Quantum coherence and entanglement are fundamental features of quantum systems, separating quantum physics from its classical counterpart. In the early days of quantum mechanics entanglement has been considered as a puzzling phenomenon, and Einstein has famously termed it "spooky action at a distance". Over the last decades the situation has changed, with the existence of entanglement being confirmed in numerous experiments. Today, quantum entanglement is considered as a resource for the emerging quantum technologies, allowing us to surpass limitations of classical devices. This has led to the development of the *resource theory of entanglement*, allowing us to investigate the role of entanglement for technological applications, such as quantum teleportation and quantum cryptography.

Recent results show that not all quantum technological applications are based on the presence of entanglement, but require other types of nonclassicality. An important example is quantum computation: a process which uses the laws of quantum mechanics to solve problems which are not efficiently solvable on classical computers, e.g. prime factorization. As of today, we do not have a full understanding which quantum features are responsible for the advantage of quantum computers. While an ideal quantum computer – operating on noiseless quantum states – requires entanglement to show exponential speedup over classical computation, the role of entanglement for noisy quantum computation is unknown. This opens the possibility for quantum algorithms operating on unentangled noisy states at a high temperature, while the quantum algorithms still solve certain classes of problems exponentially faster than any known classical algorithm. This brings us to the main question of this project: *is quantum speedup possible without entanglement?* An affirmative answer to this question would radically change the way we think about quantum computation today. The methods developed for tackling this question will lead to new quantum algorithms and quantum computational models which are resilient against noise, and make direct use of noisy quantum states at high temperature without quantum error correction, while solving important problems which cannot be solved efficiently on a classical computer. Preliminary results show that *quantum coherence* might be more suitable than entanglement for capturing the performance of noisy quantum computation. The recently developed *resource theory of coherence* will thus serve us as a starting point for this investigation, and the project will also make use of the variety of techniques available within *general quantum resource theories*.

In this project we will also investigate resource catalysis for general quantum resource theories and establish speed limits for resource generation, i.e., the minimal time to create a certain amount of a quantum resource, such as coherence or entanglement, but also general types of resources resorting to fundamental properties of quantum resource theories. This project will study local resources required for quantum communication, which arise from local energy constraints, but also constraints on general quantum resources which are available locally to the communicating parties. We will further provide methods to reduce decoherence, by letting a decohering system interact with a coherent ancilla.

We expect that the methods and results developed in this project also find applications beyond the field of quantum theory. The investigation of quantum phenomena in biology and medicine is a very timely topic, and our ideas will potentially give new significant insights in these directions.