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> ONE MONTH, ONE PROTEIN <

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foam etc.

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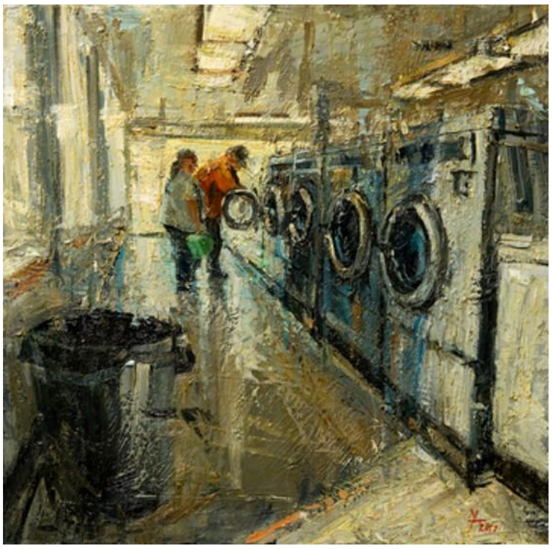
The nice thing about shampoo is the foam it produces. When it doesn't, we usually add a little more to froth things up – because foam is a very pleasant part of the procedure. This said, as our thoughts spark off in all directions under the shower, how many of us ever wonder why shampoo foams at all? Foaming agents is the answer. If you're using an eco-friendly shampoo, there's a chance that one of these agents is saponin, an organic chemical found in plants – notably in a plant commonly known as soapwort, soapweed, crow soap or even wild sweet William. Though native to Europe, soapwort grows naturally in many parts of the world, usually in open undisturbed places which many of us would qualify as 'overgrown': on the sides of riverbanks, on roadsides, in fields, in pastures, in rundown gardens and on abandoned home sites. It's the kind of plant we tend to ignore, although scientists are developing a keen interest in it. This is because, besides producing foam, saponins have several biological activities that could be of therapeutic interest. For this reason, a lot of effort has been put into understanding how plants synthesize saponins. It turns out that they are the end product of a metabolic pathway which involves fourteen steps and as many enzymes.



Laundromat 029, oil on canvas

by Donald Yatomi (courtesy of the artist)

The notion of 'metabolic pathway' is not old. Today, it may seem obvious to us that biological compounds are frequently the result of an initial compound that has been tinkered with to produce a final compound that is either of use to cells or to organisms as a whole (such as ATP, H_2O or antibiotics for instance) or is waste (O_2 in plants or CO_2 in animals for example). But barely 100 years ago, no one was talking about metabolic pathways. It all began with alcohol, or more precisely the wine and brewery industry. Brewers and winemakers wanted to know why – and how – the sweet juice of fruits turns into alcohol. Nowadays the process is called fermentation but it took 300 years of research to understand and unravel the process.

Back in 1747, the German chemist Andreas Marggraf announced that glucose was the sweetness to blame. In 1789, the French chemist Antoine Lavoisier revealed that sugars are assemblies of carbon, hydrogen and oxygen. Half a century later, a team of French and German scientists discovered that yeast is responsible for transforming glucose into alcohol – and that yeast is a living cell. The idea that another 'form of life' such as microorganisms could cause fermentation did not go down too well within scientific circles at the time, and it took the work of Louis Pasteur, in 1850, to settle the issue: microorganisms are indeed needed for fermentation.

But how does yeast do it? Today we know that it takes a metabolic pathway known as glycolysis and then fermentation to produce alcohol, and that each step is performed by a different enzyme. The various steps and enzymes involved in glycolysis were only characterized in the 1940s following major advances made by three biochemists Gustav Embden, Otto Meyerhof and Jakub Parnas, and soon followed the conviction that glycolysis was not exclusive to yeast but that it occurs in every single living cell. In fact, glycolysis is just one metabolic pathway among hundreds of others. Possibly thousands.

Saponins are the product of a metabolic pathway which only occurs in plants. There are many different types of saponins even within one same plant, in its different tissues and depending on its developmental stage. *Quillaja saponaria* or the soapbark tree, for instance, synthesizes up to 70 different saponins, all of which have different activities. These different activities are the result of two kinds of building blocks that combine: glycones (oligosaccharides) on the one hand and compounds called aglycones (sapogenol or sapogenein) on the other. In saponins, one aglycone compound forms a scaffold onto which are added one or more glycones. The overall result is an amphiphilic entity where the glycone moieties are water soluble and the aglycone moiety is lipid soluble. This is why saponins make good detergents. Historically, plants that produce saponin like the soapbark tree were boiled down to make soaps for cleaning textiles, especially woollen fabrics.

