# Biophilie et Biodesign

## Végétal et qualité dé l'air dans le bâtiment

13/10/2016

***MAHY Grégory***
**Professeur**, *Ulg, Gembloux AgroBio-Tech, Biodiversité et Paysage*

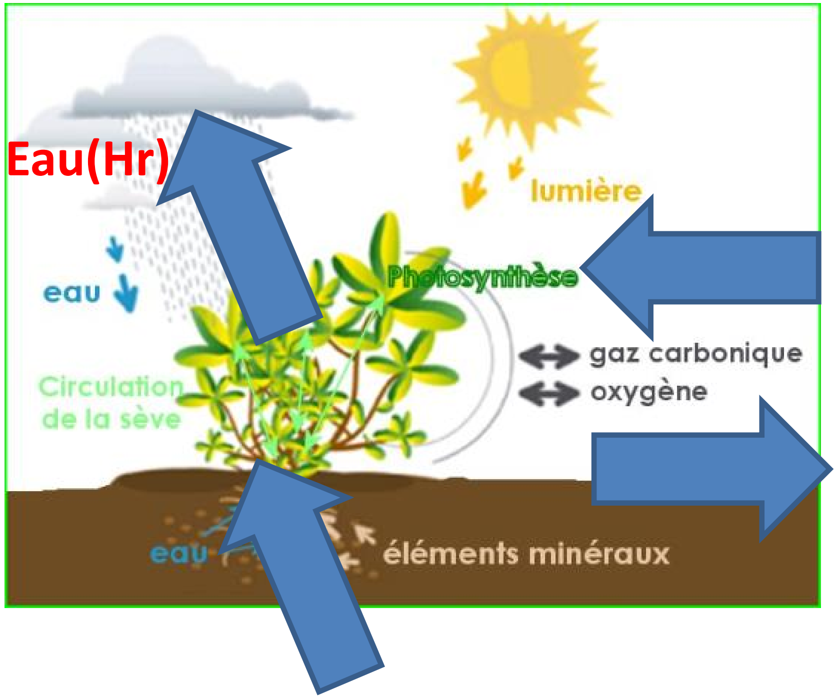
Atic
for HVAC professionals

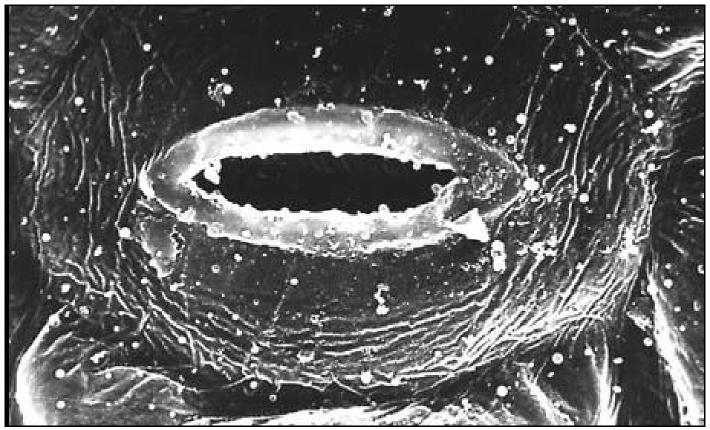
**Plants as air regulators can support autonomous closed ecosystems**

**Plants for air quality ?**

$$12H_2O + 6CO_2 + \text{Energie solaire} \xrightarrow[\text{Enzyme}]{\text{Chlorophylle}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

