A house for the critters

Feeding trials using larvae on biowaste

School project

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TOP CITIZEN SCIENCE - SCHOOL PROJECT

Six-legged Livestock: Rearing Black Soldier Fly on Biowaste

Project script

Organic waste generation in Austria

In the year 2016, over a million tons of "organic wastes from households and similar facilities" (Federal Ministry of Sustainability and Tourism (BMNT), 2018) were generated. "Organic wastes from households" summarize green wastes from gardens and public areas such as grass cuttings, prunings, flowers, foliage as well as wastes from the preparation of foods (kitchen waste) and food leftovers.

The amount of organic wastes represents one quarter of the total municipal solid waste (waste consisting of everyday items discarded by the public) including residual waste, waste paper, and lightweight packaging.

In Tyrolean households, the total volume of organic wastes added up to 100,000 tons in the year 2016. About half of it was collected as green wastes in container collections or in waste collection centres. The other half corresponds to the waste collected in organic waste bins.

- Every Tyrolean generates 136 kg organic wastes per year.
- This corresponds to a weekly amount of 2.6 kg organic wastes per person.

Furthermore, in the year 2016 over 113,400 tons of kitchen and food waste were generated in food and beverage companies, gastronomy, food wholesales, and canteen kitchens in hospitals and similar public facilities.

What happens to our organic waste?

The following figure from the Status Report of the BMNT (2018) illustrates the pathways of kitchen and food wastes from gastronomy, food wholesales, and canteen kitchens:

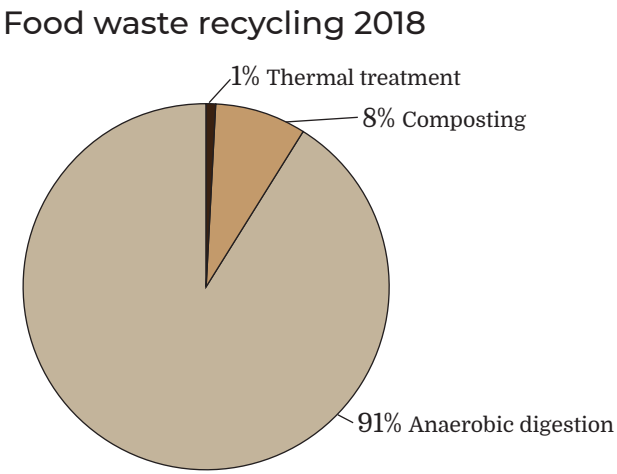


Figure 1: Kitchen and food waste recycling. (Data from BMNT (2018))

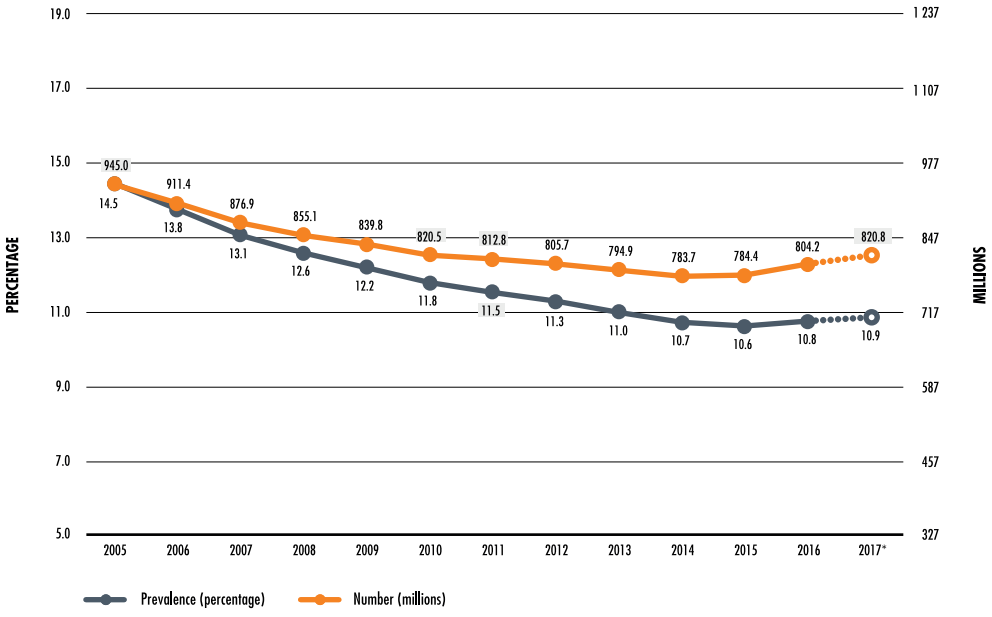
The largest part (91%) of the kitchen and food wastes is treated via anaerobic digestion, which is a type of fermentation (Figure 1). During this process, the organic material is metabolized by a consortium of microorganims (mostly bacteria and archaea) under exclusion of oxygen (= anaerobic conditions). This creates biogas, which in turn can be used to produce energy and heat. The digestate (residues) can e.g. be applied as fertilizer in agriculture.

