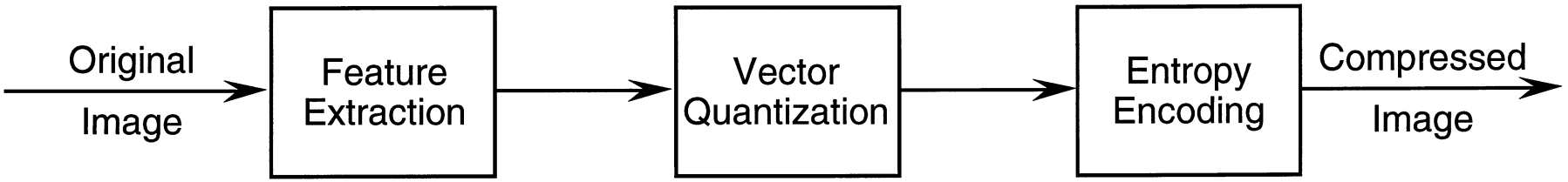
Key Elements of an Image Encoder



Entropy Encoding

- Convert stream of prototype vectors to a stream of binary codewords
- Objective is to minimize average number of binary digits per prototype vector
- Shannon showed that theoretical minimum is given by source entropy
- Process is generally lossless

Entropy Encoding (cont.)

- **Source alphabet (prototype vectors)** $a_1, \ldots, a_M$
- **Source probability distribution** $p_1, \ldots, p_M$
- **Source entropy**

$$H = -\sum_{m=1}^{M} p_m \log_2(p_m) \quad \text{bits / source symbol}$$

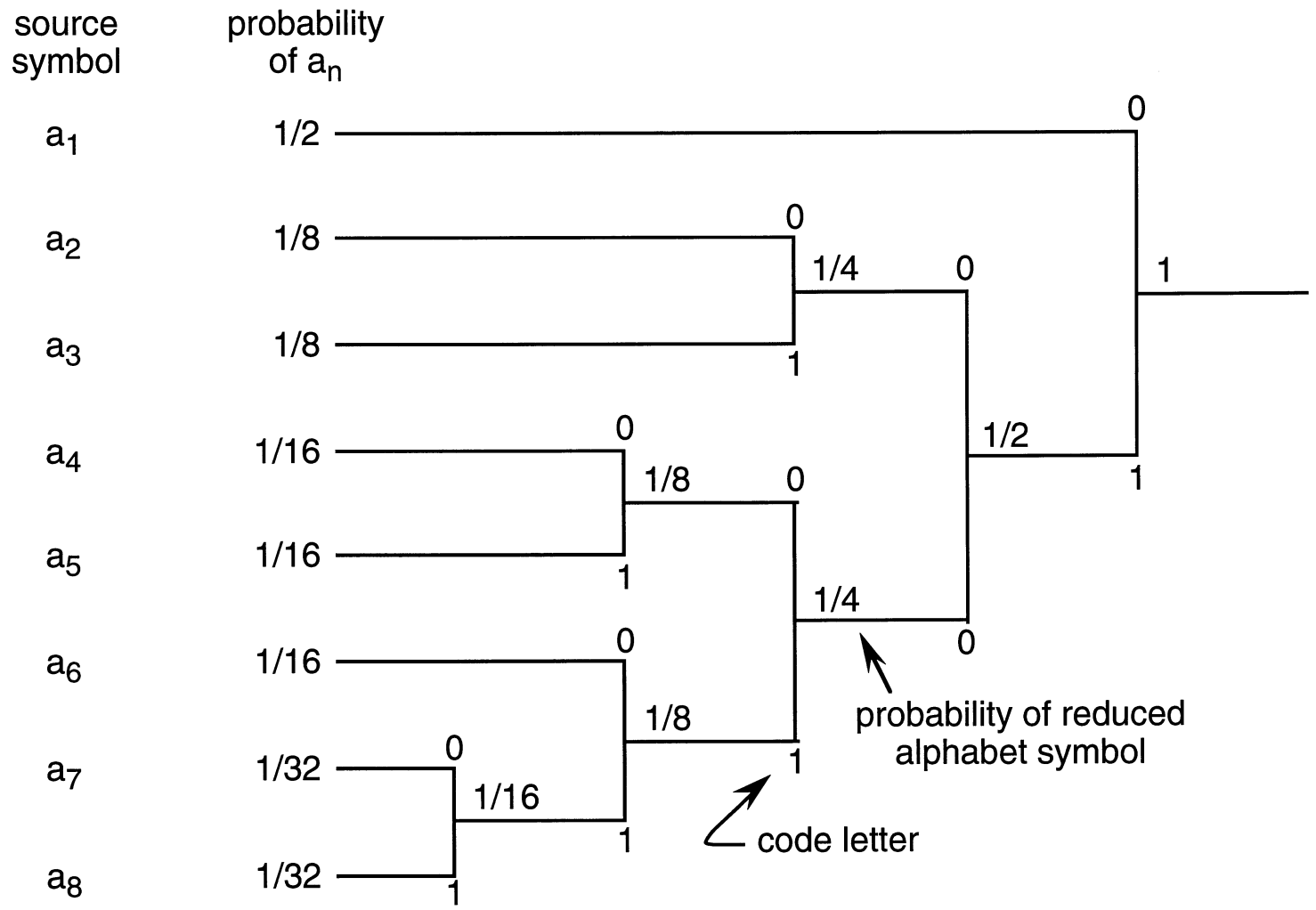
- **Codeword lengths** $l_1, \ldots, l_M$
- **Average codeword length**

$$\bar{l} = \sum_{m=1}^{M} p_m l_m \quad \text{binary digits / source symbol}$$

Entropy Coding Example

Source Symbol	Probability	Fixed-Length Code	Huffman Code
a_1	1/2	000	0
a_2	1/8	001	100
a_3	1/8	010	101
a_4	1/16	011	1100
a_5	1/16	100	1101
a_6	1/16	101	1110
a_7	1/32	110	11110
a_8	1/32	111	11111
	$H = 2.31$ bits / source symbol	$\bar{l} = 3$ binary digits / source symbol	$\bar{l} = 2.31$ binary digits / source symbol

Huffman Code



Huffman Code (cont.)

- **Huffman code is optimum variable-length code**
- **Rate for Huffman code will always be within 1 binary digit of source entropy**
- **By encoding source symbols in blocks of length L, can get to within 1/L binary digits of source entropy**
- **Huffman code satisfies prefix condition - no codeword is the prefix of another $\Rightarrow$ no markers are needed to separate codewords**
- **JPEG standard for lossy coding specifies entropy coding using either Huffman code or arithmetic code**

Summary of JPEG Picture Quality

- For color images with moderately complex scenes

Rate (bits/pixel)	Quality
0.25 - 0.50	Good to Very Good
0.50 - 0.75	Moderate to Good
0.75 - 1.5	Excellent
1.5 - 2.0	Indistinguishable from Original