Nano Innovation 2020 — Rome, 15-18 September

Environmental Nanotechnologies: the issue of micro-nanoplastics – Impact and mitigation measures of micro and nanoplastics

Impact of nanoplastics on health

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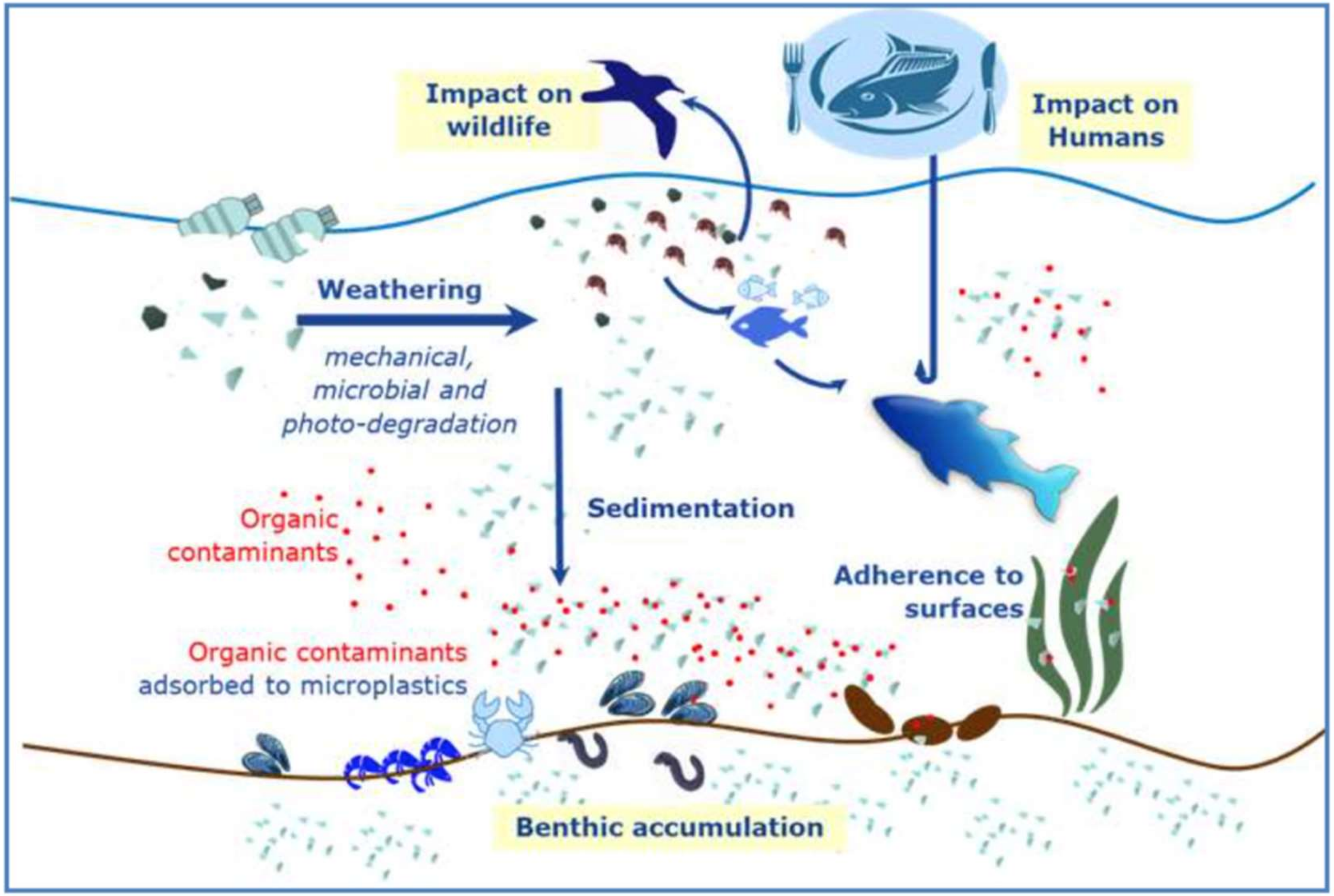
Micro and nanoplastics: a worldwide problem for the enviroment

- Scientists define microplastics as plastic fragments less than 5 mm in diameter that current water purification systems cannot hold.
- They are derived from a variety of sources ending up in waste waters, from the bristles of the toothbrushes to the bottle caps, as well as from the direct degradation of plastic products reaching seas and oceans.
- Nanoplastics are even smaller, with diameters less than 0.001 mm.

Micro and nanoplastics: impact on wildlife and human health



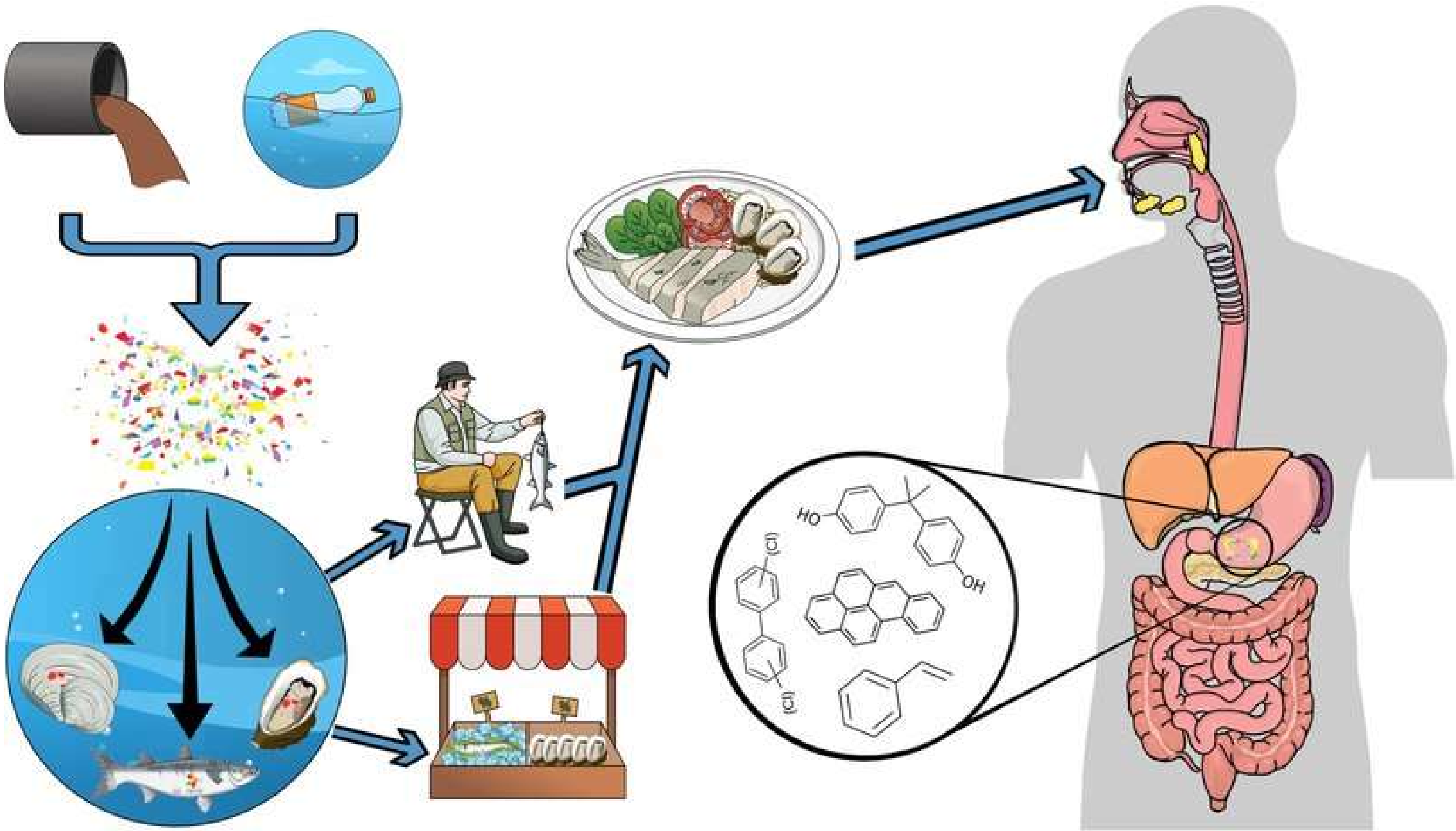
The presence of microplastics in the environment represents an environmental and health problem of enormous proportions, since a part of the plastic produced in the last 60 years -about 8.3 billion tons –inevitably arrived in water basins directly in the form of microplastic or nanoplastic objects which then mechanically degraded, thus entering the water cycle and biological cycles.

