# Summary and further reading

Ideally, all future pharmaceuticals would be:

- Manufactured in a sustainable way, with low environmental impact over its entire lifecycle;
- Stable during processing and formulation, and for many years at a range of temperatures and humidities;
- Active and efficacious when taken by the patient;
- Completely metabolised or decomposed in the environment on excretion.

In practice, this is near-impossible to achieve and stakeholders within the pharmaceutical industry are recognising this. It would be great if some future APIs can be designed to fit this ideal synthesis, but it is very unlikely to be the case for all small molecules. Additionally, these new molecules and syntheses would not replace current treatments within the coming decades, meaning that the environmental legacy of current APIs will remain an issue for many years to come.

Whilst the introduction and use of totally environmentally benign APIs is currently a long way off, there are a number of defined measures society can take:

- Look at the environmental footprint per treatment/dose;
- New operating models/philosophy related to health are needed;
- Sensible and targeted prescribing, proper use, take back schemes and effective disposal will all help in reducing the burden of PIE;
- Develop more potent medicines – design more active API with lower doses;
- Maximise bioavailability of APIs;
- Develop better formulation and delivery systems;
- Targeted/personalised medicines – many that are prescribed stop working, or never work efficiently – need for more genotyping of patients and disease;
- Reduce/stop illegal off-label uses of APIs and stop discharges of APIs into the

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environment;
- Transparency in data on environmental impact of products - payers/patients can choose.

**Recommended reading:**

K. Kümmerer, Presence, Fate and Risks of Pharmaceuticals in the Environment, in *Green and Sustainable Medicinal Chemistry: Methods, Tools and Strategies for the 21st Century Pharmaceutical Industry*, The Royal Society of Chemistry, 2016, ch. 6, pp. 63-72.

K. Kümmerer, Benign by Design, in *Green and Sustainable Medicinal Chemistry: Methods, Tools and Strategies for the 21st Century Pharmaceutical Industry*, The Royal Society of Chemistry, 2016, ch. 7, pp. 73-81.

*Green and Sustainable Pharmacy*, (ed. M. Hempel) Springer-Verlag Berlin Heidelberg, 2010.

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