The good news is that many pretrained LLMs, available as open source models, can be used as general-purpose tools to write, extract, and edit texts that were not part of the training data. Also, LLMs can be fine-tuned on specific tasks with relatively smaller datasets, reducing the computational resources needed and improving performance.

We will implement the code for pretraining and use it to pretrain an LLM for educational purposes. All computations are executable on consumer hardware. After implementing the pretraining code, we will learn how to reuse openly available model weights and load them into the architecture we will implement, allowing us to skip the expensive pretraining stage when we fine-tune our LLM.

1.6 A closer look at the GPT architecture

GPT was originally introduced in the paper "Improving Language Understanding by Generative Pre-Training" (https://mng.bz/x2qg) by Radford et al. from OpenAI. GPT-3 is a scaled-up version of this model that has more parameters and was trained on a larger dataset. In addition, the original model offered in ChatGPT was created by fine-tuning GPT-3 on a large instruction dataset using a method from OpenAI's InstructGPT paper (https://arxiv.org/abs/2203.02155). As figure 1.6 shows, these models are competent text completion models and can carry out other tasks such as spelling correction, classification, or language translation. This is actually very remarkable given that GPT models are pretrained on a relatively simple next-word prediction task, as depicted in figure 1.7.

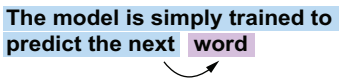

Figure 1.7 In the next-word prediction pretraining task for GPT models, the system learns to predict the upcoming word in a sentence by looking at the words that have come before it. This approach helps the model understand how words and phrases typically fit together in language, forming a foundation that can be applied to various other tasks.

The next-word prediction task is a form of self-supervised learning, which is a form of self-labeling. This means that we don't need to collect labels for the training data explicitly but can use the structure of the data itself: we can use the next word in a sentence or document as the label that the model is supposed to predict. Since this next-word prediction task allows us to create labels "on the fly," it is possible to use massive unlabeled text datasets to train LLMs.

Compared to the original transformer architecture we covered in section 1.4, the general GPT architecture is relatively simple. Essentially, it's just the decoder part without the encoder (figure 1.8). Since decoder-style models like GPT generate text by predicting text one word at a time, they are considered a type of *autoregressive* model. Autoregressive models incorporate their previous outputs as inputs for future

predictions. Consequently, in GPT, each new word is chosen based on the sequence that precedes it, which improves the coherence of the resulting text.

Architectures such as GPT-3 are also significantly larger than the original transformer model. For instance, the original transformer repeated the encoder and decoder blocks six times. GPT-3 has 96 transformer layers and 175 billion parameters in total.