(https://www.focus.it/ambiente/ecologia)

Micro and nanoplastics: a worldwide problem for human health

- Microplastic presence in seafood and foodstuff have been documented globally in recent studies.
- Consequently, human exposure to microplastics through the ingestion of contaminated food is inevitable and pose a risk to food security and human health

Anthropogenic activity cause microplastics to enter the food web, make a path to our food and, ultimately, our organs



De-la-Torre GE. J Food Sci Technol, 2020

Micro and nanoplastics in sea urchins influence immunity

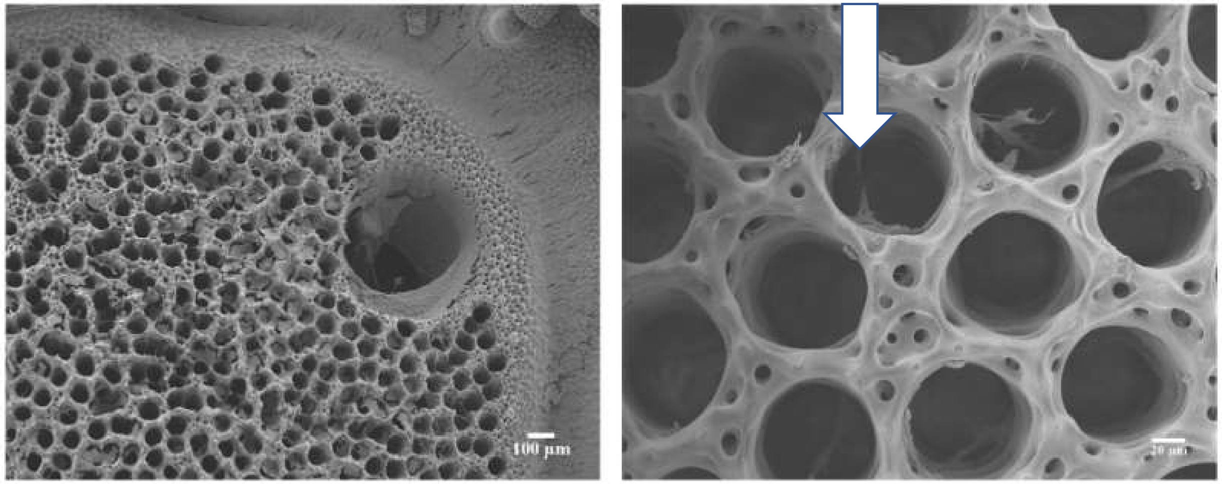
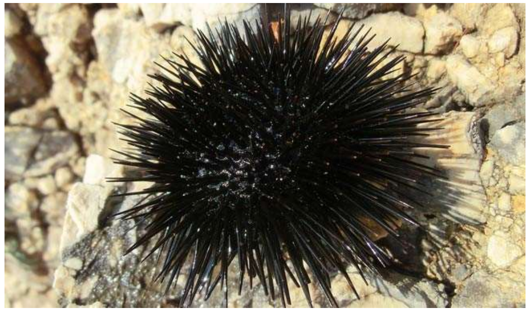


Fig. 1. Aboral views of *Paracentrotus lividus* madreporite examined with scanning electron microscope (SEM).



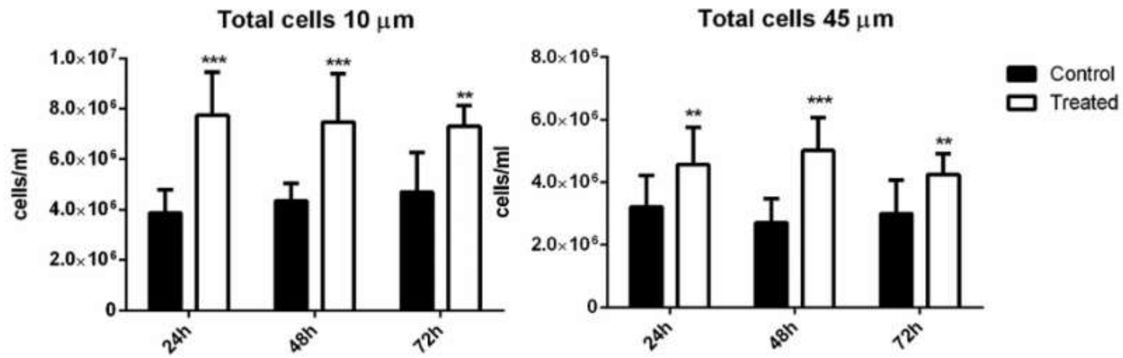
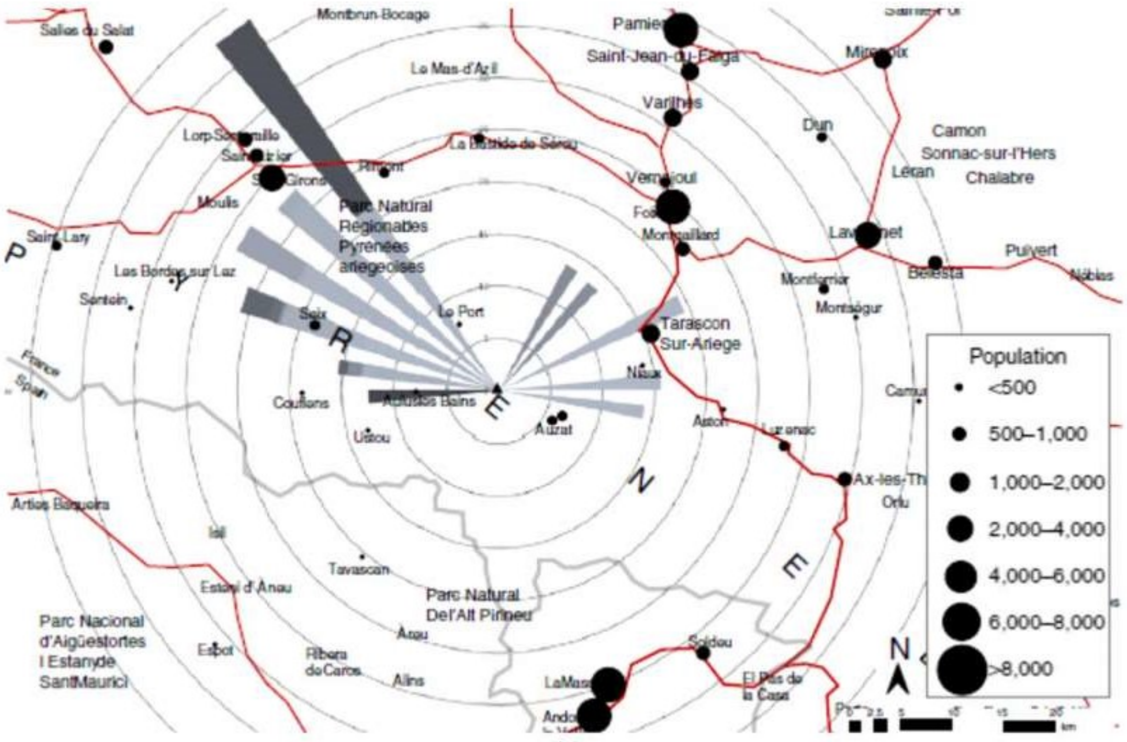


Fig. 3. Total immune cells count of sea urchin at different time of exposure to a PS-MPs (10 µm and 45 µm). All data were analysed by Two-way ANOVA followed by Bonferroni post-test compared with the respective control. Bars represent mean ± SD. Asterisks indicate values that are significantly different from the control, $^{**}P < 0.01$, $^{***}P < 0.001$.

Murano C et al. Enviromental pollution, 2020

The contamination cycle: ecological risk involves not only water but also air and soil



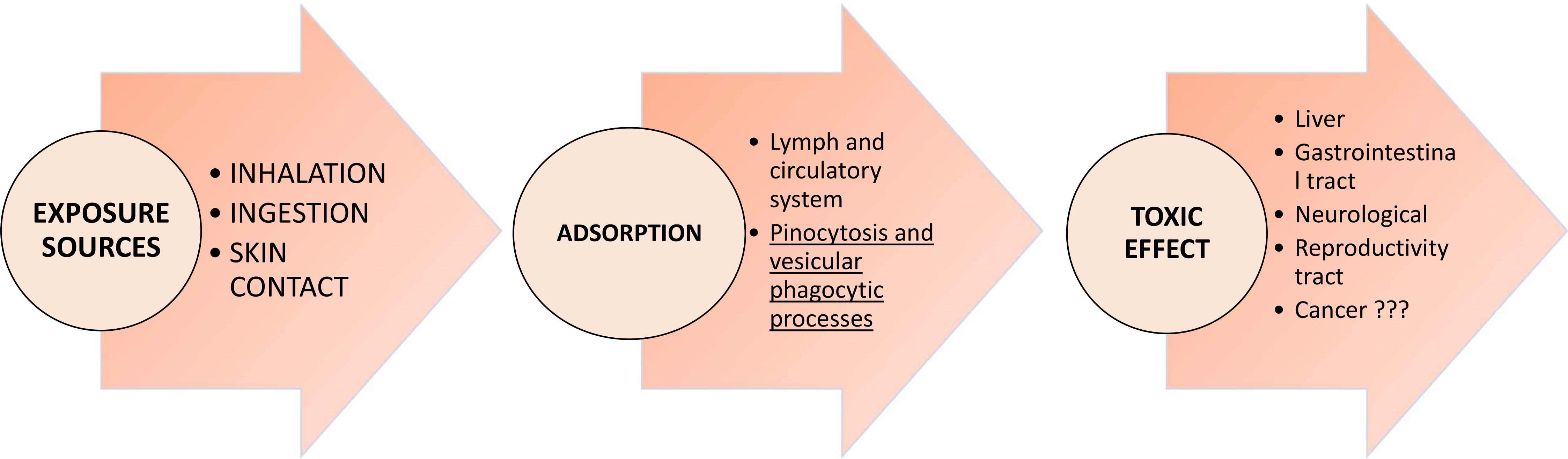
AtmosphericTransport trajectories of airborne microplastic

Implications by microplastic presence in aquatic and soil ecosystems have been well studied and documented, but less attention has been paid on airborne microplastic.

