For the sake of clarity, we reproduce here the algebraic manipulations done in class.
We consider state $|y\rangle$, consisting on n qubits, that is $|y\rangle = |y_1 \dots y_n\rangle = |y_1\rangle \otimes \cdots \otimes |y_n\rangle$, which gives us $2^n \equiv N$ basis states.
The Quantum Fourier Transform is the change of basis:

$$\underbrace{|\tilde{x}\rangle}_{\text{Fourier basis}} \equiv QFT \underbrace{|x\rangle}_{\text{Computational basis}} = \frac{1}{\sqrt{N}} \sum_{y=0}^{N-1} e^{\frac{2\pi i x y}{N}} |y\rangle \tag{1}$$

We now plug in y written in the binary representation $y = \sum_{k=0}^{n} y_k 2^{n-k}$:

$$\frac{1}{\sqrt{N}} \sum_{y=0}^{N-1} e^{\frac{2\pi i x}{2^n} \sum_{k=0}^{n} y_k 2^{n-k}} |y\rangle \overset{\text{simpler}}{=} \frac{1}{\sqrt{N}} \sum_{y=0}^{N-1} e^{2\pi i x \sum_{k=0}^{n} y_k 2^{-k}} |y\rangle$$

A summation on the exponent turns into a product:

$$\frac{1}{\sqrt{N}} \sum_{y=0}^{N-1} \prod_{k=0}^{n} e^{2\pi i x y_k 2^{-k}} |y_1 \dots y_n\rangle$$

Now the key idea is that we can split the summation into n summations, one for each qubit with possible values $\{0, 1\}$:

$$\frac{1}{\sqrt{N}} \sum_{y_1=0}^{1} \cdots \sum_{y_n=0}^{1} \prod_{k=0}^{n} e^{2\pi i x y_k 2^{-k}} |y_1 \dots y_n\rangle \tag{2}$$

Let us work out in detail using (2) for the case of two qubits (n=2):

$$\frac{1}{2} \sum_{y_1=0}^{1} \sum_{y_2=0}^{1} \prod_{k=1}^{2} e^{2\pi i x y_k 2^{-k}} |y_1 y_2\rangle = \frac{1}{2} \sum_{y_1=0}^{1} \sum_{y_2=0}^{1} e^{2\pi i x [\frac{y_1}{2} + \frac{y_2}{2^2}]} |y_1 y_2\rangle = \frac{1}{2} \sum_{y_1=0}^{1} e^{2\pi i x y_1/2} \left[e^{2\pi i x 0/2^2} |y_1 0\rangle + e^{2\pi i x 1/2^2} |y_1 1\rangle \right]$$

The final expression we get can be easily recast as a tensor product:

$$\frac{1}{2} \left[|00\rangle + e^{2\pi i x/2^2} |01\rangle + e^{2\pi x i/2} |10\rangle + e^{2\pi i x [\frac{1}{2} + \frac{1}{2^2}]} |11\rangle \right] = \frac{1}{2} \left(|0\rangle + e^{2\pi i x/2^2} |1\rangle \right) \otimes \left(|0\rangle + e^{2\pi i x/2} |1\rangle \right)$$

With a bit of work, we get an idea of the structure of the transform for the general case (n qubits) by performing the summation for some qubits:

First:

$$\frac{1}{\sqrt{N}} \sum_{y_1=0}^{1} \cdots \sum_{y_{n-1}=0}^{1} \prod_{k=0}^{n-1} e^{2\pi i x y_k 2^{-k}} \left[|y_1 \dots y_{n-1} 0\rangle + e^{2\pi i x/2^n} |y_1 \dots y_{n-1} 1\rangle \right]$$

Second:

$$\frac{1}{\sqrt{N}} \sum_{y_1=0}^{1} \cdots \sum_{y_{n-2}=0}^{1} \prod_{k=0}^{n-2} e^{\frac{2\pi i x y_k}{2^k}} \left[|y_1 \dots y_{n-2} 00\rangle + e^{2\pi i x/2^n} |y_1 \dots y_{n-2} 01\rangle + e^{2\pi i x/2^{n-1}} |y_1 \dots y_{n-2} 10\rangle + e^{2\pi i x [\frac{1}{2^{n-1}} + \frac{1}{2^n}]} |y_1 \dots y_{n-2} 11\rangle \right]$$

and so on. We see we get 2^n states in this fashion, whose coefficients we know how to write down. For example, some of them are:

$$|0 \dots 0\rangle + \cdots + e^{2\pi i x/2^{n-2}} |0 \dots 0100\rangle + e^{2\pi i x [\frac{1}{2^{n-2}} + \frac{1}{2^n}]} |0 \dots 0101\rangle + \cdots + e^{2\pi i x/2} |10 \dots 0\rangle + \cdots + e^{2\pi i x [\sum_k \frac{1}{2^k}]} |1 \dots 1\rangle$$

Finally, convince yourself that you can write those terms as n tensor products:

$$\frac{1}{\sqrt{N}} (|0\rangle + e^{2\pi i \frac{x}{2^1}} |1\rangle) \otimes \overbrace{\cdots}^{n} \otimes (|0\rangle + e^{2\pi i \frac{x}{2^n}} |1\rangle) = \frac{1}{\sqrt{N}} \bigotimes_{l=1}^{n} [|0\rangle + e^{2\pi x 2^{-l} i} |1\rangle]. \tag{3}$$