Eight percent of the kitchen and food wastes are composted. During composting, the organic material is degraded without oxygen limitation (aerobic conditions), similar to the compost heaps that can be found in many gardens. Instead of biogas, the microorganisms turn the material into compost, an organic plant nutrient and humus provider.

Thermal treatment (1%) describes the incineration of wastes. The energy released in this process can be emitted as electrical energy or heat.

Organic wastes from households take a similar path: separately collected organic wastes are being utilized in agricultural, communal or commercial composting and biogas plants. Subsequently, the compost is used in agriculture, applied as fertilizer in public green areas, cemeteries or sport centers, or distributed to the general public to be used for horticulture or landscaping. The biogas generated in biogas plants is used to produce energy and heat while the accumulating digestate is composted or directly used in agriculture (BMNT, 2018).

If organic waste is so full of energy that one can generate electricity out of it, what other potential does it offer?



* Projected values, illustrated by dotted lines and empty circles.
SOURCE: FAO.

Figure 2: Number of malnourished people worldwide 2005-2017 (FAO, 2018)

According to the statistics of the Food and Agriculture Organisation (FAO), the number of people suffering from hunger is steadily increasing since 2015 (Figure 2). In the year 2017, over 821 million people worldwide suffered from hunger. This means that, statistically speaking, every ninth person does not have enough to eat. (FAO, 2018).

The population will increase from about 7.6 billion people[1] to around 8.1 to 10.6 billion people in the year 2050 (Fiebelkorn, 2017). According to a report of the FAO, the demand for animal protein will increase up to 80%.

[1]https://countrymeters.info/de/World (03.01.2019).

To satisfy these demands, several feed sources can be made use of:

a) Fishmeal

Fishmeal can be made out of fish and fish scraps using a special drying and grinding process. The resulting product is used as protein-rich feed for livestock and aquaculture. In Europe, up to 435,000 tons of fishmeal and oil were produced in the year 2019[2]. However, challenges like overfishing and uncertain climate forecasts make the market unstable. This leads, in addition to ecological problems, to increasing market prices[3], which is why alternative solutions are being sought.

b) Soybeans

Soybeans are protein-rich plants used for various applications: "As a plant-based oil for human nutrition, as raw material for industrial products (colours, glue, cosmetics, etc.), and as animal feedstuff for growing livestock in industrial and emerging economics." (Ermann et al., 2018).

It is estimated that the soybean production increased to up to 347 million tons[4] in 2017/2018. In the last 32 years, the amount of cultivated soy increased up to 350%. The countries producing most of the soybeans (80%) are Brazil, Argentina, and the USA Wide areas of forest need to be transformed to arable land to meet the increasing demand. According to the World Wide Fund for Nature (WWF) in Germany, 24 hectare land in South America were transformed to arable areas within one decade between the years 2000 to 2010. 80% of the soy imported to Germany is being used exclusively to produce animal feed[5].

Dealing with environmental problems such as overfishing, climate change, scarcity of resources, loss of green space is becoming increasingly important, creating the need to find alternative measures. Insects are one of the most promising candidates to address some of these issues.

c) Insects

In the year 2013, the FAO published a report with the title "Edible insects. Future prospects for food and feed security." In this report, an outlook on the chances and possibilities in using insects for food and feed is presented.