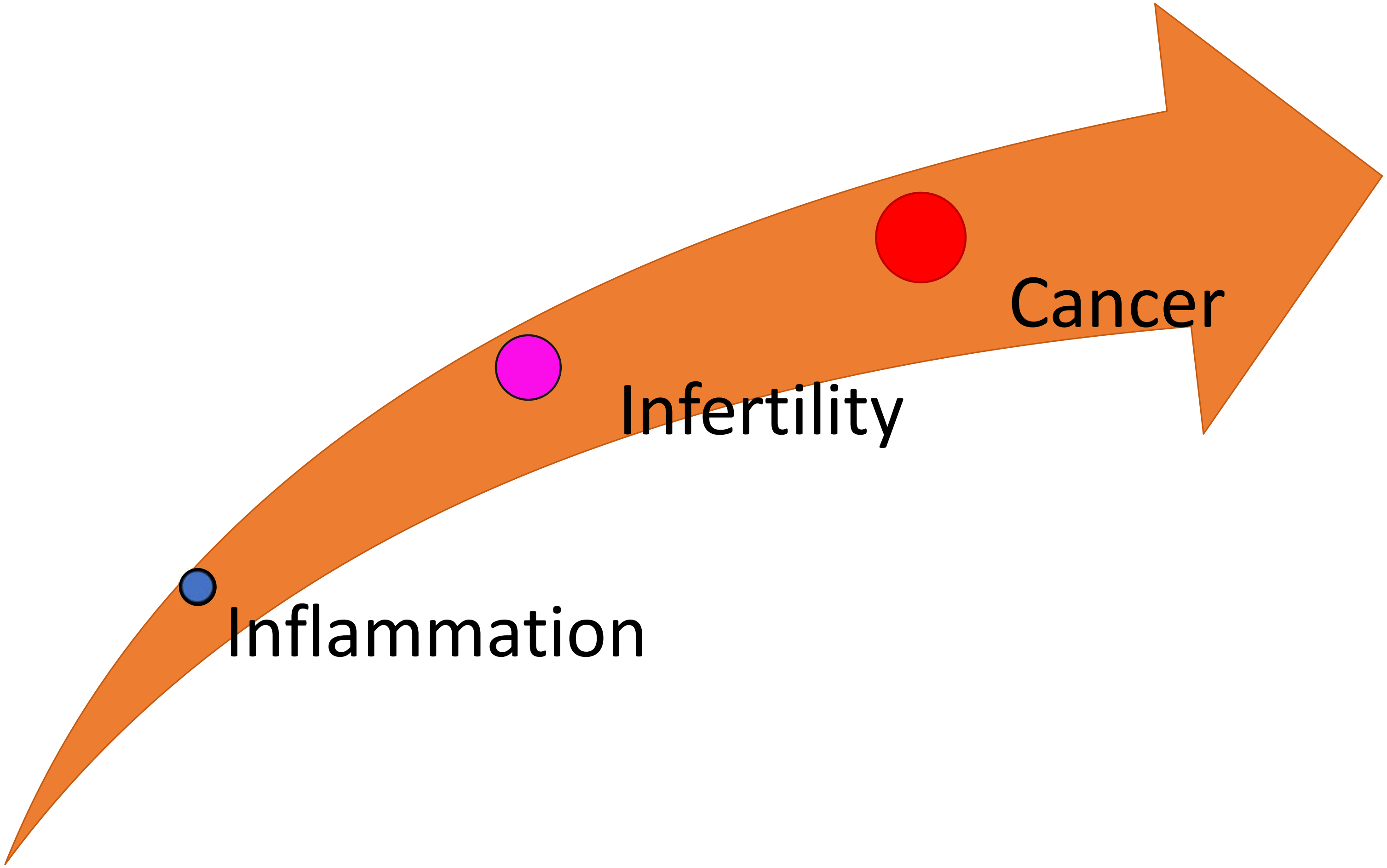
Microplastics have been observed in atmospheric fallouts in indoor and outdoor environments using a sampling or vacuum pump, rain sampler, and/or particulate fallout collector.
Identification and quantification have been carried out by visual, spectroscopic, and spectrometric techniques.
Factors such as meteorological, climatic, and anthropogenic influence the distribution and movement of airborne MP. Human exposure may be through inhalation, dermal, and open meal during fallout, with their potential biopersistence and translocation

Allen, S. Nature Geoscience 2019
E. Enyoh, Environ Monit Assess 2019

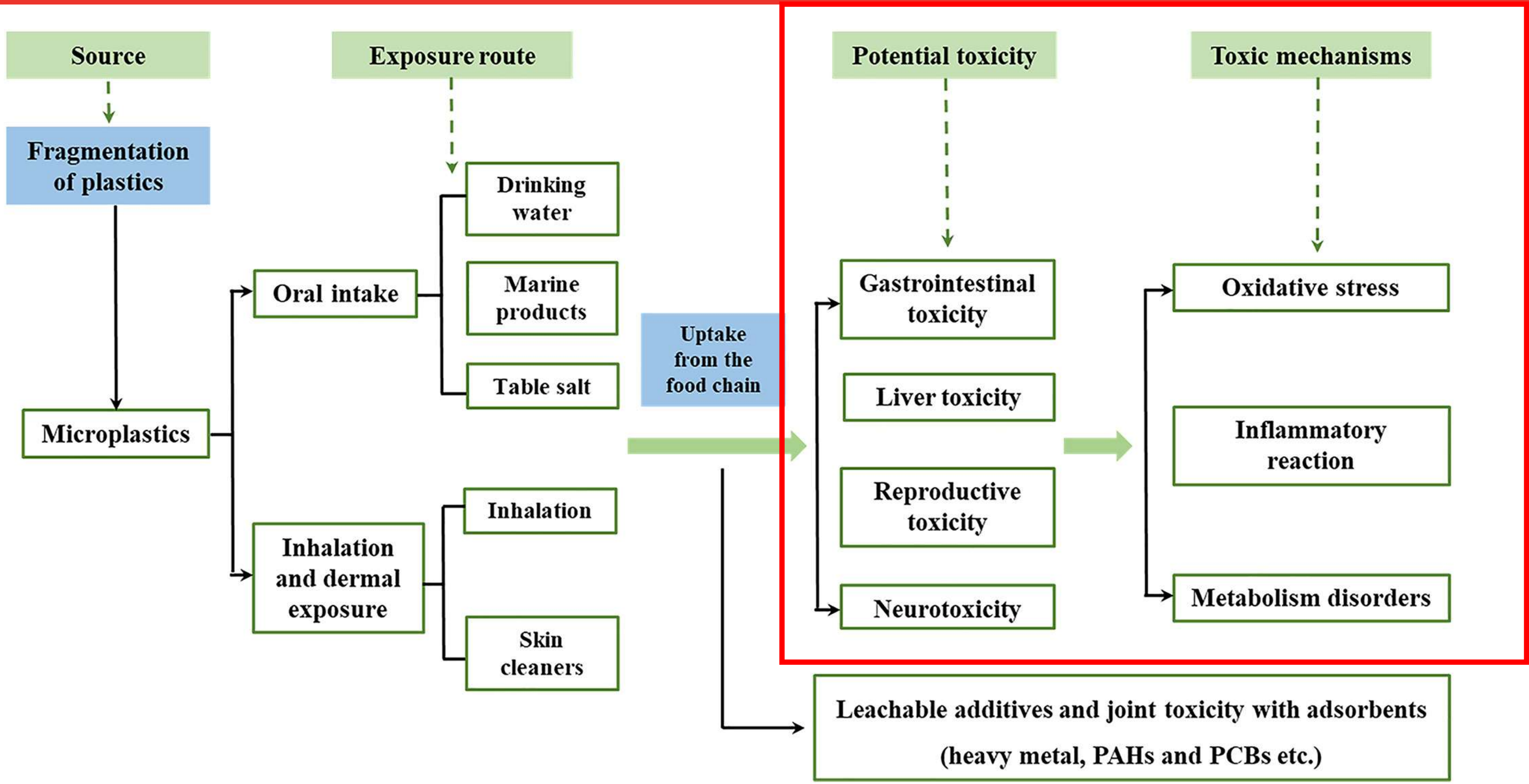
Workflow of microplastic route from exposition to toxic events



Research in wildlife and animal models has linked micro- and nanoplastic exposure to several diseases, but health outcomes in people are currently unknown