$$C_6H_{12}O_6 + O_2 \xrightarrow{\text{Enzymes}} CO2 + H2O + \text{energy}$$



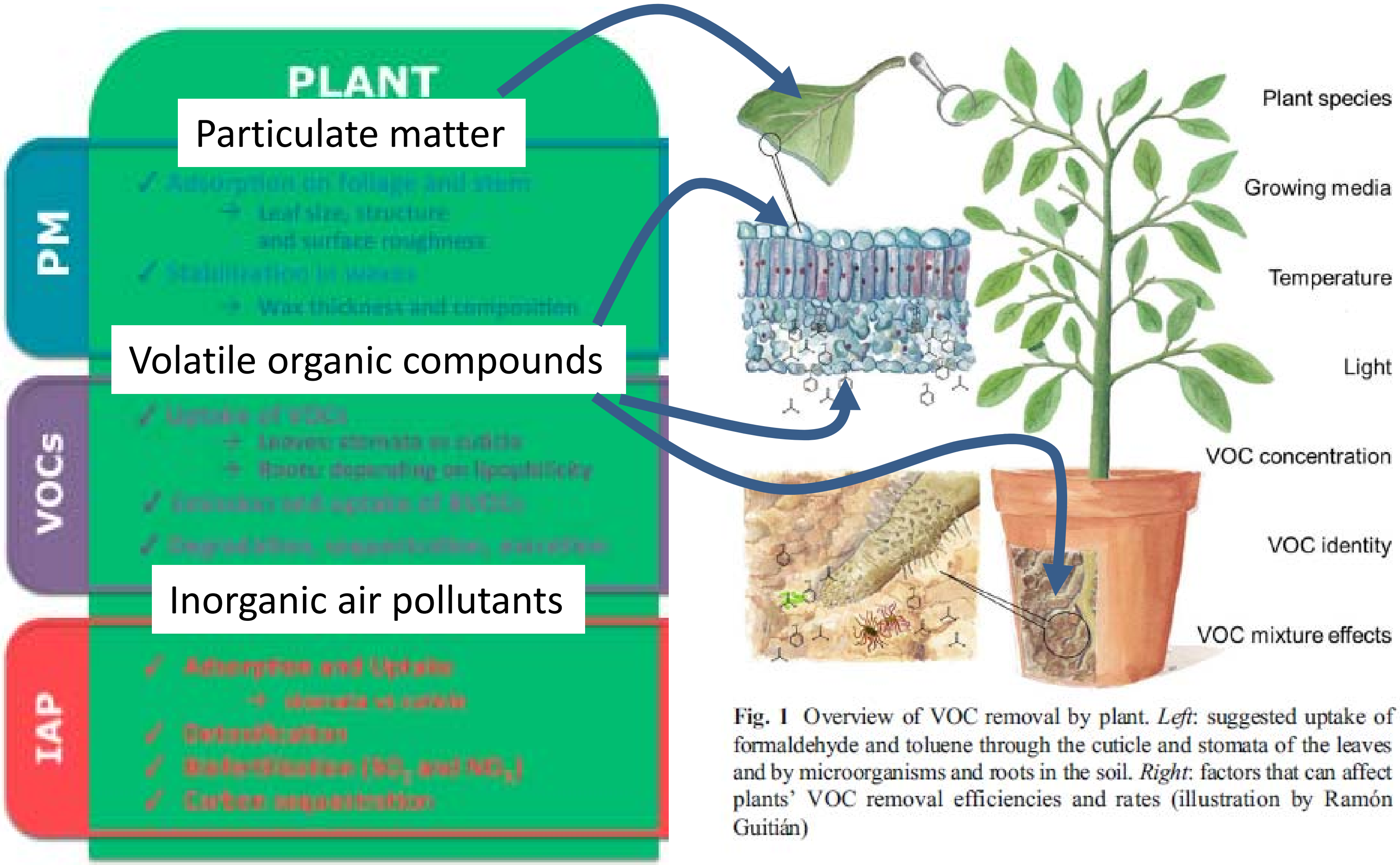
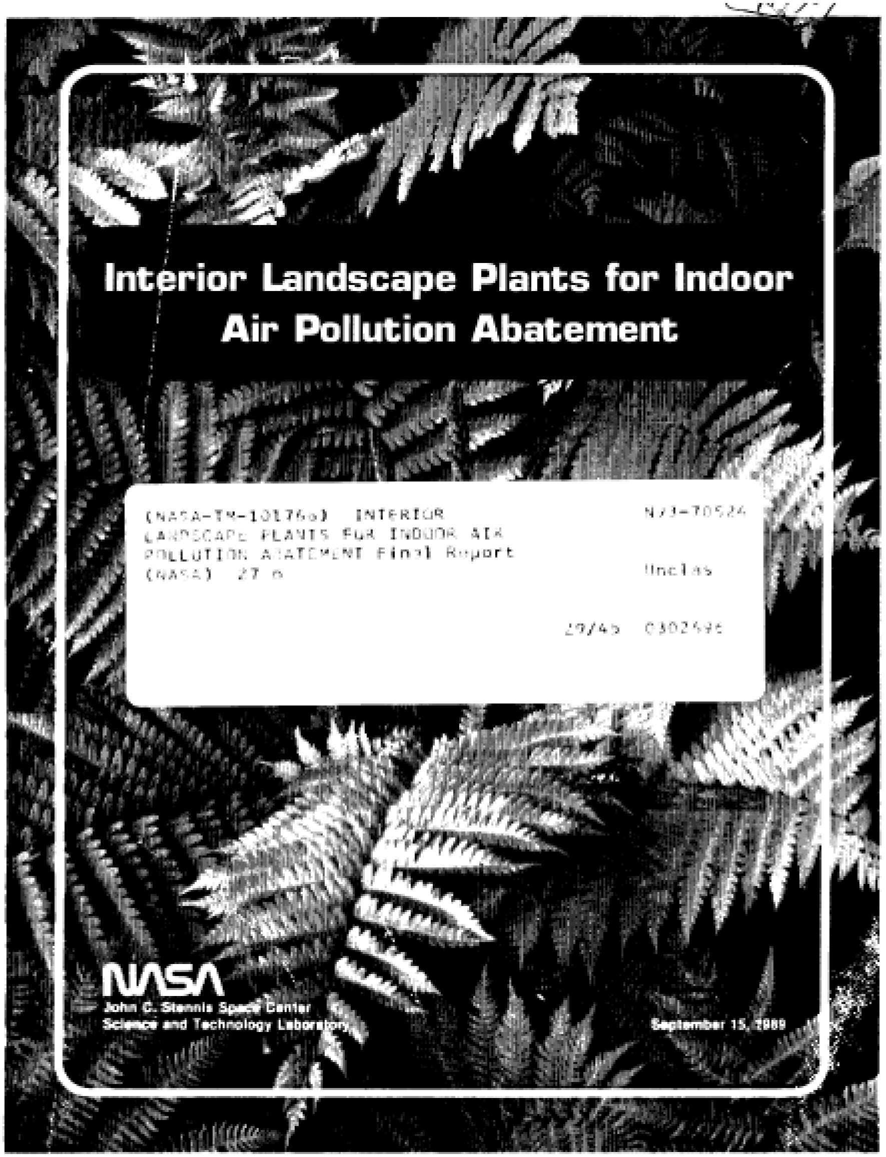



**Fig. 1** Overview of VOC removal by plant. *Left*: suggested uptake of formaldehyde and toluene through the cuticle and stomata of the leaves and by microorganisms and roots in the soil. *Right*: factors that can affect plants' VOC removal efficiencies and rates (illustration by Ramón Guitián)




# INTERIOR LANDSCAPE PLANTS FOR INDOOR AIR POLLUTION ABATEMENT

FINAL REPORT—SEPTEMBER 15, 1989

B.C. Wolverton, Ph.D.
Principal Investigator

Anne Johnson, M.S.

and

Keith Bounds, M.S.
Sverdrup Technology, Inc.

This work was jointly supported by the NASA Office of Commercial Programs—Technology Utilization Division, and the Associated Landscape Contractors of America (ALCA).

