

membrane vesicle secretion of methicillin-resistant *S. aureus* under conditions of subinhibitory concentrations of vancomycin. Vancomycin treatment led to modification of the contents of the vesicles, which were enriched in proteins, facilitating the formation of a biofilm.

### 9.2.3 Horizontal Transfer of Encoding $\beta$ -Lactamase Genes

A significant increase in the concentration of antibiotic resistance genes has been observed in biofilms collected downstream of wastewater treatment plant discharge points, favoring the increase and spread of antibiotic resistance among streambed biofilms (Proia et al. 2016). The health relevance of biofilms is widely demonstrated by the increase in antibiotic-resistant bacteria hosted in biofilms in hospitals and the interaction of these bacteria with immune system cells (Obst et al. 2006; Dupin et al. 2015). Some bacterial strains belonging to serotypes associated with human infections are able to persist within the processing plants, forming biofilms (Osman et al. 2016). In addition, commonly used prophylactic antibiotic treatments, such as cefazolin, have been unable to eradicate bacterial biofilms and prevent colonization on model implant surfaces (Dastgheyb et al. 2015), questioning the use of these antibiotics for prophylaxis.

Biofilms are also facilitators of genetic material transfer and plasmid stability (Marti et al. 2017; Ridenhour et al. 2017). Mo et al. (2017) demonstrated dissemination of *bla*<sub>CMY-2</sub>-carrying plasmids in European broiler production, the intergenus transfer of *bla*<sub>CMY-2</sub>-carrying plasmids from *E. coli* to environmental bacteria in the food-processing chain, and their capacity for conjugative transfer between different poultry-associated bacterial genera. Li et al. (2001) also showed that biofilm-grown *Streptococcus mutans* cells were transformed at a rate 10- to 600-fold higher than planktonic cells and that dead bacteria in the biofilms could act as donors of a chromosomally encoded erythromycin resistance determinant under control of the active pheromone ComC.

However, Yoon et al. (2015) showed that natural transformation and plasmid transfer are diminished in recipients overproducing the multidrug efflux pump AdeABC in biofilm conditions following alteration of the membrane.

Finally, co-transfer of genes encoding antibiotic resistance and facilitating biofilm formation and/or persistence has been observed in large plasmidic pathogenicity islands (Van Schaik et al. 2010).

### 9.2.4 Influence of Subinhibitory Concentrations of Antibiotics on Biofilm

At sub-MIC concentrations, some macrolide antibiotics (e.g. azithromycin) (Hoffmann et al. 2007; Starner et al. 2008), beta-lactam antibiotics (e.g. ceftazidime) (Otani et al. 2018), and fluoroquinolone antibiotics (e.g. ciprofloxacin)