Potential health impact of environmental micro- and nanoplastics pollution



Chang X, et al. *J Appl Toxicol*. 2020

TABLE 3 Potential toxicity of microplastics on human health

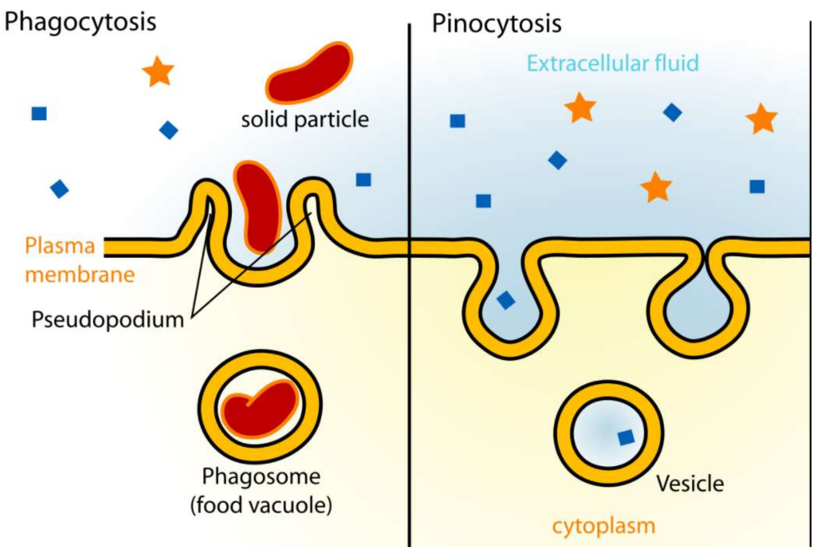
Toxic effects	Microplastics	Model	Main findings	References
Gastrointestinal toxicity	Fibers	Freshwater fish	18 anthropogenic particles were found in fish stomachs, with length of 2.41 mm	Collard et al., 2018
	PE	Blue mussel *Mytilus edulis* L.	Notable histological change and a strong inflammatory response	von Moos et al., 2012
	PS	Adult male zebrafish	PS microplastics increased the expression of IL-1α, IL-1β and interferon in the gut; indicated microbiota dysbiosis and inflammation	Jin et al., 2018
	PA, PE, PP, PVC and PS	Zebrafish and nematode	Villi cracking and splitting of enterocytes	Lei et al., 2018
	PS	Male mice	Accumulation of PS microplastics in mice guts, consequently caused the reduction of intestinal mucus secretion damage of gut barrier function; metabolic disorders in mice	Jin et al., 2019
	PS	AGS cells	Inflammatory gene expressions such as IL-6 and IL-8	Forte et al., 2016
Liver toxicity	PS	Zebrafish	Accumulation of PS microplastic in liver and gut	Lu et al., 2016
	PS	Zebrafish	Inflammation and lipid accumulation both in 5 μm and 70 nm; oxidative stress and alterations in their metabolic profiles; disturbance of lipid and energy metabolism	Lu et al., 2016
Liver toxicity	PS	*Eriocheir sinensis*	Decreased activities of AChE, CAT, and ALT in *Eriocheir sinensis* liver; antioxidants CAT, SOD, GPx and GST level decreased in the liver; expressions of the genes encoding p38 in the MAPK signaling pathway was upregulated while significantly declined in ERK, AKT and MEK	Yu et al., 2018
	PS	Mouse	TG and TCH levels declined; decreases on key gene expressions related to lipogenesis and TG synthesis in liver indicating mouse hepatic lipid disorder	Lu et al., 2018
Neurotoxicity	PS	Zebra mussel *Dreissena polymorpha*	Dopamine concentration increased	Magni et al., 2018
	PS	T98G cells	Increases of ROS and then caused the oxidative stress	Schirinzi et al., 2017
	PS	Male mice	Increased AChE activity; reduced cholinergic neurotransmission	Deng et al., 2017
Reproductive toxicity	PS	Oysters	Oocyte number, diameter and sperm velocity decreased in oysters	Sussarellu et al., 2016
	PS	acs-22 mutant *Caenorhabditis elegans*	Accumulation of nanopolystyrene particles in gonad	Qu, Su, Li, Liang, & Shi, 2018

AChE, acetylcholinesterase; AGS, gastric adenocarcinoma; ALT, alanine aminotransferase; CAT, catalase; ERK, extracellular regulating kinase; GPx, glutathione peroxidase; GST, glutathione *S*-transferase; IL, interleukin; MAPK, mitogen-activated protein kinase; PA, polyamide; PE, polyethylene; PP, polypropylene; PS, polystyrene; PVC, polyvinyl chloride; ROS, reactive oxygen species; TCH, total cholesterol; TG,

Chang X, et al. *J Appl Toxicol*. 2020

ADSORPTION IS MEDIATED BY PINOCYTOSIS AND PHAGOCITIC PROCESS

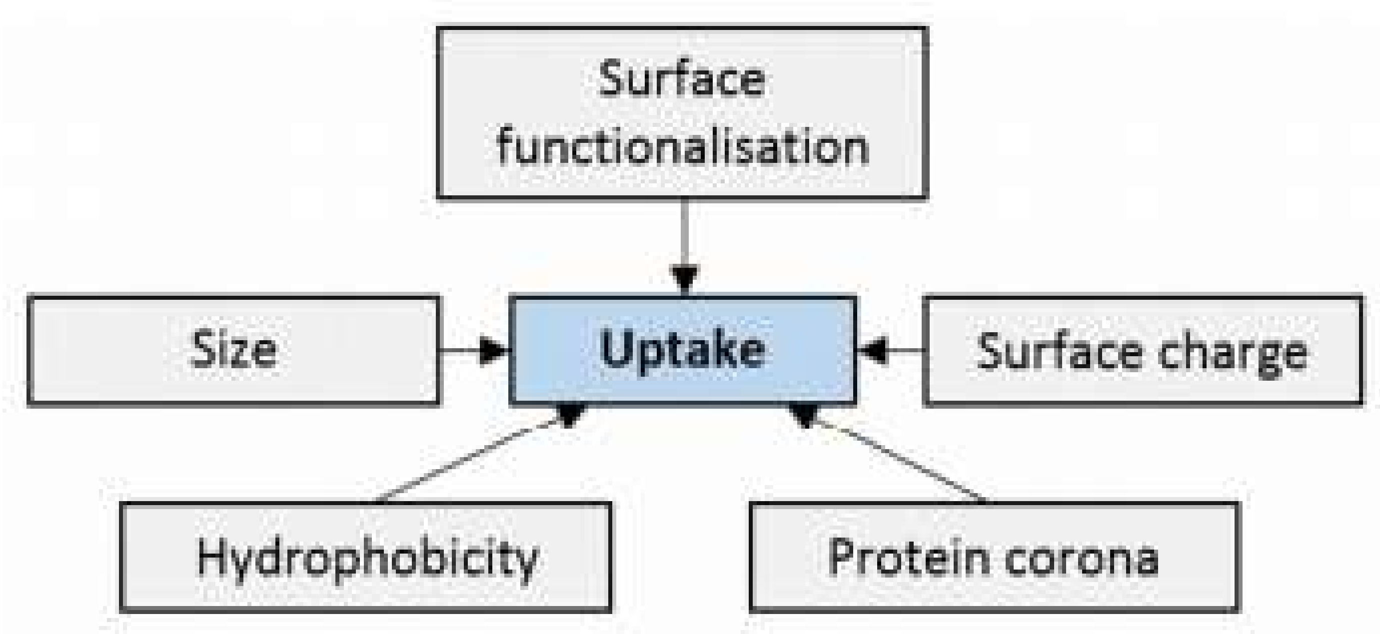
- Following microplastic ingestion, particles smaller than 150 µm may translocate to the lymph and circulatory system**, but absorption is expected in less than 0.3% of the ingested particles**



- Absorption happens through pinocytosis and vesicular phagocytic processes; Microfold cells in the Peyer's patches are the main site of uptake for nanoparticles to enter the circulatory system and through the lymphatic system.

Chang X, et al. *J Appl Toxicol*. 2020

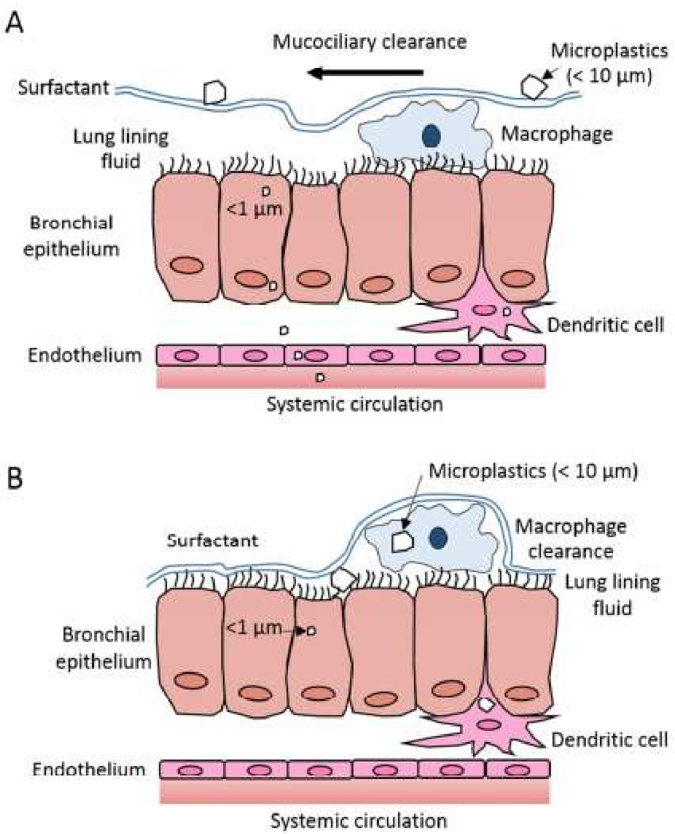
Particle characteristics predicted to influence micro- and nanoplastic uptake



