also serve as one of the languages of communication? We discussed before the regulatory role of signaling via γ-butyrolactone for antibiotic synthesis. It appeared that, similarly to this signaling, antibiotics can also coordinate antibiotic biosynthesis via "pseudo"-γ-butyrolactone receptors (Xu et al. 2010). Indeed, γ-butyrolactones and antibiotics are recognized as signaling molecules playing fundamental roles in intra- and interspecies communications (Li et al. 2015b). This suggests that certain regulatory circuits in microbial communities are replicated, with the combination of quorum sensing and antibiotic signaling. Supporting this view is the evolutionary relationship and biological relevance found between the regulatory systems of quorum sensing and multidrug resistance (Xu 2016).

The redundancy of signaling networks built into microbial communities could be explained by the need to guarantee that a message is conveyed and received, even under the continuously changing environmental conditions. Also, the role could be in amplification of a weak or rapidly decaying signal to make it stronger and less specific so it can be sensed by other community members, which are less capable of perceiving and deciphering the environmental cues. Or attenuate the signal if it is too intense. The acyl-homoserine lactone quorum signal, for example, decays very rapidly in many soil types (Wang and Leadbetter 2005). The function of antibiotic resistance via antibiotic degradation/modification could be then similar to the attenuation of signal intensity via quorum quenching in the quorum-sensing communication (Dong et al. 2001). For example, removal of the initial quorum-sensing signal affects antibiotic susceptibility of *Streptococcus anginosus*, which makes it more sensitive to antibiotics (Ahmed et al. 2007). The negative feedback loop of a secondary signaling system, antibiotics, may then suppress the primary quorum-sensing signaling network (Tateda et al. 2004; Skindersoe et al. 2008), thus providing fine-tuning between the two signaling networks.

23.18 Convergent Evolution of Antibiotics as Signaling Molecules

Regulatory effects of antibiotics in antibiotic-producing and nonproducing bacteria discussed above strongly support the view for the signaling role played by antibiotics in natural microbial communities. If antibiotics evolved as the language for intra- and interspecies communication in microbial communities, then we should expect another supporting argument for this, at the evolutionary level. What is expected is the pattern of convergent evolution in biosynthesis of antibiotics – in other words, the evolvement of same type of "language" (signaling antibiotics) to be "understood" by taxonomically divergent bacteria, which, nevertheless, may employ different biosynthetic pathways to generate