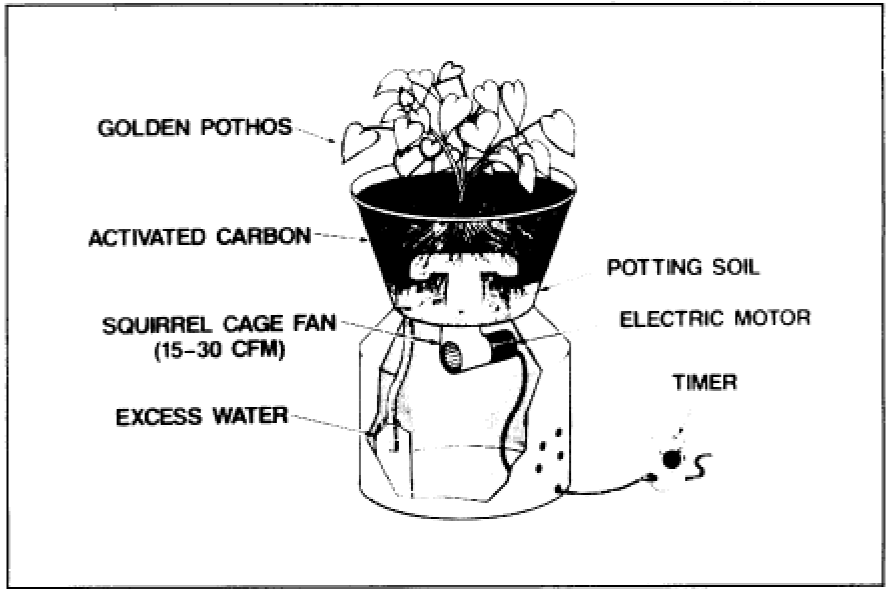



*Figure 1. Indoor air purification system combining houseplants and activated carbon.*

# STRONG pollutant abatment ?

**Table 3. Formaldehyde Removed from a Sealed Experimental Chamber by Houseplants and Soil During a 24-h Exposure Period**

| | Total Plant Leaf Surface Area ($cm^2$) | Total Micrograms Removed per Plant |
|---|---|---|
| Banana<br>*(Musa oriana)* | 1,000 | 11,700 |
| Mother-in-law's tongue<br>*(Sansevieria laurentii)* | 2,871 | 31,294 |
| English ivy<br>*(Hedera helix)* | 985 | 9,653 |
| Bamboo palm<br>*(Chamaedorea seifrizii)* | 14,205 | 76,707 |
| Heart leaf philodendron<br>*(Philodendron oxycardium)* | 1,696 | 8,480 |
| Elephant ear philodendron<br>*(Philodendron domesticum)* | 2,323 | 9,989 |
| Green spider plant<br>*(Chlorophytum elatum)* | 2,471 | 10,378 |
| Golden pothos<br>*(Scindapsus aureus)* | 2,723 | 8,986 |
| Janet Craig<br>*(Dracaena deremensis "Janet Craig")* | 15,275 | 48,880 |
| Marginata<br>*(Dracaena marginata)* | 7,581 | 20,469 |
| Peace lily<br>*(Spathiphyllum "Mauna Loa")* | 8,509 | 16,167 |
| Lacy tree philodendron<br>*(Philodendron selloum)* | 2,373 | 8,656 |
| Chinese evergreen<br>*(Aglonema modestum)* | 1,894 | 4,382 |
| Aloe vera | 713 | 1,555 |

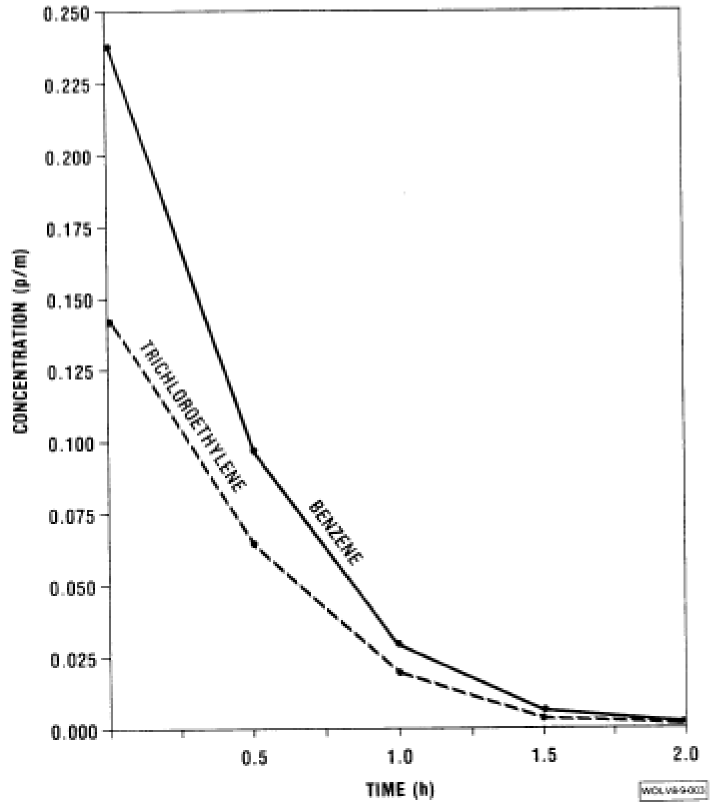
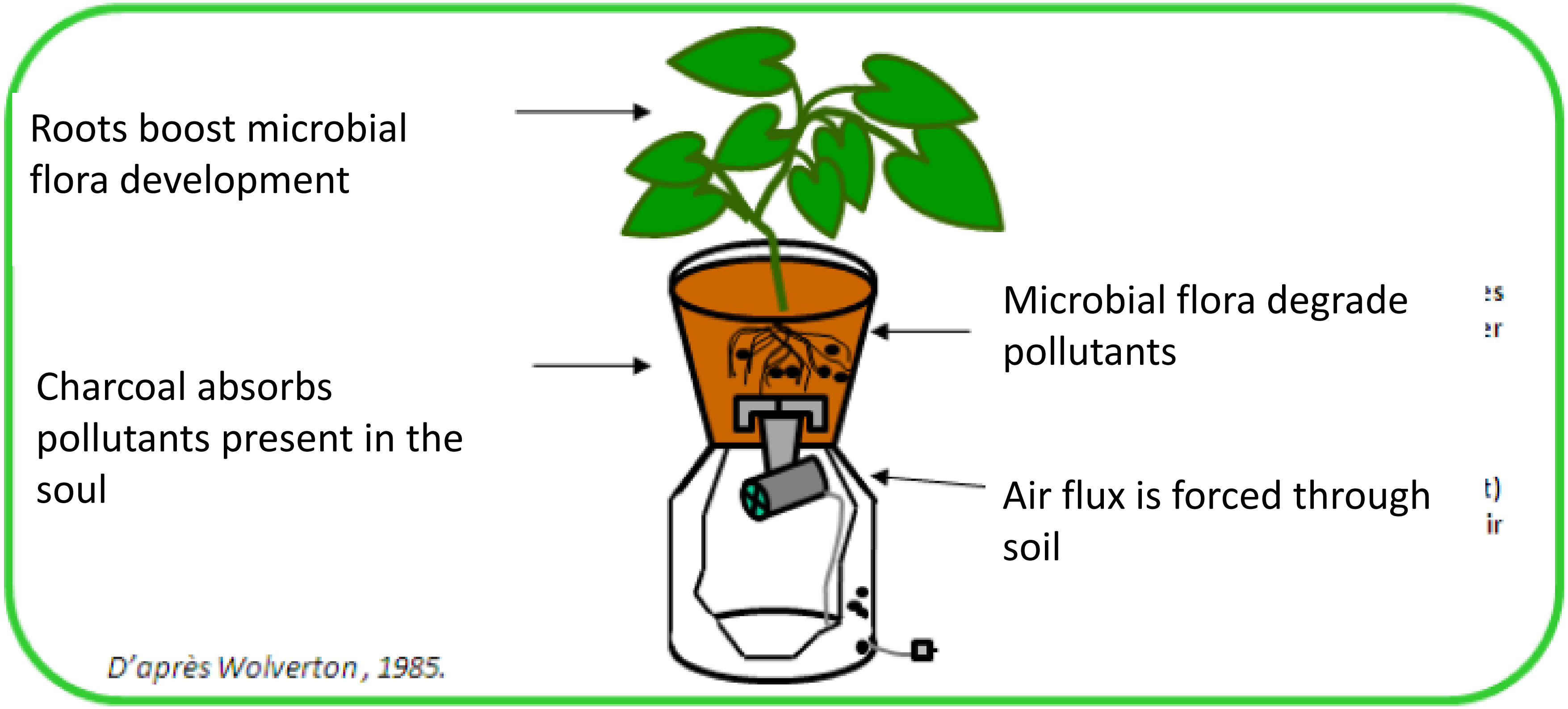



