

Synthesis of nanoparticles by fungi



LEC.5



- Throughout human history, fungi have been utilized as a source of food and harnessed to ferment and preserve foods and beverages. In the 20th century, humans have learned to harness fungi to protect human health ([antibiotics](#), anti-cholesterol statins, and immunosuppressive agents), while industry has utilized fungi for large scale production of [enzymes](#), [acids](#), and [biosurfactants](#).
- With the advent of modern [nanotechnology](#) in the 1980s, fungi have remained important by providing a greener alternative to chemically synthesized nanoparticle.



- The most common nanoparticles synthesized by fungi are [silver](#) and [gold](#), however fungi have been utilized in the synthesis other types of nanoparticles including [zinc oxide](#), [platinum](#), [magnetite](#), zirconia, silica, titanium, and cadmium sulfide and cadmium selenide [quantum dots](#).



- **Silver nanoparticle production**
- Synthesis of silver nanoparticles has been investigated utilizing many ubiquitous fungal species including *Trichoderma*, *Fusarium*, *Penicillium*, *Rhizoctonia*, *Pleurotus* and *Aspergillus*. Extracellular synthesis has been demonstrated by *Trichoderma viride*, *Aspergillus niger*, *Pleurotus ostreatus*, *Cladosporium cladosporioides*, *Penicillium brevicompactum*,
- while intracellular synthesis was shown to occur in a *Verticillium* species, and in *Neurospora crassa*.