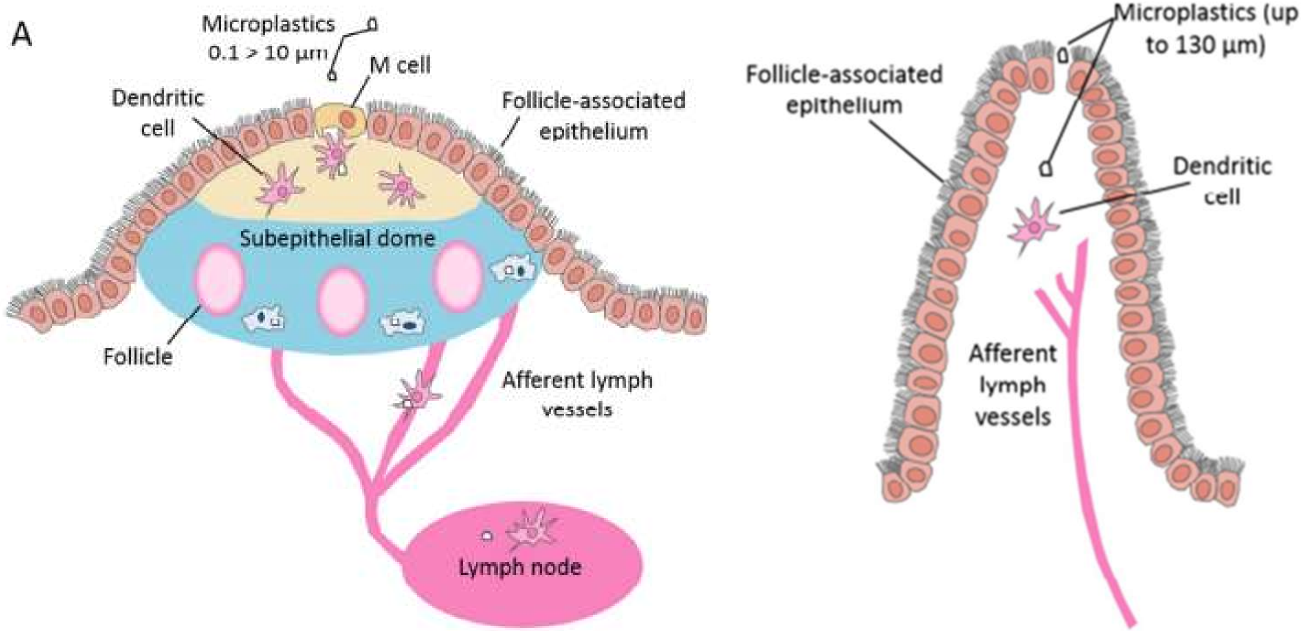
Wright S et al. *Environmental Science & Technology, 2017*

Microparticles uptake and clearance mechanisms

Lung

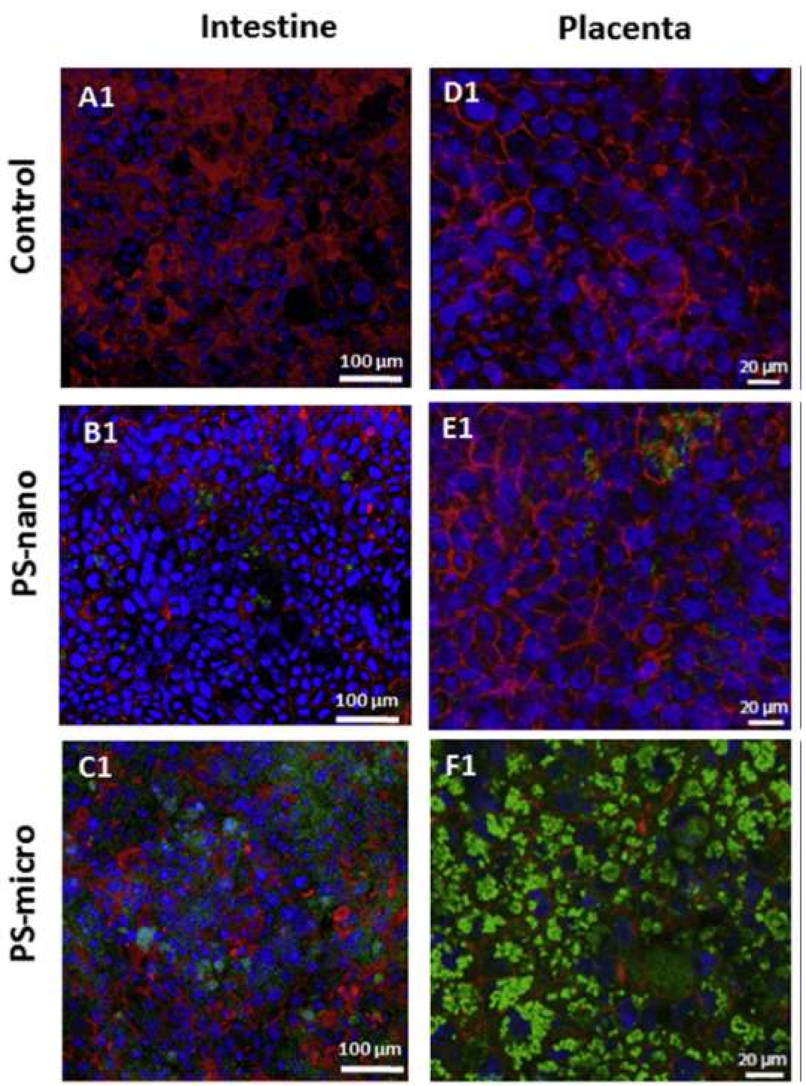


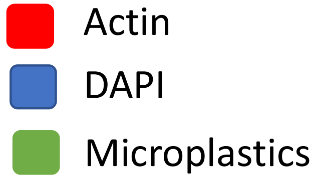
Gastrointestinal tract



Wright S et al. *Environmental Science & Technology, 2017*

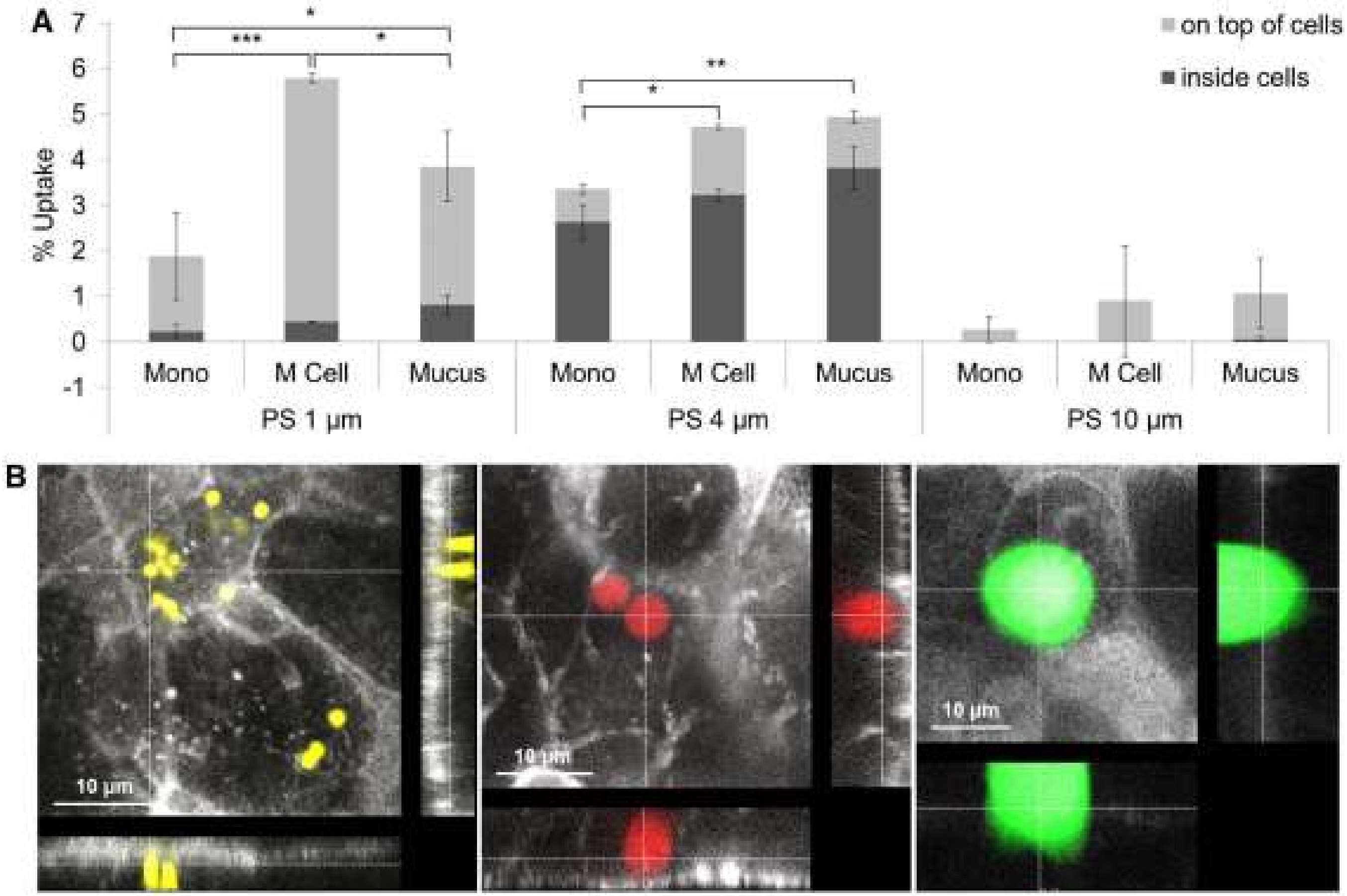
Micro and nanoplastics uptake in human cells