[2]www.statista.com/statistics/614383/fish-meal-production-volume-european-union-28/ (2020-09-12)
[3]www.fao.org/in-action/globefish/market-reports/resource-detail/en/c/1113356 (2020-09-12)
[4]www.soymeal.org/soy-meal-articles/world-soybean-production (2020-09-12)
[5]www.wwf.de/themen-projekte/landwirtschaft/produkte-aus-der-landwirtschaft/soja (2020-09-12)

The three major reasons to establish insects in the feed and food industry are Health, Environment, and Economy.

1) Insects (Figure 3) are considered healthy due to their high content in proteins and unsaturated fatty acids.

2) They are sustainable to produce as their greenhouse gas emissions and space requirements are much lower compared to current livestock production (Figure 4). Moreover, a broad spectrum of substrates can be used to grow them.
Insects in general are good substrate converters. However, the conversion rates of substrate to biomass (i.e. how much substrate is used yield 1 kg in biomass weight gain) strongly depend on the species and the method used to grow it. On average, insects can convert 2 kg of substrate to 1 kg of their own biomass, whereas cattle need 8 kg of feed to gain 1 kg in body mass.

3) The rearing of insects offers economic opportunities for poorer, less developed regions and lower social classes. Basic rearing systems are cost-efficient and the insects are low-maintenance and not tied to specific geographic regions.

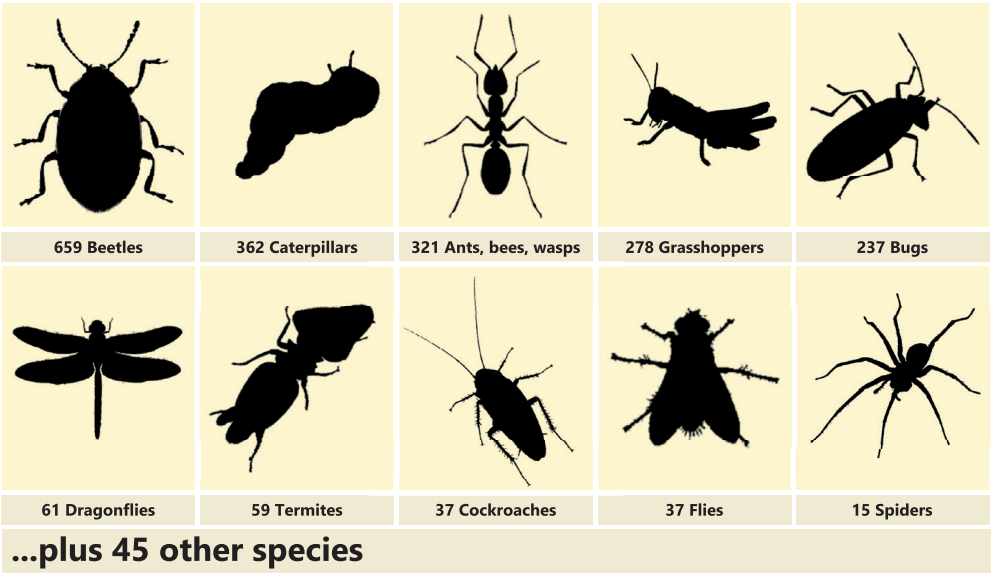


Figure 3: Number of edible insect and spider species (as reported by Yde Jongema, 2015)

An overview on the approximate efficiency of insects in comparison to meat is given by the following figure:

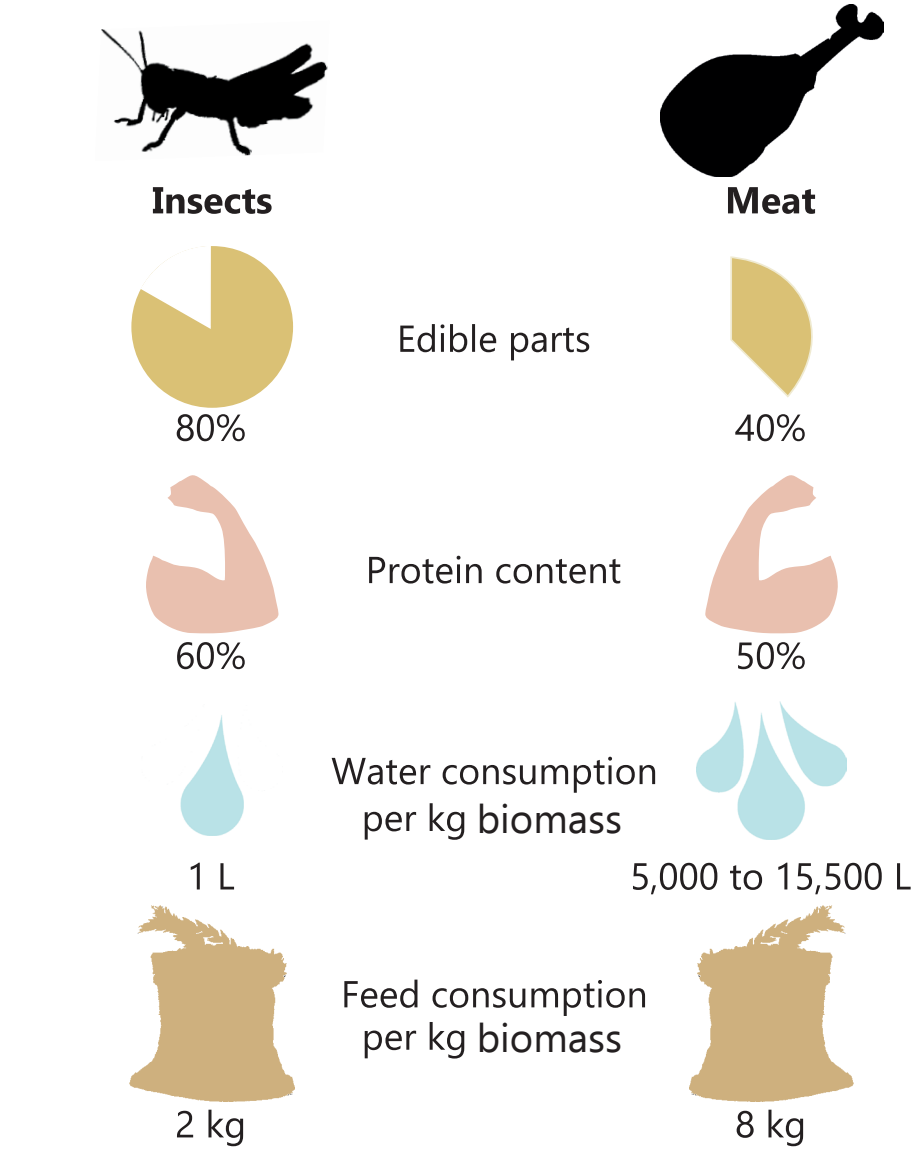


Figure 4: How do meat and insects compare in their efficiency?

The Black Soldier Fly

The Black Soldier Fly (BSF; *Hermetia illucens;* Figure 5) belongs to the order of the Diptera which is part of the family of Soldier Flies (Stratiomyidae) (Schremmer, 1986). It has a holometabolous life cycle, meaning the fly goes through a complete metamorphosis, starting with the larvae that subsequently turn into pupae from which the adult flies emerge. The entire life cycle from the egg to sexually mature adult takes about 44 days. The fly has a wasp-like appearance which it uses as mimicry to protect itself from predators. Larvae as well as adults can grow up to 2 cm in length.

Figure 5: Black Soldier Fly

The BSF is native in South America, but since the 20th centruy it started to spread to Europe where it was observed for the first time on Malta in 1926 (Martínez-Sánchez, 2011). The fly has not spread through Northern Europe as it would not survive the cold winters.

Up to today, there have been no reports on the BSF acting as vector for pathogens that could be transmitted to humans. Possible reasons for this are that the larvae are able to produce antimicrobial molecules (Cullere, 2016). Moreover, the reduced mouthparts and the missing gut of the adult fly make it unable to sting or bite. Once it reached the adult life stage, the fly only takes up water making it harder for pathogens to exploit it as a vector.

Why the Black Soldier Fly?

The insect has many advantages that are especially interesting for the feed industry:

1) The BSF can degrade almost any organic substrate. This means that rearing the BSF can be used to treat various types of organic waste (kitchen wastes, green-cuttings, human feces, manure, etc.).

2) The larvae can reduce the formation of malodours in biologically active substances.

3) The feed conversion capacity is comparable to other insects and is significantly better than observed for poultry, cattle, and pigs.

Table 1: Comparison of protein and fat content (Fiebelkorn, 2017; Wang and Shelomi, 2017).