***Figure 3. Removal of low concentrations of benzene and trichloroethylene from the air inside sealed experimental chambers using golden pothos in an 8-in. activated carbon filter system.***

**Are plants responsible for pollutant epuration?**




Source Appa, 2012

## More and more tests … experimental tests !

**Single dose at high concentration**

Photo LSVF (D. Cuny)

**Continuous flux at lower concentration**

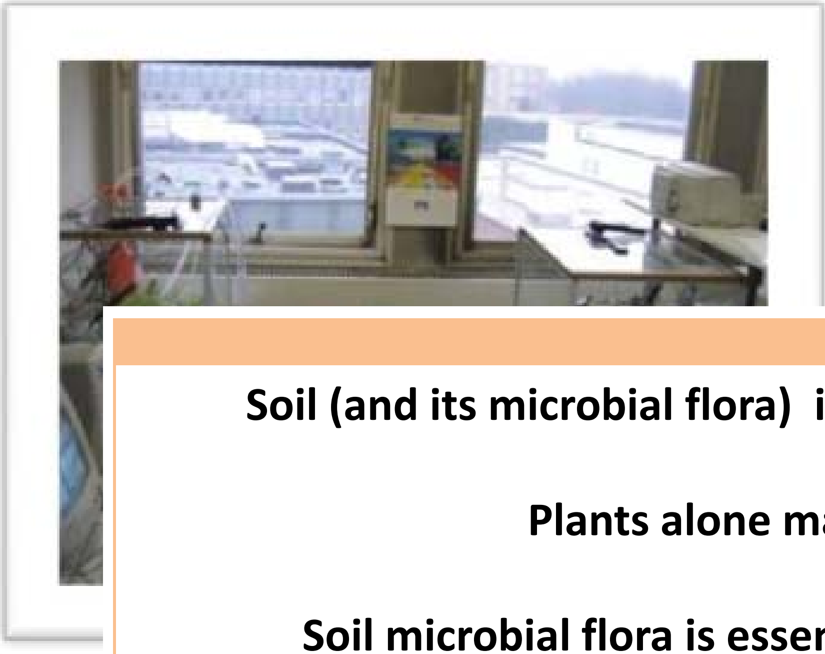
Photo LSVF (D. Cuny)

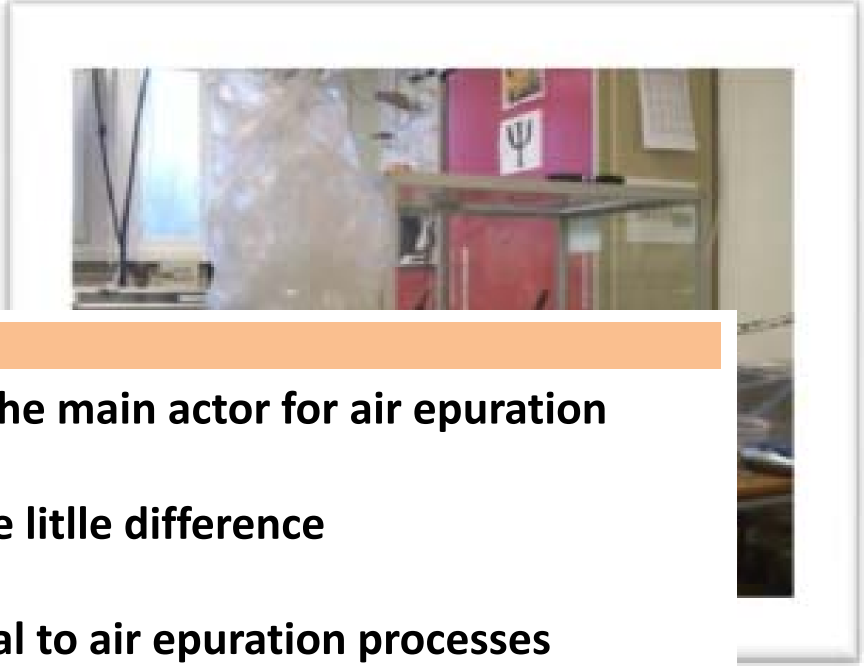
# > 100 plants species tested for VOC removal by indoor plants