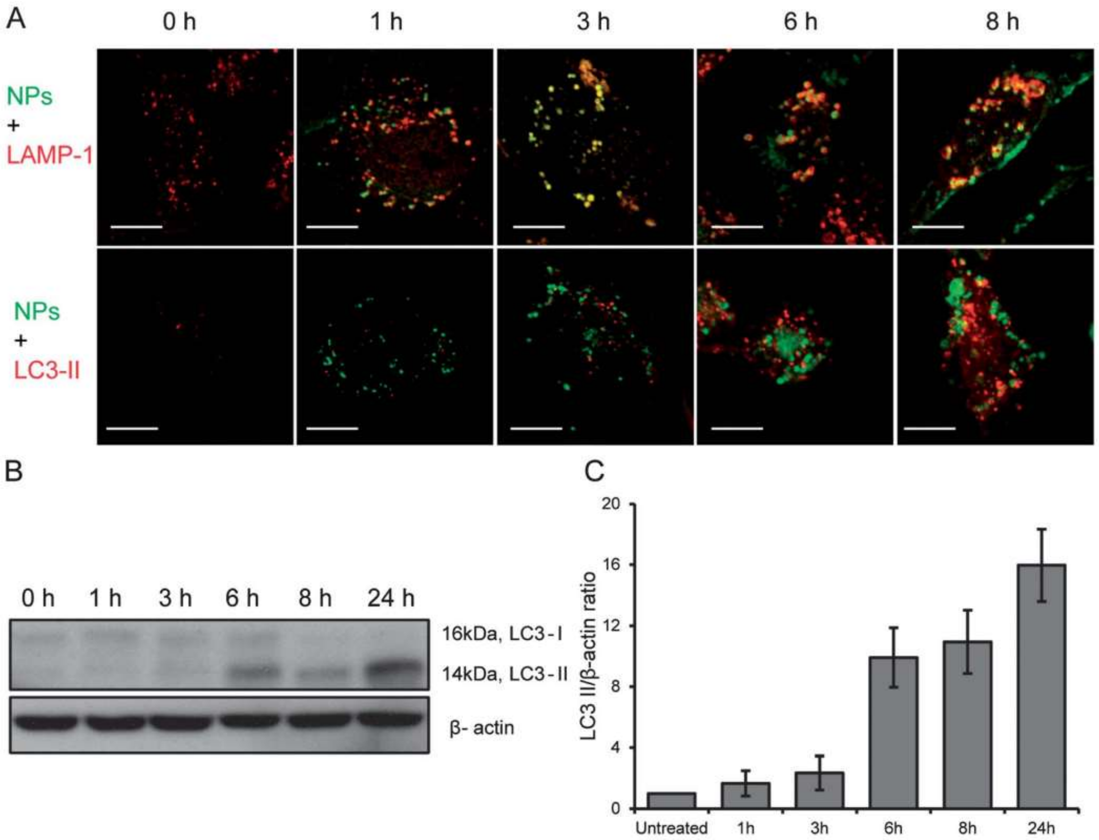
Hesler M, et al. *Toxicol In Vitro*. 2019

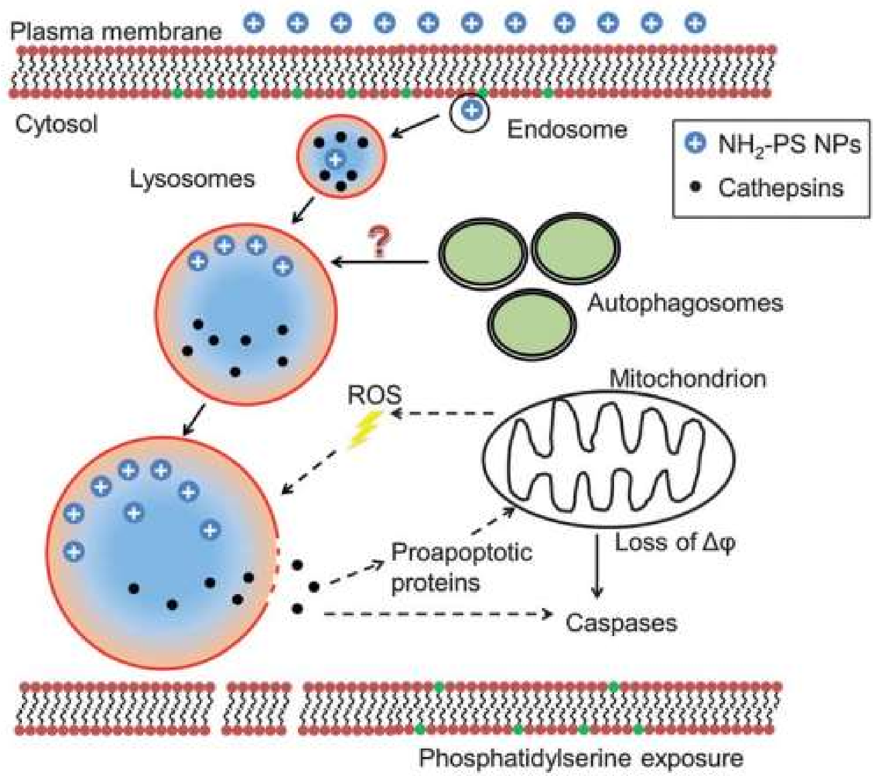
Micro and nanoplastics uptake in human cells



Stock V et al. Archives of Toxicology, 2019

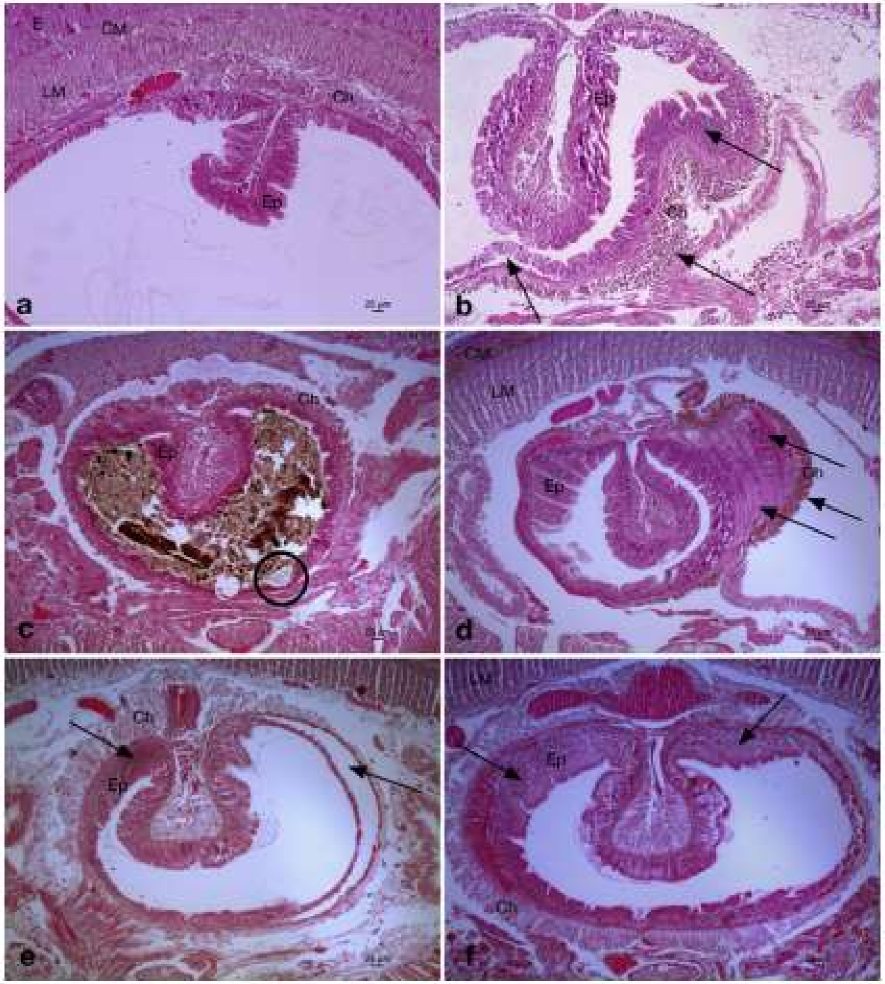
Micro and nanoplastics can induce cell death through autophagy de-regulation