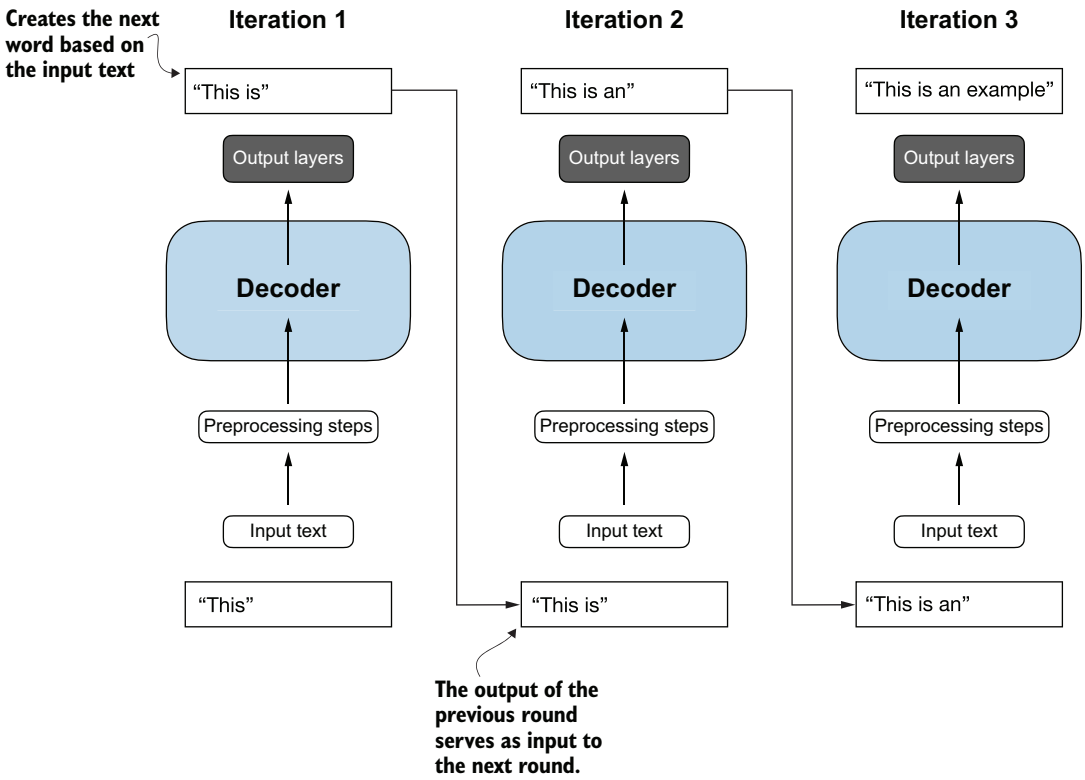

Figure 1.8 The GPT architecture employs only the decoder portion of the original transformer. It is designed for unidirectional, left-to-right processing, making it well suited for text generation and next-word prediction tasks to generate text in an iterative fashion, one word at a time.

GPT-3 was introduced in 2020, which, by the standards of deep learning and large language model development, is considered a long time ago. However, more recent architectures, such as Meta's Llama models, are still based on the same underlying concepts, introducing only minor modifications. Understanding GPT remains highly relevant. I focus on implementing the prominent architecture behind GPT and provide pointers to specific tweaks used by alternative LLMs.

Although the original transformer model, consisting of encoder and decoder blocks, was explicitly designed for language translation, GPT models—despite their larger yet

simpler decoder-only architecture aimed at next-word prediction—are also capable of performing translation tasks. This capability was initially unexpected to researchers, as it emerged from a model primarily trained on a next-word prediction task, which is a task that did not specifically target translation.

The ability to perform tasks that the model wasn't explicitly trained to perform is called an *emergent behavior*. This capability isn't explicitly taught during training but emerges as a natural consequence of the model's exposure to vast quantities of multilingual data in diverse contexts. The fact that GPT models can "learn" the translation patterns between languages and perform translation tasks even though they weren't specifically trained for it demonstrates the benefits and capabilities of these large-scale, generative language models. We can perform diverse tasks without using diverse models for each.

1.7 Building a large language model

Now that we've laid the groundwork for understanding LLMs, let's code one from scratch. We will take the fundamental idea behind GPT as a blueprint and tackle this in three stages, as outlined in figure 1.9.

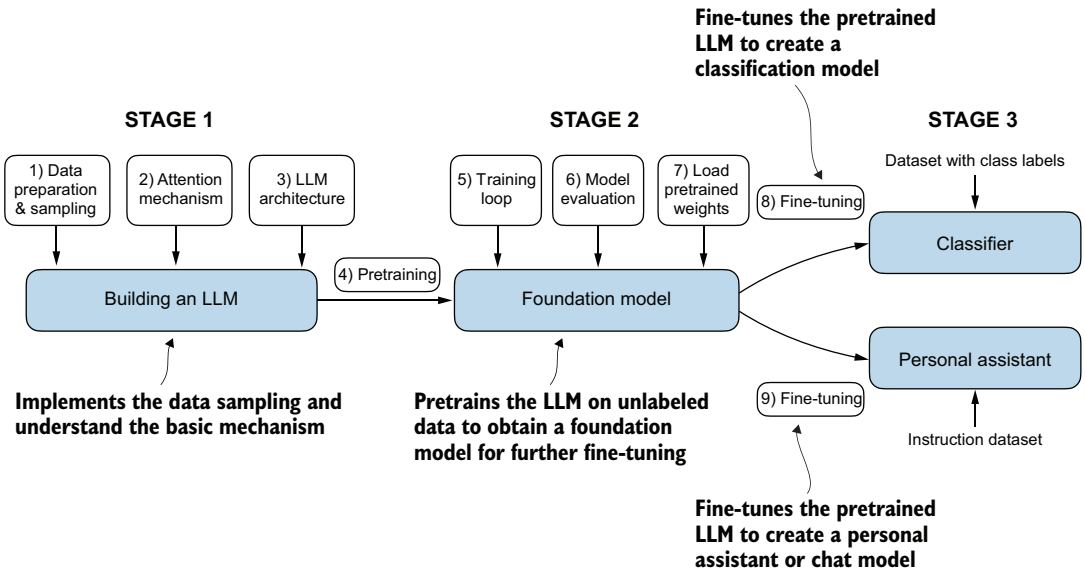

Figure 1.9 The three main stages of coding an LLM are implementing the LLM architecture and data preparation process (stage 1), pretraining an LLM to create a foundation model (stage 2), and fine-tuning the foundation model to become a personal assistant or text classifier (stage 3).