Table 1 Overview of studies conducted in laboratories on VOC removal by indoor plants

| Reference | Plant species | VOC | VOC concentration (μg/m³) | Removal rate or removal efficiency |
|---|---|---|---|---|
| Aydogan and Montoya (2011) | *Chrysanthemum morifolium*, *Dieffenbachia compacta*, *Epipremnum aureum*, *Hedera helix* | Formaldehyde | 2,000 | 81–96 % in 24 h |
| Baosheng et al. (2009) | *Epipremnum aureum*, *Phoenix roebelenii* | Formaldehyde, acetone, benzene, toluene, xylene, styrene | 5,650–9,787 | 2.5–34 l/h[a] |
| Chun et al. (2010) | *Ficus elastica*, *Pachira aquatica*, *Syngonium podophyllum* | Benzene, toluene, *m/p*-xylene, *o*-xylene | 15,116 | 28–91 % in 12 h[a] |
| Cornejo et al. (1999) | *Chlorophytum comosum*, *Dracaena deremensis*, *Ficus elastica*, *Kalanchoe blossfeldiana*, *Magnolia* sp., *Pelargonium domesticum*, *Primula sinensis*, *Saxifraga stolonifera*, *Tradescantia fluminensis* | Benzene, pentane, toluene | 33,543 | 0.6–8.5 μg/g/day |
| De Kempeneer et al. (2004) | *Azalea indica* | Toluene | 339,000 | DT95%: 7–76 h |
| Godish and Guindon (1989) | *Chlorophytum comosum* | Formaldehyde | N/A | 29–90 % |
| Hasegawa et al. (2003) | *Schefflera arboricola* | Formaldehyde | N/A | N/A |
| Hasegawa et al. (2004) | *Schefflera arboricola*, *Nephrolepis exaltata* | Formaldehyde | 80,600 | N/A |
| Irga et al. (2013) | *Syngonium podophyllum* 'White Butterfly' | Benzene | 80,360 | 7.39–14.44 μg/m³/h per pot |
| James et al. (2008) | *Nicotiana tabacum* | 1,1,1-Trichloroethane, benzene, bromodichloromethane, carbon tetrachloride, chloroform, perchloroethylene, toluene, trichloroethylene, vinyl chloride | 2,500–22,000,000 | 0–157 μg/l[a] |
| Jin et al. (2013) | *Hedera helix*, *Melissa officinalis* | Formaldehyde | 2,500 | 2.22–25.06 mg/m³/h |
| Kim and Kim (2008) | *Ardisia japonica*, *Epipremnum aureum*, *Spathiphyllum* sp., *Stephanotis floribunda*, *Syngonium podophyllum* | Formaldehyde | 2,488 | 0.14–0.88 μg/m³/cm² in 5 h |
| Kim and Lee (2008) | *Cymbidium* sp., *Cymbidium* Meglan 'Mt Taipei', *Dendrobium phalaenopsis*, *Ficus benjamina*, *Oncidium* sp., *Phalaenopsis* sp., *Sansevieria trifasciata*, *Sedirea japonica* | Formaldehyde | 2,472 | 0.14–1.36 mg/m³/cm² in 5 h[a] |
| Kim et al. (2008) | *Fatsia japonica*, *Ficus benjamina* | Formaldehyde | 2,472 | T50%: 96 min — not reached |
| Kim et al. (2009) | *Epipremnum aureum*, *Gardenia jasminoides*, *Rosmarinus officinalis* | Formaldehyde | 2,472 | 3.4–6.6 mg/m³/h/m³ plant volume |
| Kim et al. (2010) | 86 plant species divided into five groups: woody foliage plants, herbaceous foliage plants, Korean native plants, ferns and herbs | Formaldehyde | 2,472 | 0.13–6.64 mg/m³/cm² in 5 h |
| Kim et al. (2011b) | *Aloysia triphylla*, *Ardisia crenata*, *Ardisia japonica*, *Ardisia pusilla*, *Begonia maculata*, *Cinnamomum camphora*, *Davallia mariesii*, *Eurya emarginata*, *Farfugium japonicum*, *Fittonia verschaffeltii*, *Hedera helix*, *Ilex crenata*, *Ligustrum japonicum*, *Melissa officinalis*, *Mentha piperita*, *Mentha piperita* 'Citrata', *Mentha suaveolens*, *Mentha suaveolens* 'Variegata', *Pelargonium graveolens*, | Toluene | 5,000 | −4.3 to 950.3 μg/m³/h/m² |