	BSF	Mealworm	Chicken	Pig	Cattle
Protein content	42%	49%	22%	22%	21%
Fat content	29 - 35%	35%	6%	2%	4%

4) The comparatively “long” larval stage results in a high nutrient content (Figure 6). At the end of this stage, the larvae migrate to a dry and protected place where they can turn into pupae. In a dry spot, the larvae are less prone to get infested by mold and the risk for eclosing adults to drown in fluids can be minimized. This migration event lets the larvae harvest themselves (”self-harvesting ability”), thereby bringing economic advantages by reducing the efforts to collect the larvae manually or via machines.

5) The BSF larvae have a high fat content which has to be considered when used for the production of food or feedstuff (Table 1). As in most cases the larvae are processed to meal, the excessive fat can be separated more easily. The extracted fat can be used for other applications such as the production of biodiesel.

6) The substrate residues are rich in nitrate. Nitrate is an essential nutrient for plant growth and is often used in agriculture in form of nitrate-rich fertilizer. Therefore, the leftovers from the larval degradation process can be used as a natural alternative to mineral fertilizers.

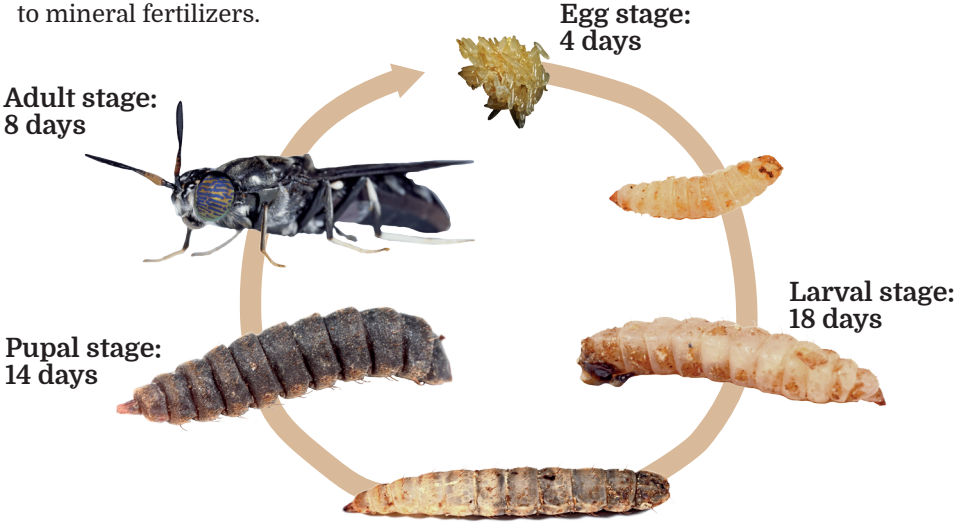


Figure 6: Life cycle of the Black Soldier Fly

References - Scientific publications

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• Fiebelkorn, F., 2017: **Entomophagie. Insekten als Nahrungsmittel der Zukunft.** In: Biologie in unserer Zeit. 2/2017 (47). 104-110.

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• Bundesministerium für Nachhaltigkeit und Tourismus (2018): **Die Bestandsaufnahme der Abfallwirtschaft in Osterreich.** Statusbericht 2018. Wien: Bundesministerium für Nachhaltigkeit und Tourismus.

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• Wang, Y., Shelomi, M., 2017: **Review of Black Soldier Fly (Hermetia illucens) as Animal Feed and Human Food.** In: Foods 6, 91. 1-23.

Internet resources

• Fishmeal:

www.fao.org/in-action/globefish/market-reports/resource-detail/en/c/1113356/ (2020-09-12)

• Fishmeal production in Europe:
www.statista.com/statistics/614383/fish-meal-production-volume-european-union-28/ (2020-09-12)

• Soy production:

https://www.soymeal.org/soy-meal-articles/world-soybean-production/ (2020-09-12).

• Land consumption of soy (German):

https://www.wwf.de/themen-projekte/landwirtschaft/produkte-aus-der-landwirtschaft/soja/ (2020-09-12).

• World population:

https://countrymeters.info/de/World (2020-09-12).

