Obstacles: Decoherence, Error Correction, Scalability (need to scale to 1000 Bits for "practical" applications). "Operating a quantum computer is a race against the clock." The same phenomenon enabling the potential computing power of quantum computers — entanglement — is also responsible for decoherence when it occurs with unmonitored degrees of freedom. The main challenge of quantum computing is to quickly build entanglement between the qubits before imperfections or decoherence overly corrupt the quantum state. This decoherence is an intrinsic characteristic of any quantum computer and its origin and consequences must be understood thoughtfully. But in all hardware realizations, it means each operation incurs a loss of fidelity relative to the ideal target quantum state."
What Limits the Simulation of Quantum Computers? Yiqing Zhou, PHYSICAL REVIEW X 10, 041038 (2020)

II. A Brief History of Quantum Computing

In 1961, Rolf Landauer stated the following Principle: An irreversible change in information stored in a computer, such as merging two computational paths, dissipates a minimum amount of heat (per bit) to its surroundings, $E \geq k_b * T * \ln 2$, where k_b is Boltzmann's constant. This principle asserts that all information is physical. This Law established a fundamental energy limits on computation. This limit can be transcended in QC by using reversible computing gates. Some people refer to Landauer as the "Godfather of quantum computation."

In 1981, Richard Feynman gave a lecture entitled “Simulating Physics with Computers” In this talk, he argued that a classical system could not simulate quantum phys cis. At the quantum level, all Physics is time reversible, but classical Physics, because of entropy, is not.

In 1985, David Deutsch, a physicist at Oxford, suggested a more comprehensive framework for quantum computing in his 1985 paper. In this work, he describes in detail what a quantum algorithm would look like.
He gave an algorithm that would **run exponentially faster** than **any possible deterministic classical** algorithm.

In 1993, Umesh Vazirani and his student Ethan Bernstein (BV) picked up where Deutsch and Jozsa left off. described an algorithm that showed clear quantum-classical separation even when small errors are allowed.

In 1994, Shor was a researcher in the mathematical division of Bell Labs in New Jersey. Shor studied the work of Deutsch, BV and Simon and realized he could construct an algorithm for factoring large numbers into two prime factors; factoring large numbers is believed to be intractable on a classical computer.

In 1999-2001, Yasunobu Nakamura built and demonstrated a functioning, controllable superconducting qubit. Nakamura used Josephson junctions to create a two-level system.

In 1995, Cirac and Zoller proposed an ion trap as the physical system to perform quantum computation.
In 1995, Grover developed the fastest possible quantum algorithm (O(N1/2)) for searching an unsorted database.

1996 Shor and Robert Calderbank, and independently Andrew Steane, saw a way to finesse the seemingly show-stopping problems of quantum mechanics to develop quantum error correction techniques. Today, quantum error correction is arguably the most mature area of quantum information processing.

2023 IBM Unveils 433 Qubit-Plus Quantum Processor. IBM expects to offer a 10000 qubit machine in 2025. Its qubits known as **transmons**, which are essentially **superconducting resonators** that can **store 0 or 1 microwave photons.** These qubits can be manipulated by applying microwave pulses of different frequencies to them from outside the processor, connected to each other with busses, different frequencies, can control them independently, passive microwave circuitry, which does not deliberately absorb or emit microwave signals but redirects them, microwave resonators that measure the state of the qubits, filters that protect the qubits from decaying out of a drive line, and transmission lines that deliver microwave signals to the qubits and to and from the readouts. Temp = 0.02K