# Are plants responsible for pollutant epuration?

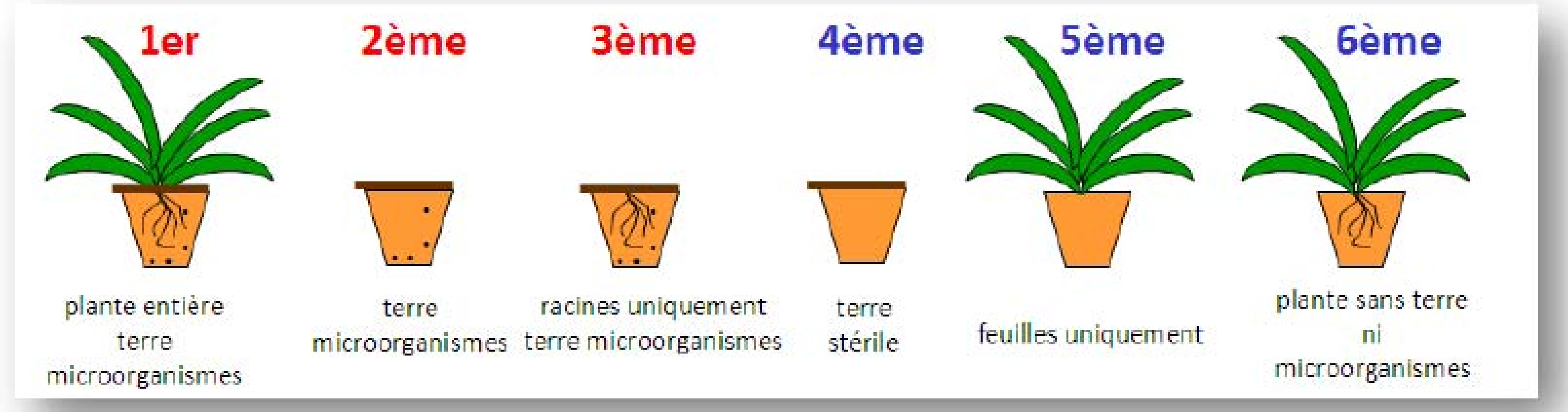




**Soil (and its microbial flora) is the main actor for air epuration**

**Plants alone make litlle difference**

**Soil microbial flora is essential to air epuration processes**



# Are plants responsible for pollutant epuration?

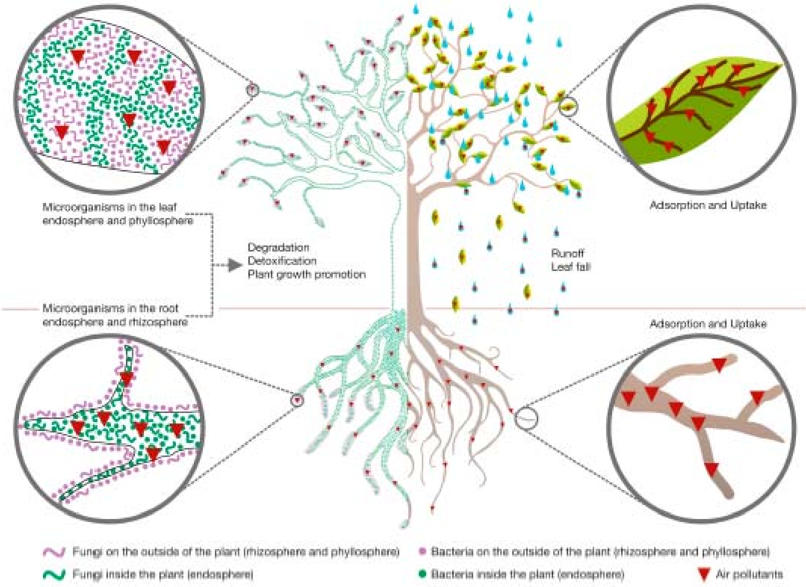



**Figure 1.** Schematic overview of phytoremediation of air pollution.

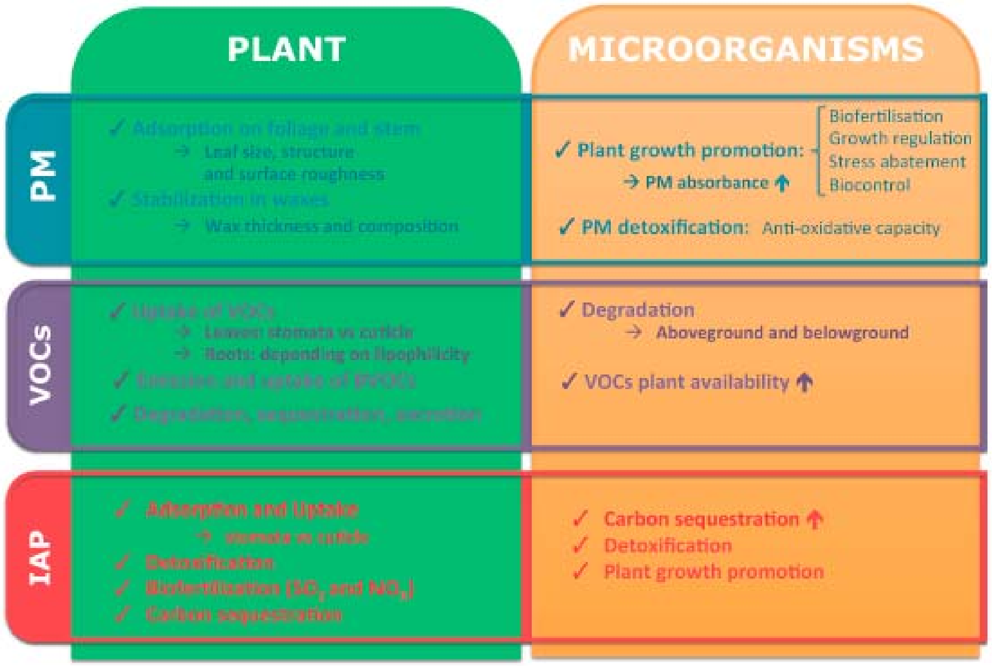



**Figure 2.** A concise overview of the specific contributions of the plant and its microbiome to the phytoremediation of the different categories of air pollution (increasing effects are indicated with ↑).

## From experiments to living situations

Photo PC2A (B. Hanoune)

**From experiments to living situations**

**Only few studies have been carried out in real-life offices and homes.**

3-6 Dracaena deremensis in 18 naturally ventilated and air-conditioned offices (50 m3)
**Reduction of 50 % in total VOC**
(Wood et al. 2006).

Newly constructed building combination - Ventilation and introduction of plants
**Formaldehyde decrease** : 80.8 to 66.4 µg/ m3
**Toluene decrease** : 275 to 106 µg/m3,
(Kim et al. 2011a)

Formaldehyde, benzene, ethylbenzene, toluene and xylene
**unaffected, decrease or increase** regardless of plant placement
(Kim et al. 2013).

Six potted plants in a classroom of 52.5 m2
**total VOC decrease** by approximately 73 %
(Pegas et al. 2012).

