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Mini-review

# Bacterial diversity losses: A potential extracellular driving mechanism involving the molecular ecological function of hydrophobic polycyclic aromatic hydrocarbons☆

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ABSTRACT

The DNA transformation is vital to the horizontal gene transfer (HGT). The low-efficiency transformation of bare plasmid exposed to hydrophobic polycyclic aromatic hydrocarbons (PAHs) decreases the gene transfer level, and is possibly related to the loss of bacterial diversity at present. PAHs have great affinity for bare DNA through dispersion force and π–π overlap between PAHs and bases. These noncovalent interactions between PAHs and bases reduced the transformational efficiency of plasmid into bacterial recipients. Meanwhile these low-efficiency transformations for plasmid are controlled by the ions like $Ca^{2+}$ in environment, in turn, presence of 0.5 mmol $L^{-1}$ $Ca^{2+}$ recovered the efficiency from 3.2 (phenanthrene), 3.5 (pyrene) to about 4.45 and 4.75, respectively. The combination of $Ca^{2+}$ with the $—POO^{-}—$ groups in DNA forms strong electrovalent bonds, weakening the molecular effect of DNA on PAHs and in turn promoting the gene transfer exposed to PAHs.

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Until now, researchers, including ecologists and environmentalists, have generally attributed the losses in bacterial diversity caused by anthropological contaminants to merely the direct intracellular damages. Public document has proposed that the interaction of intracellular DNA with contaminants induces changes in genetic information via the effects of mutation, teratogenesis, and carcinogenesis [1–3], and hold that these effects result in the death of organisms. Such viewpoints are acted as the main theoretical basis for the bacterial diversity losses caused by hydrophobic organic contaminants. Although researchers recognize that these lateral transfers effectively change the ecological and pathogenic characteristics of bacterial species [4], few doubt that the diversity loss caused by anthropogenic contaminants is also dominated by the effects of contaminants on DNA transfer. The DNA transformation, which means transformation of competent cells through uptake of extracellular DNA, is vital to the horizontal gene transfer (HGT). The low-efficiency transformation of bare plasmid exposed to hydrophobic polycyclic aromatic hydrocarbons (PAHs) decreases the gene transfer level. Primary case study implies that the gene transfer of bare DNA affected by the interaction of DNA with polycyclic aromatic hydrocarbon (PAH) contaminants may be related to the loss of bacterial diversity [4,5].

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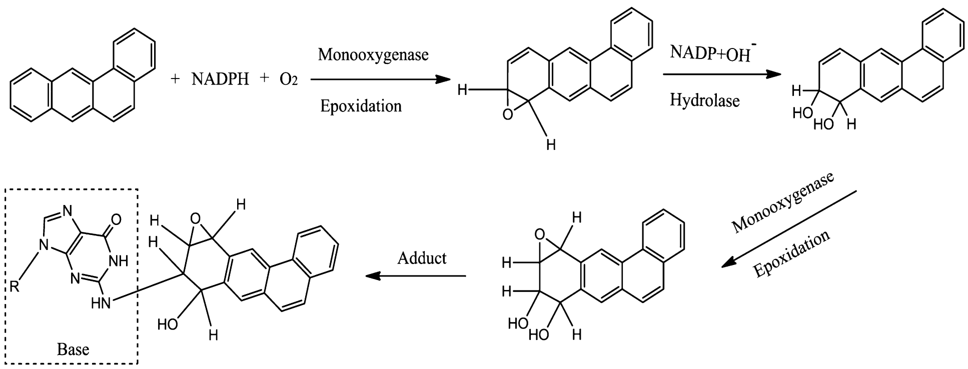


**Fig. 1.** The reported main pathway by which PAHs affect interacellular DNA [15].

## 1. Role of bare DNA in bacterial diversity and evolution

Horizontal gene transfer (HGT) is an important process by which a bacterium takes up exogenous free DNA and incorporates it into its own chromosome via homologous recombination or converts it into an autonomous extrachromosomal replicon [6,7]. This plays an important role in genetic variation and heredity, ecological and genetic diversity, and evolution [4,8]. On the death of an organism, the intracellular germplasm and extracellular materials are released into the soil and water, where they can be transferred to other living cells and expressed in the new host [9]. Many such gene transfers between different organisms have been reported [10]. For example, up to between 10% and 16% of *Escherichia coli* DNA has originated due to HGT [4,11]. In addition, *E. coli* isolated from the intestines of Japanese individuals was found to contain gene segments that originated from the ocean environment via edible seafood, which indicates that gene transfer between microorganisms and animals is ubiquitous in natural environments [12,13].