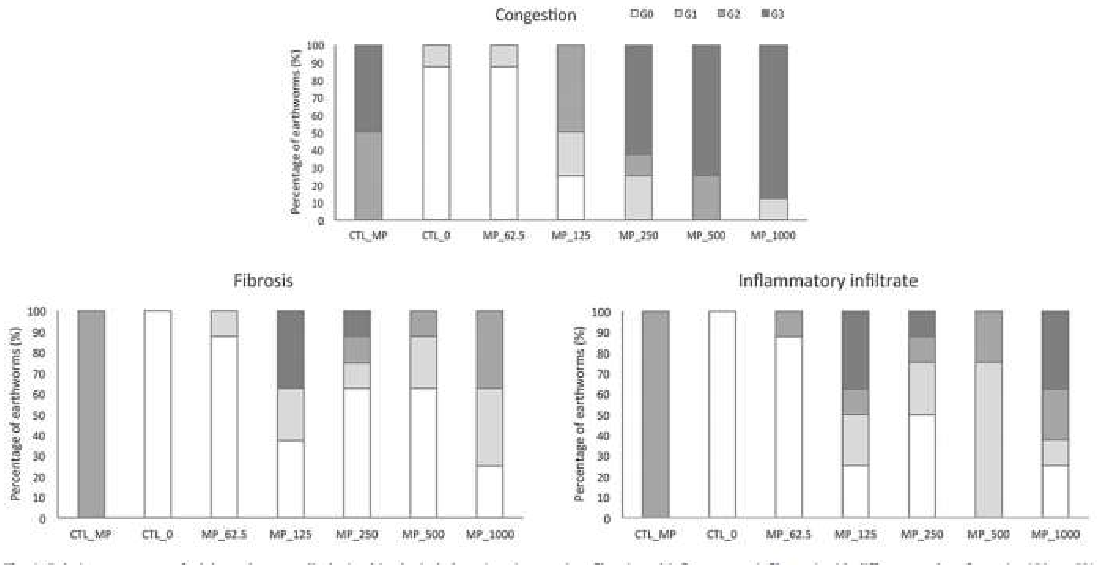




Wang F et al, Nanoscale 2013

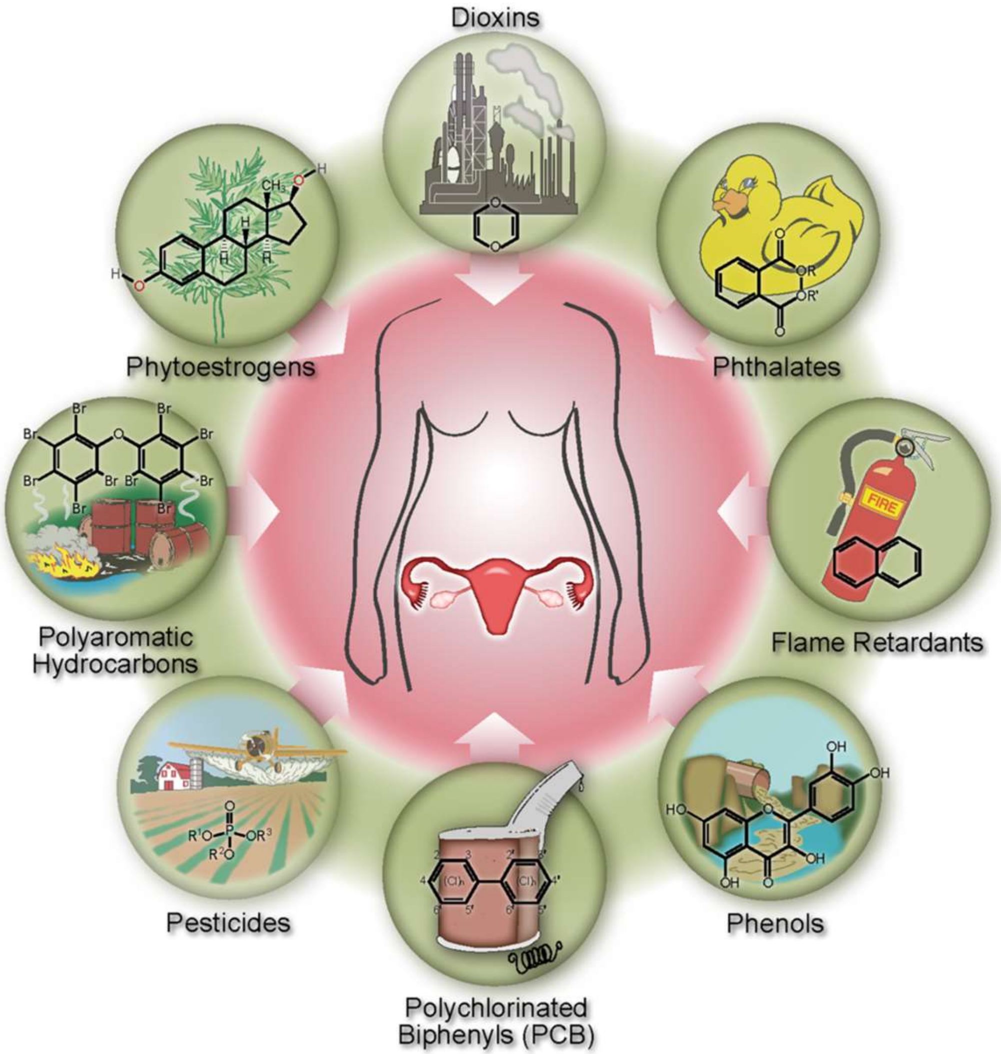
Histopathological effects of microplastics





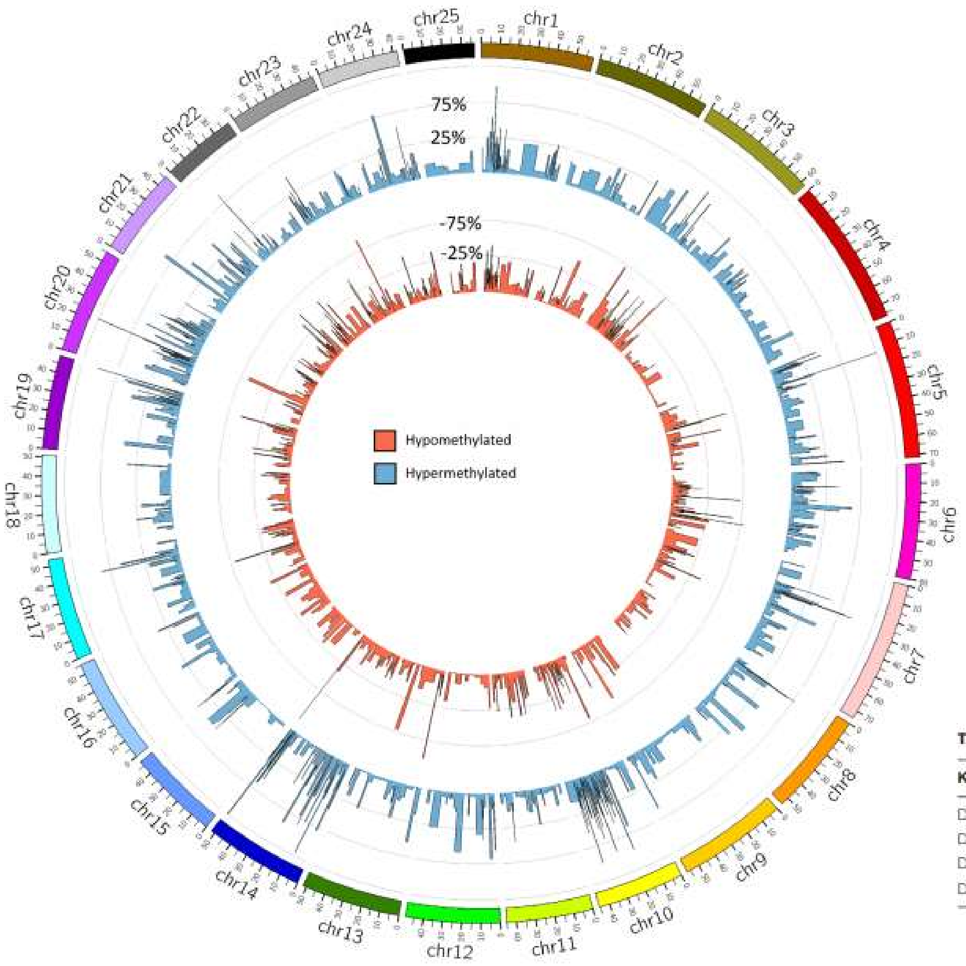
A. Rodriguez-Seijo, *Environmental Pollution, 2017*

Microplastics as vehicle of other toxic compounds



Research have shown that other chemical compounds present in plastics or adhered to microplastics, like residual low molecular weight styrenes, polyvinyl chloride monomer, PAHs, PCBs, OCPs, PBDEs, and pharmaceuticals, including their metabolites, could become carcinogenic, mutagenic and endocrine disruptors after being uptaken.