Spathiphyllum ‘Sweet Chico’
**total VOC increase**
because Spathiphyllum had started **flowering**

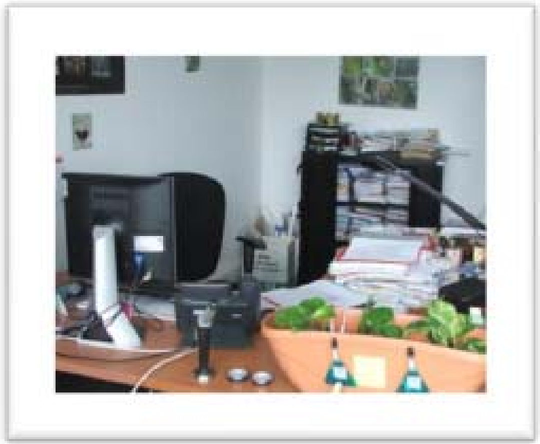


Photo APPA NPC

**From experiments to living situations**

**Only few studies have been carried out in real-life offices and homes...**
**And results are difficult to interpret**

“Lack of **statistical analysis”**

“The level of statistical significance was not given”

« … unfortunately, not possible from the statistical analysis carried out in the study to evaluate if the abovementioned results are significant…”

“Difficult to disentangle the **effect of plants and ventilation** (natural or induced)”

**Plant density HIGH** : 20 plant/20m2

.

*Photo APPA NPC*

**Plants as air regulators can support autonomous closed ecosystems**

## The experimental / living gap

## A multifactor facet

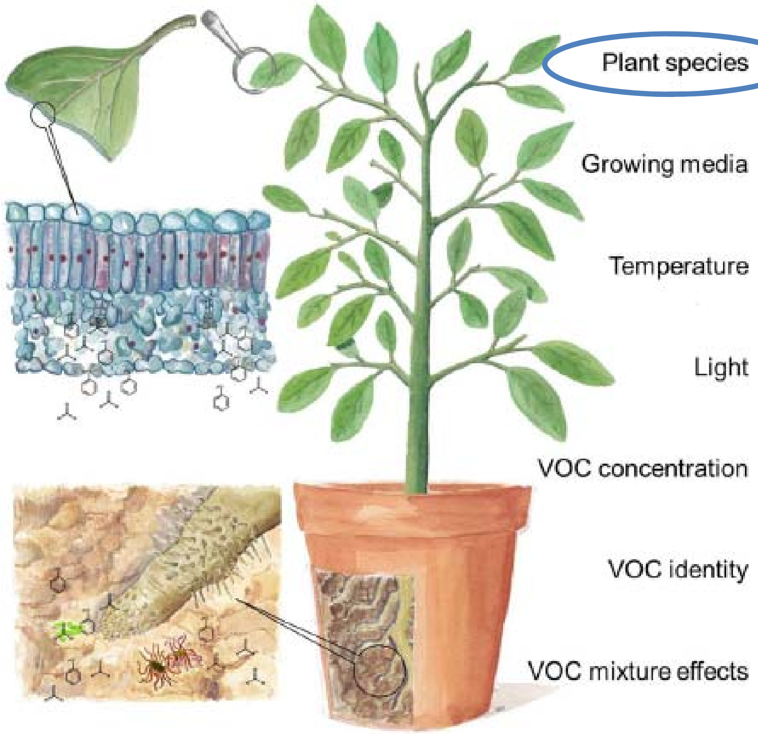



**Fig. 1** Overview of VOC removal by plant. *Left*: suggested uptake of formaldehyde and toluene through the cuticle and stomata of the leaves and by microorganisms and roots in the soil. *Right*: factors that can affect plants' VOC removal efficiencies and rates (illustration by Ramón Guitián)

It is well documented that VOC removal rates depend on plant species (Liu et al. 2007; Orwell et al. 2004; Wolverton and Mcdonald 1982; Yang et al. 2009) (Table 1). Even differences between cultivars have been observed (Kim et al. 2011b; Orwell et al. 2004; Zhou et al. 2011).

FERNS > HERBS for formaldehyde

C4 epuration day / CAM epuration night

Stomate density, Wax quantity and quality, hairness, ….

The effects of increased temperature on removal efficiencies are various (Baosheng et al. 2009; Sawada et al. 2007; Sawada

