TOPIC 2:
Sustainable Polymers

Jenny Alongi
jenny.alongi@unimi.it
Dipartimento di Chimica
Università degli Studi di Milano
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Jenny Alongi  jenny.alongi@unimi.it
Stefano Gazzotti  stefano.gazzotti@unimi.it
Amedea Manfredi  amedea.manfredi@unimi.it
Marco Ortenzi  marco.ortenzi@unimi.it
Elisabetta Ranucci  elisabetta.ranucci@unimi.it

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Bio-derived Polymers from $\alpha$-Amino Acids

• **Challenges & goals**
  - Synthesis of eco-friendly, bio-derived flame retardants (FRs) for cellulosic fabrics and PU foams.
  - Synthesis of UV stabilizers for cellulose articles for protective garments use and Cultural Heritage conservation.

• **State of the art**
  - $\times$ In 2020 4.0 million fires with 20.8 thousand deaths
  - $\Rightarrow$ FRs have strong impact on humans and environment!
  - $\times$ Cellulosic substrates undergo light-induced yellowing
  - $\times$ $\Rightarrow$ current UV stabilizers for protective garments.
Bio-derived Polymers from $\alpha$-Amino Acids

\[
\begin{align*}
\text{GLY, ALA, VAL, LEU, HIS, SER, ASN, GLN, ASP and GLU}
\end{align*}
\]

- **Research achievements**
  - Green and easily scalable synthesis of bio-derived and bio-inspired polyamidoamines (PAAs).
  
  - PAAs act as intumescent FR for cotton, cotton/PET and PU.
  
  - In dramatically accelerated tests PAAs protected cotton fabric from the photodegradation.
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Polymeric Materials from Renewable Sources

• **Challenges & goals**
  ✓ Design of new polymeric materials for high value-added applications from low-cost natural polymers.

• **State of the art**
  ✗ There is growing interest in using cheap biopolymers in the production of bioplastics.
  ✗ These may be polysaccharides, e.g. starch, cellulose, chitin/chitosan or proteins, e.g. casein, whey, collagen, zein or silk.
  ✗ Applications range from food packaging to 3D printing, biomedical, cosmetics and others...
• **Research achievements**

- Synthesis of “lactide equivalents” comonomers for expanding PLA applications. Functionalization of PLA with bio-based molecules, e.g. carvacrol, cardanol, eugenol.

- PLLA/reinforced composite hydrogels for tissue engineering.

- Tough silk/reinforced composite hydrogel membranes for the absorption of Cr(VI) from water.
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Assessment of Eco-toxicity of Polymers

• **Challenges & goals**
  - Studies on the eco-compatibility of synthetic polymers in different environments.
  - Establishing specific tests to achieve this goal.

• **State of the art**
  - Growing number of studies on the eco-toxicity of polymers & microplastics released in the environment.
  - Standard tests for macro- and microplastics are lacking.
  - Many literature data on microplastics are not significant.
  - Toxicity varies according to:
    - polymer structure
    - physico-chemical properties
    - environment (soil, waters)
    - nature of the degradation products
Assessment of Eco-toxicity of Polymers

- **Research achievements**
  - Degradation studies on plastics bottle use and microplastics release
  - Tests on invertebrates: sea urchins, giant snails and Manila clams.
  - Degradation studies in model environments.
  - Phyto-toxicity tests through seed germination tests.
  - Tests on vertebrates: Zebra fish.

HDPE cap heavily deteriorates after 100 opening/closing cycles

PET bottleneck is almost unchanged
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![Diagram showing germination tests](image)

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