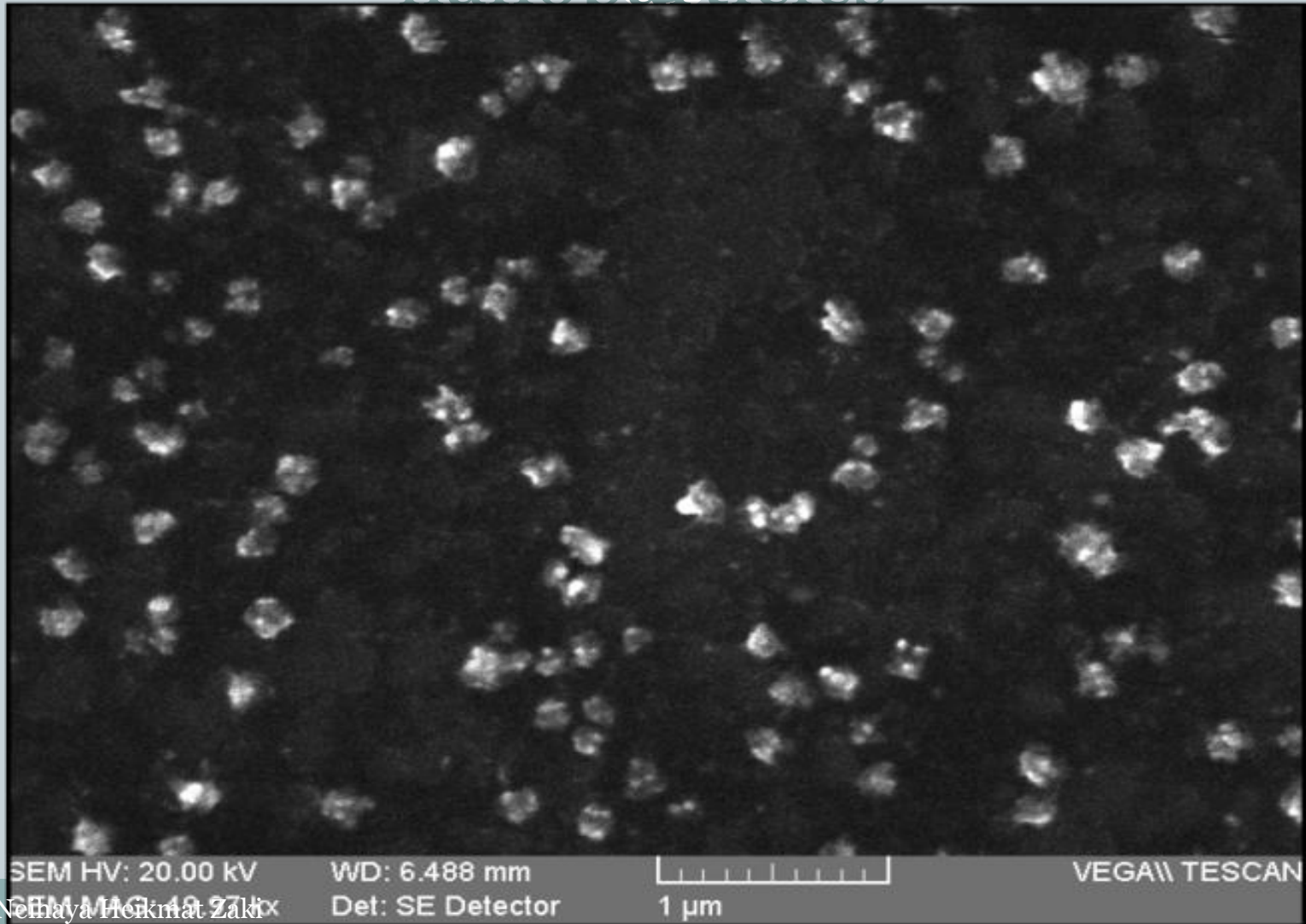


- **Gold nanoparticle production**
- Synthesis of gold nanoparticles has been investigated utilizing *Fusarium*, *Neurospora*, [*Verticillium*](#), yeasts, and *Aspergillus*.
- Extracellular gold nanoparticle synthesis was demonstrated by *Fusarium oxysporum*, *Aspergillus niger*, and cytosolic extracts from [*Candida albican*](#).
- Intracellular gold nanoparticle synthesis has been demonstrated by a *Verticillium* species, *V. luteoalbum*



- **Miscellaneous nanoparticle production**
- In addition to gold and silver, *Fusarium oxysporum* has been used to synthesize zirconia, titanium, cadmium sulfide and cadmium selenide nanosize particles.
- Cadmium sulfide nanoparticles have also been synthesized by [*Trametes versicolor*](#), [*Schizosaccharomyces pombe*](#), and *Candida glabrata*. The white-rot fungus *Phanerochaete chrysosporium* has also been demonstrated to be able to synthesize elemental selenium nanoparticles.