Scientists recently managed to determine in detail the metabolic pathway of saponin biosynthesis in one plant: *Saponaria officinalis*, or soapwort. Soapwort produces at least 40 different kinds of saponin, but attention was given to the plant's major saponins: saponarioside A (SpA) and saponarioside B (SpB). In a series of elegant assumptions, the team worked out that saponin biosynthesis occurs in a total of 14 steps, each of which is carried out by one distinct enzyme. In a nutshell, in the first four steps of the pathway, the aglycone core scaffold (quillaic acid, QA) is synthesized from one of the most common plant aglycone scaffolds, β-amyrin. Then ten other enzymes move in, one after the other, to prepare and combine glycone (sugar) moieties onto each end of QA. In the very last steps, SpA and SpB are synthesized, where SpA simply has an extra sugar moiety (D-xylose).

Metabolic pathways will be metabolic pathways. Today, we know that although you can isolate in theory one pathway, every pathway is linked to another, as they feed each other metabolites. One surprising find in soapwort saponin biosynthesis, however, was the apparent binding of a glycone known as D-quinovose – a sugar moiety more commonly found in marine animals like starfish or sea cucumbers! The origin of D-quinovose in plants remains elusive. However, in soapwort, the research team found that it was added by a noncanonical enzyme, a glycosyl hydrolase (SoGH1) which, unlike the other enzymes, does not localize to the plant cell's vacuole but to its cytosol. It seems, too, that SoGH1 is able to accept a wide range of sugar substrates which guarantees further structural diversity and hence saponin activity.

Although saponins got their name from the Latin *sapon* meaning soap, they display a wide spectrum of biological actions other than that of being good detergents. Plants produce mixtures of saponins – from their roots to their leaves, fruits and seeds – as a means of defence during growth and development. They are bitter to the taste to ward off large creatures who feed off them, but they also have antifungal, antiparasitic and insecticidal properties against smaller creatures – and these are properties of therapeutic interest. To date, saponins have been studied for their anti-inflammatory, immunomodulatory, antibacterial, antiviral, antioxidant, anti-cancer, dermatological, neuroprotective, gastro-intestinal and anti-diabetic properties, not to mention their use in detergents, as flavour modifiers, food preservatives, in cosmetics and as foaming agents in beverages. The list seems endless, and once scientists know exactly how nature builds saponins, you can fine-tune or even lengthen the list by engineering your own. The prospects are promising and varied. In plants, such a variety of one same type of compound is simply another wonderful demonstration of Nature's ability to adapt to different challenging environments over time.

Cross-references to UniProt

beta-amyrin 28-monoxygenase CYP716A379, *Saponaria officinalis* (Common soapwort) : A0AAW1JA93
Quillaic acid 3-O-glycosyltransferase CSL1, *Saponaria officinalis* (Common soapwort) : A0AAW1HA02
Beta-amyrin 28-monooxygenase CYP716A378, *Saponaria officinalis* (Common soapwort) : A0AAW1NEA3
Echinocystic acid 23-monooxygenase, *Saponaria officinalis* (Common soapwort) : A0AAW1J8D7
Glycosyl hydrolase-like protein 1, *Saponaria officinalis* (Common soapwort) : A0AAW1I778
Short-chain dehydrogenase/reductase 1, *Saponaria officinalis* (Common soapwort) : A0AAW1NHX6
Beta-amyrin synthase 1, *Saponaria officinalis* (Common soapwort) : A0AAW1L0L7
Serine/threonine-protein phosphatase, *Saponaria officinalis* (Common soapwort) : A0AAW1K819
UDP-glucosyl transferase 73M2/73CC6/74CD1/79T1/79L3, *Saponaria officinalis* (Common soapwort) : A0AAW1J1B8/ J9R8/M2U7/IQ05/MQS1
BAHD acyltransferase 1, *Saponaria officinalis* (Common soapwort) : A0AAW1LG41

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