org/10.1249/mss.0b013e31821ece12
      https://doi.org/10.1080/02701367.2018.1487754
      https://doi.org/10.1016/j.jshs.2023.10.010
  - Questionnaire, Direct observation of behavior, Heart Rate Monitoring, Calorimetry, Doubly Labeled Water, ...
- Sedentary behavior is not merely the absence of physical activity and is emerging as a potential independent health risk.

Sedentary Behavior

- Sedentary behaviors may be defined as engagement in pursuits that require expending low amounts of energy i.e. >0.9 (sleeping) but <1.5|2.0 (sitting) METS https://www.measurement-toolkit.org/physical-activity/introduction/sedentary-behaviour
- Measurement of Sedentary Behaviors
  - Typically, physical activity is assessed and individuals are classified according to their 'score' as being active or not; inactive is said to be sedentary.
  - There are 4 categories of sedentary behaviors, which ideally, should all be measured; the first two are the most dominant:
    - 1. Technological (screen time)- TV, computer use (leisure), small screen use
    - 2. Socializing – chat, phone, texts
    - 3. Motorized transport
    - 4. Homework (for children) or reading
  - Ideally, when measuring sedentary behavior the aim is to capture accurately:
    - What was done
    - Who with - friends, family, self (social context)
    - Where - indoor, outdoor (physical environmental context)
    - Frequency and duration
- Self-report, observation, parental report and real time data capture are the main measurement tools used to assess sedentary behaviors. Self-report can be either by questionnaire or diary. Accelerometers which show total inactivity or the absence of physical activity do not provide the context of the behavior.

BMR (Basal Metabolic Rate)

- "The basal metabolism of an animal is the minimal rate of energy expenditure compatible with life." (Mitchell, 1962)
- Anthropometry-based method
  - Durnin (1981) https://www.fao.org/4/m2845e/m2845e00.htm https://www.fao.org/4/aa040e/AA040E15.htm
  - Henry (2007) https://doi.org/10.1079/PHN2005801
- Calorimetry
  - Measuring O2 and CO2 in breath.
  - The macronutrients are each metabolised in the presence of O2 to produce CO2, H2O and heat; usually protein does not contribute significantly to energy production except in periods of prolonged negative energy balance, e.g., starvation.
  - VCO2/VO2 is known as the respiratory exchange ratio (RQ) and will determine the kJ or kcal equivalent value for each litre of oxygen consumed. When 100% carbohydrate is metabolised the RQ is 1.0, and when 100% fat is metabolised the RQ is 0.7; a mixture of the two 50:50 is equivalent to a RQ of 0.85.
  - Weir's equation (Weir 1949): REE = [VO2 (3.94) + VCO2 (1.11)] 1440 min/day
  - When the body covers a more significant proportion of the work from anaerobic (non-oxygen requiring) sources (e.g. maximal work for a few minutes, such as 400 to 800 meters running) of chemical energy, the proton concentration of the blood (from lactic acid) will shift the CO2 – carbonic acid equilibrium towards an excess release of CO2, the measurement of CO2 will enhance the precision of the estimated energy expenditure.
- Doubly-labeled water method (DLW)
  - It measures total energy expenditure (TEE) by observing the differential rates of elimination of a bolus dose of the stable isotope tracers 2H (deuterium) and 18O.
  - The tracers used are non-radioactive and occur naturally in all waters (including drinking waters), and therefore completely safe to use in any population.
  - Used in adults, children and infants to measure TEE, in many diverse investigations including the energy costs of clinical conditions, and the energy utilisation of people participating in intensive physical activities under extreme conditions.
  - It has also been used widely to validate other methods of assessment of dietary and physical activity.
  - Indeed the application of DLW led to seminal work in the identification of widespread under-reporting in dietary assessment.

AMR (Active Metabolic Rate)

- Questionnaire
  - PAQs and RAPA
- Diary / Log
  - Self-recording such as Ainsworth (2000) https://doi.org/10.1097/00005768-200009001-00004
- Observation
  - Time-saving spot check method such as Suda (1994) https://doi.org/10.1537/ase.102.13
- Pedometer / Accelerometer
- Heart rate monitoring
  - FLEX heart rate monitoring
- Combination heart sensor
- Indirect calorimetry and doubly labeled water method are also available for assessing AMR, not only BMR

PAQs and RAPA

- Self-report methods are the most convenient and cheapest way to collect physical activity data from a large number of people in a short time. Physical activity questionnaires (PAQs) are the most widely used self-report instrument to assess physical activity and have been used extensively in research. Self-report measures include self or interviewer administered (Matthews, 2002): Activity diaries or logs; Recall questionnaires; Quantitative history; Global self report
- Questionnires vary greatly in their detail. Recall questionnaires typically contain 5-15 items and aim to stratify the population into broad categories of physical activity. Some may also try to estimate energy expenditure. The reference time frame varies depending on the objectives of the study but typically tends to be between a week and a month. Examples are the short version of the IPAQ and the Baecke questionnaire.
- International Physical Activity Questionnaire (IPAQ): This questionnaire is available in a short form for surveillance, and in a longer form when more detailed physical activity information is required, both forms are available in a number of languages (https://sites.google.com/view/ipaq/home). The questionnaire was rigorously tested for reliability and validity (Craig et al, 2003) and this has been replicated in a number of countries; this questionnaire is not designed to provide a detailed assessment of physical activity in all domains.
  - https://doi.org/10.1079/PHN2005898
  - https://doi.org/10.1371/journal.pone.0219193.s010
- Global Physical Activity Questionnaire (GPAQ): This questionnaire was developed under the auspices of the World Health Organisation and it collects information on participation in physical activity in three domains: activity at work, travel to and from places and recreational activities.
  - https://www.who.int/publications/m/item/global-physical-activity-questionnaire
  - https://www.who.int/docs/default-source/ncds/ncd-surveillance/gpaq-analysis-guide.pdf
- Both the IPAQ and the GPAQ were developed for surveillance studies and the GPAQ more specifically for surveillance studies in developing countries. These instruments are not recommended for other purposes.
- RAPA (Rapid Assessment of Physical Activity) → scoring activity level, not intended to estimate quantitative energy expenditure.
  - https://depts.washington.edu/hprc/resources/products-tools/rapa/