Bisphenol A can affect methylated sites in zebrafish



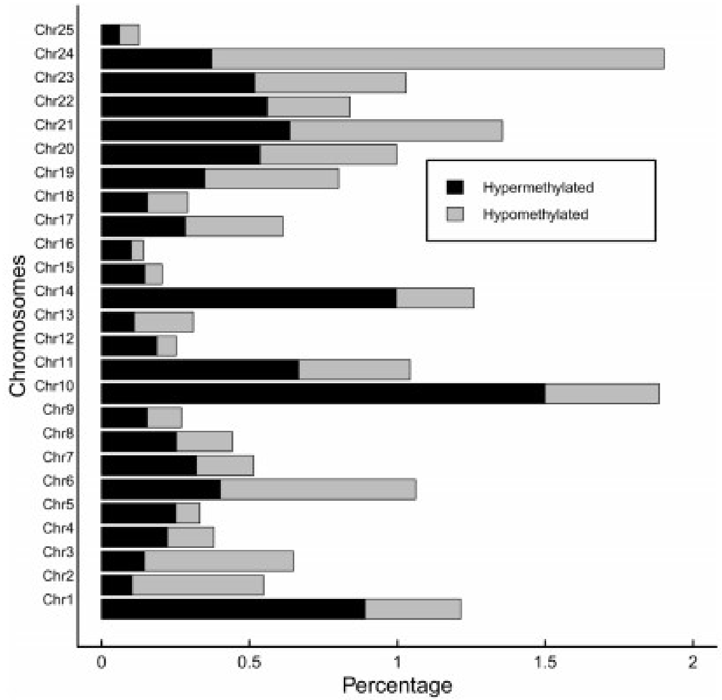
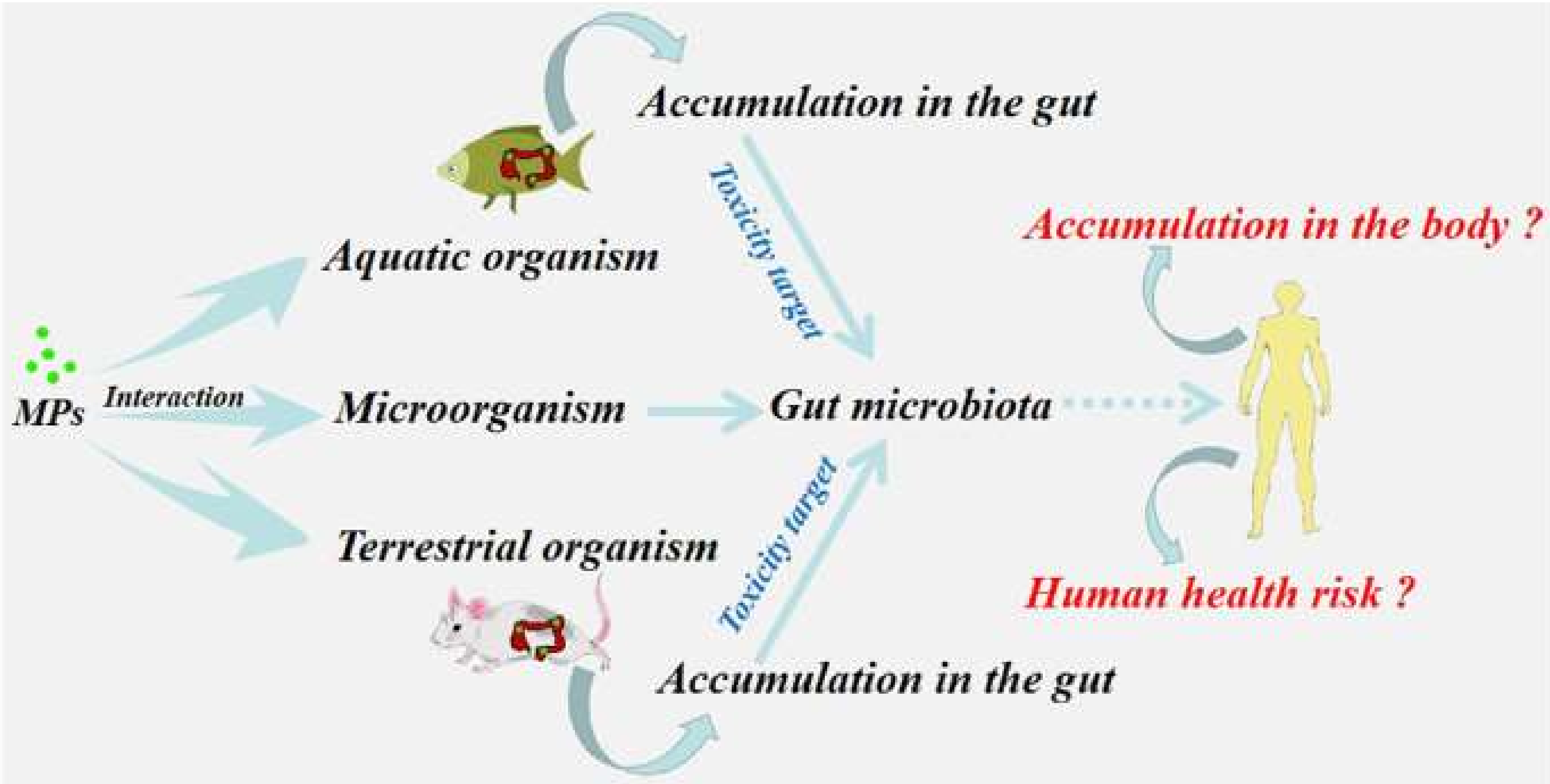


TABLE 3 | Enriched KEGG pathways for genes containing differentially methylated cytosines.

KEGG pathway	Count	%	*P*-value	Fold enrichment	Benjamini
Dre04070: Phosphatidylinositol signaling system	46	1.083372586	5.78E-07	2.045716063	8.78E-05
Dre04370: VEGF signaling pathway	32	0.753650495	3.02E-04	1.868899326	0.022686307
Dre04010: MAPK signaling pathway	89	2.096090438	9.44E-04	1.365264965	0.046711852
Dre00562: Inositol phosphate metabolism	30	0.706547339	0.001297272	1.773460107	0.048131455

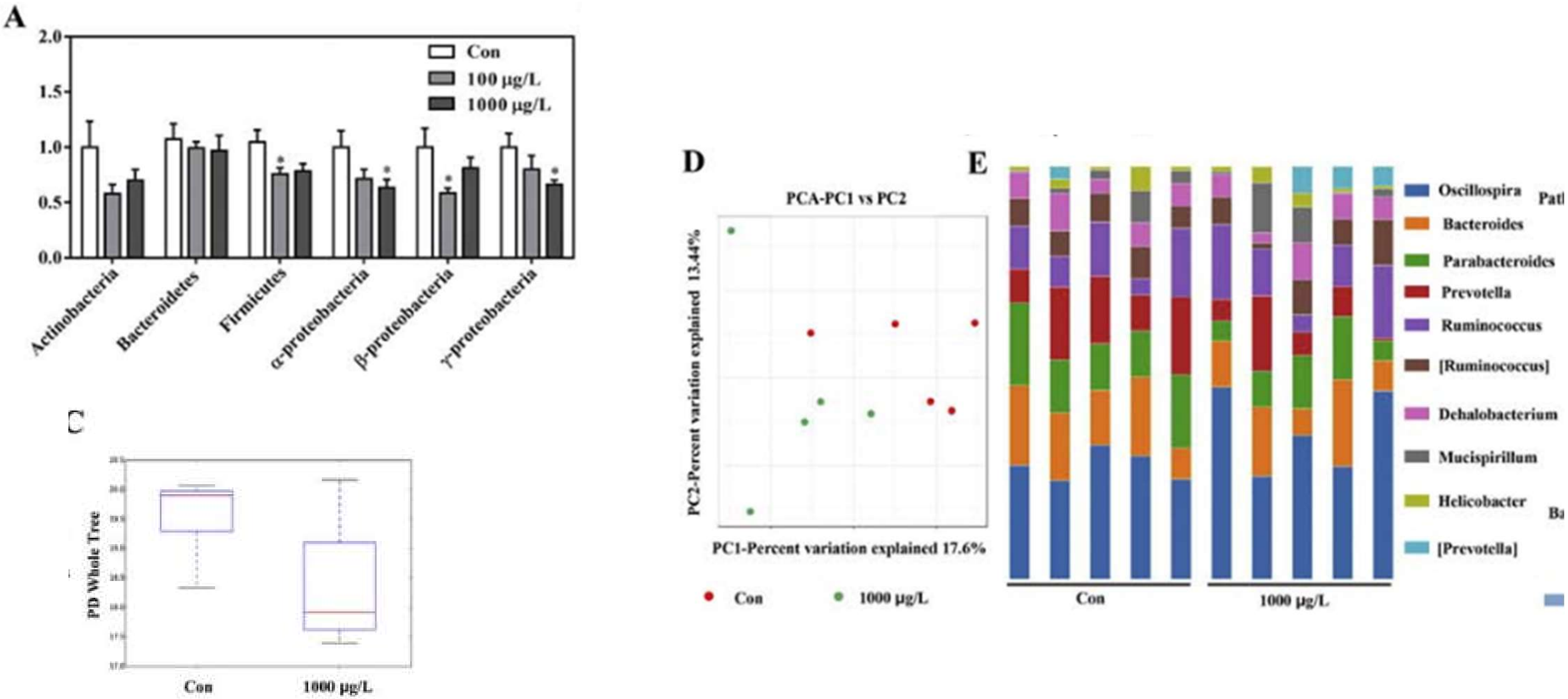
Pål A. Olsvik et al. Frontiers in Genetics, 2019

Interaction between microplastics and microorganism as well as gut microbiota



Lu L, et al. *Sci Total Environ*. 2019

Impacts of microplastic on the gut barrier, microbiota and metabolism of mice



Jin Y, et al. *Sci Total Environ*. 2019

Knowledge gap

- What are the overall exposure concentrations from dietary and airborne sources?
- Are microplastics able to accumulate in the body?
- What is the cellular mechanism of uptake? Does subcellular localisation or translocation occur?
- Does dissemination and/or elimination occur? Are there target secondary organs?
- Do size and shape influence toxicity? Does this depend on the point of entry (i.e. lungs or gastrointestinal tract)?

Uno studio americano ha analizzato campioni di organi e tessuti umani. Scoprendo presenza diffusa di materiale plastico. L'idea è creare un campionamento mondiale per verificare l'esposizione globale. E studiare gli effetti sulla salute.
I ricercatori hanno utilizzato 47 campioni prelevati da polmoni, fegato, milza e reni, quattro organi che probabilmente sono esposti a filtrare o trattenere microplastiche, sviluppando una procedura per estrarre plastiche dai campioni di tessuti e analizzandoli poi con la tecnica spettroscopica Raman. I ricercatori hanno anche creato un programma al computer che converte le informazioni sulla quantità di particelle di plastica in unità di massa e superficie, in modo da poter condividere il modello online e ricevere da altri ricercatori risultati standardizzati che potessero dunque essere paragonabili. "Condividere i risultati ci aiuterà a costruire un database sull'esposizione alla plastica in modo che si possa fare un confronto su organi e gruppi di persone in tempi e luoghi geografici diversi," ha specificato Halden.

G.Talignani, La Repubblica, 18 agosto 2020

The PLASTICOOR project

Campionamento, classificazione, caratterizzazione e valutazione dell'impatto sull'ambiente e sulla salute dell'uomo di micro- e nano-**PLASTI**che in a**C**qua destinata al consumo umano e in atmosfera ind**OOR**

N	Partner
1	CNR IRSA (capofila)
	CNR NANOTEC
	CNR IPCF
	CNR ITM
	CNR IPCB
	CNR ISAC
	CNR ISTEC
2	Università di Bari
3	Istituto Superiore di Sanità

https://orbmedia.org/stories/Invisibles_plastics

CONCLUSIONS

- Microplastic pollution in marine environments, air and soil pose a risk to food security and human health.
- Research has proven the presence of microplastics in seafood and foodstuff around the world, meaning we are always exposed to microplastic ingestion.
- Nonetheless, little is known about its direct effects on human health
- Future research should focus on microplastic monitoring techniques along the supply chain.
- Finally, plastic waste management must be improved, along with microplastic legislation