Figure resources

• Figure 2:

FAO, IFAD, UNICEF, WFP and WHO, 2018: The state of food security and nutrition in the world 2018. Building climate resilience for food security and nutrition. Rome, FAO. URL: http://www.fao.org/3/I9553EN/i9553en.pdf

• Figure 7:

World Health Organization (WHO), 2018: https://www.who.int/gpsc/clean_hands_protection/en/

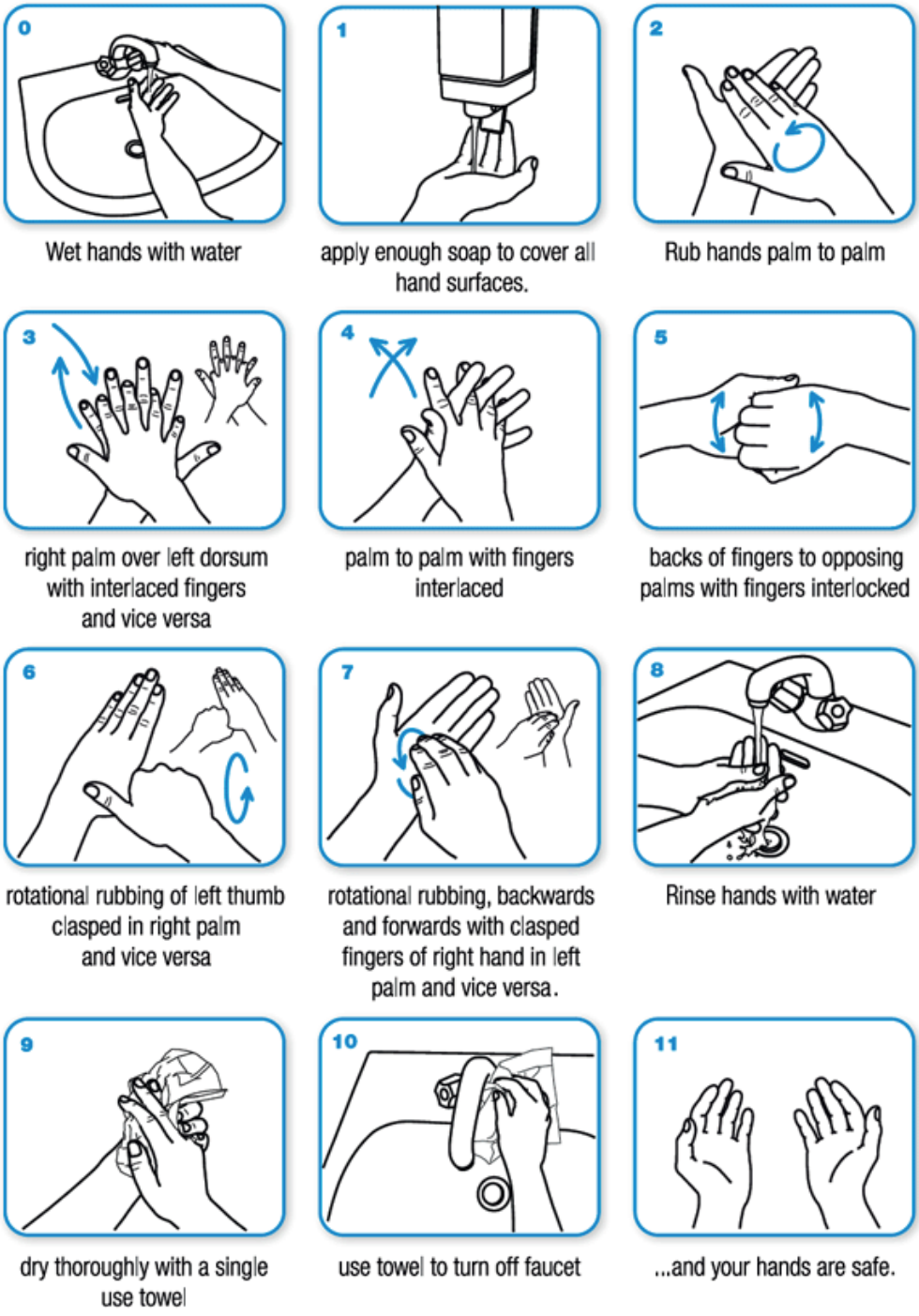

Figure 7: Clean hands protect against infection. WHO 2018