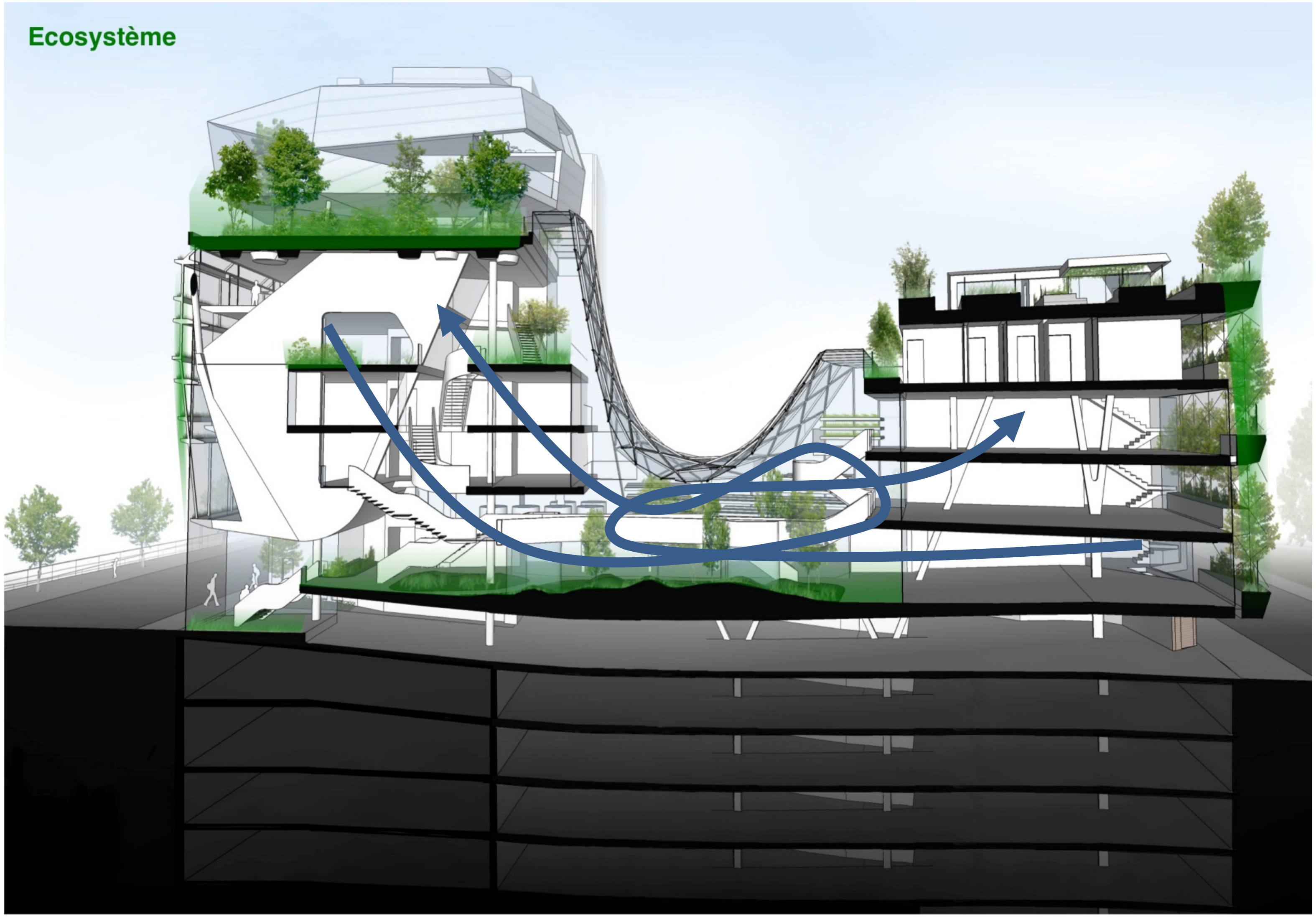
Increasing light intensity is found to have a positive effect on VOC removal efficiencies and rates (Baosheng et al. 2009;

# Take home message

- We have few (no?) evidence that adding plants to offices ameliorate air quality … as compared to ‘traditional ventilation methods’

- BUT don’t give up ….
- We need more experiments by design and controlled

# Integrate complete ecoosystems



# Take home message

- We have few (no?) evidence that adding plants to offices ameliorate air quality … as compared to ‘traditional ventilation methods’

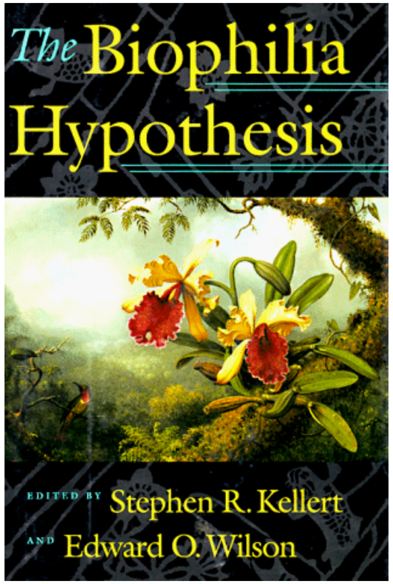
- BUT don’t give up ….
- We need more experiments by design
- Plants are more than air filters !!

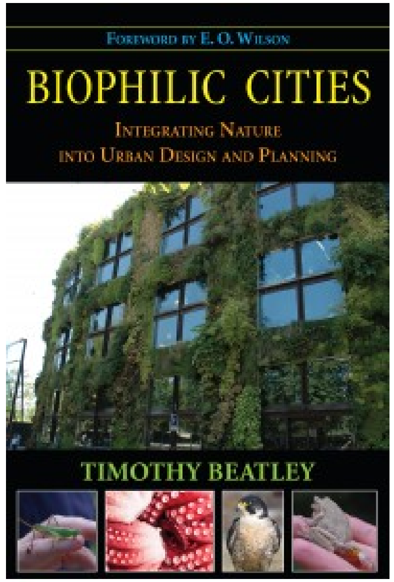
# BIOPHILIE

**« Biophilia…**

**is the innately emotional affiliation of human beings to other living organisms ….**

***Edward O. Wilson***
**The Biophilia Hypothesis**




# BIOPHILIE

L'hypothèse de la biophilie est soutenue par des recherches qui mettent en évidence le lien entre accès à la 'nature' et santé

Une vue sur la nature … réduit le séjour hospitalier / réduit la consommation d'analgésiques (ULRICH 1984)

Dans un environnement 'naturel' comparé à un environnement urbain, les sujets ont … un rythme cardiaque réduit … des fonctions immunitaires supérieures (Quing Li 2010)

10 arbres de rue par bloc urbain améliorent l'état de santé de façon équivalente à 7 ans de vieillissement (Kardan et al. 2015)

TRANFER TO INDOOR ENVIRONMENT …..

# Main References


- Dela Cruz et al., 2014. Can ornemental potted plants remove volatile organic compounds form indoor air ? – a review. Environ Sci Pollut, 21: 13909-13928.
- SCHMITZ H. et al. 2000. Assimilation and metabolism of formaldehyde by leaves appear unlikely to be of value for indoor air purification. *New Phytol*. , **147**: 307-315.
- Weyens N. et al., 2015. The role of Plant-Microbe and their exploitation for phytoremediation of air pollutants. Int. J. Mol. Sci., 16 : 25576-25604.
- Wolverton B.C. et al. 1984. Foliage Plants for Removing Indoor Air Pollutants from Energy-efficient Homes. *Economic Botany,* 38(2) : 24-228.
- Appa, 2012. Plantes et qualité de l’air intérieur : Les apports du programme PHYTAIR. www.appanpc.fr>Outiltheque>dossiers