## 2. Interaction between bare DNA and hydrophobic PAHs

Compared to DNA in the intracellular environment, “bare” DNA is quite sensitive and vulnerable to direct damage on exposure to

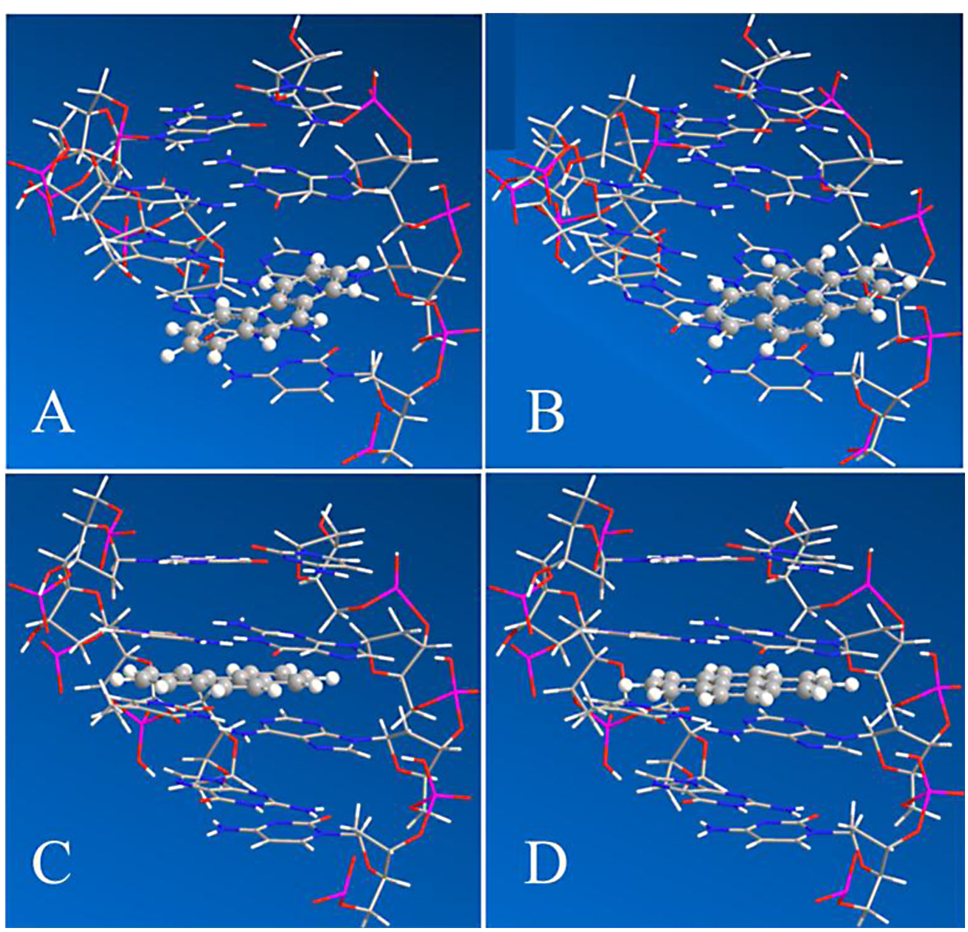


**Fig. 2.** Interaction sites between PAHs and DNA. Fig. 2A and B shows that phenanthrene and pyrene inserted into grooves in DNA; and Fig. 2C and D indicates that phenanthrene and pyrene inserted between bases through dispersion force and π–π overlap of PAHs-bases. The interaction between PAHs and DNA are calculated using the Autodock 4.2 [18], and are optimized using the Orca 1.8.1 (BLYP D3 GCP(DFT/SVP) def2-SVP def2-SVP/J) [19]. Solvent (water) effects were taken into consideration implicitly.

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