SEM image of fungal derived silver nanoparticles

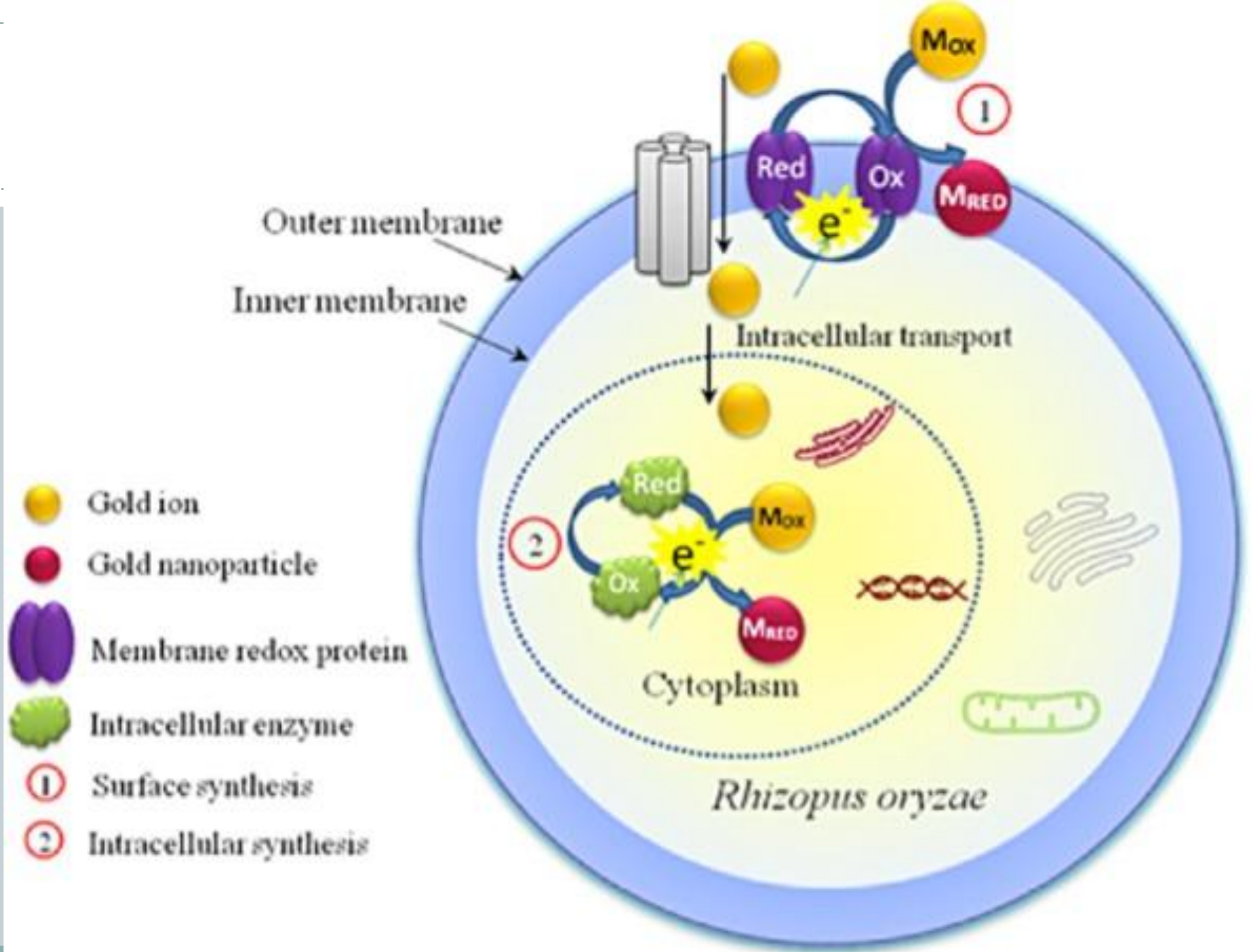




- **Formation mechanisms**
- **Gold and silver**
- Nitrate reductase was suggested to initiate nanoparticle formation by many fungi including *Penicillium* species, while several enzymes, α -NADPH-dependent reductases, nitrate-dependent reductases and an extracellular shuttle quinone, were implicated in silver nanoparticle synthesis for *Fusarium oxysporum*.
- silver nanoparticle synthesis for *A. flavus* occurs initially by a "33kDa" protein followed by a protein (cystein and free amine groups) [electrostatic attraction](#).



- Intracellular silver and gold nanoparticle synthesis is not fully understood but similar fungal cell wall surface electrostatic attraction, reduction, and accumulation has been proposed.
- External gold nanoparticle synthesis by *P. chrysosporium* was attributed to [laccase](#), while intracellular gold nanoparticle synthesis was attributed to [ligninase](#).





- **Cadmium sulfide**
- Cadmium sulfide nanoparticle synthesis by yeast involves sequestration of Cd^{2+} by glutathione-related peptides followed by reduction within the cell.
- cadmium sulfide nanoparticle synthesis by *Fusarium oxysporum* was based on a sulfate reductase (enzyme) process.

Fungi

High/Very high

(Rajapaksha *et al.*, 2004)

Commonly extracellular

(Durán *et al.*, 2011)

**Very fast in cell-free filtrate
(<1 h)**

(Du *et al.*, 2011)

**Shape and size depend on
biomass/Au ratio**

(Pimprikar *et al.*, 2009)

**NADH-reductases,
phytochelatins, melanin**

(Mukherjee *et al.*, 2001)

**Unidentified surface-bound
proteins**

(Shankar *et al.*, 2003; Das *et al.*, 2009)

More likely

**Metal toxicity
resistance**

AuNP location

Biosynthesis rate

AuNP shape and size

**Bioreducing
agent(s)**

**Bio-capping
agent(s)**

**Scalability to
industrial process**

Bacteria

Medium/High

(Rajapaksha *et al.*, 2004)

**Both intracellular and
extracellular**

(Lengke and Southam, 2006)

Relatively slow (>24 h)

(Du *et al.*, 2011)

**Prevalently spherical, small
AuNPs**

(Wen *et al.*, 2009)

**Microbially produced redox
mediators, membrane proteins
and cytochromes, inorganic redox
compounds**

(von Canstein *et al.*, 2008;
Marshall *et al.*, 2008; Mukherjee *et al.*, 2002)

Not yet identified

Less likely