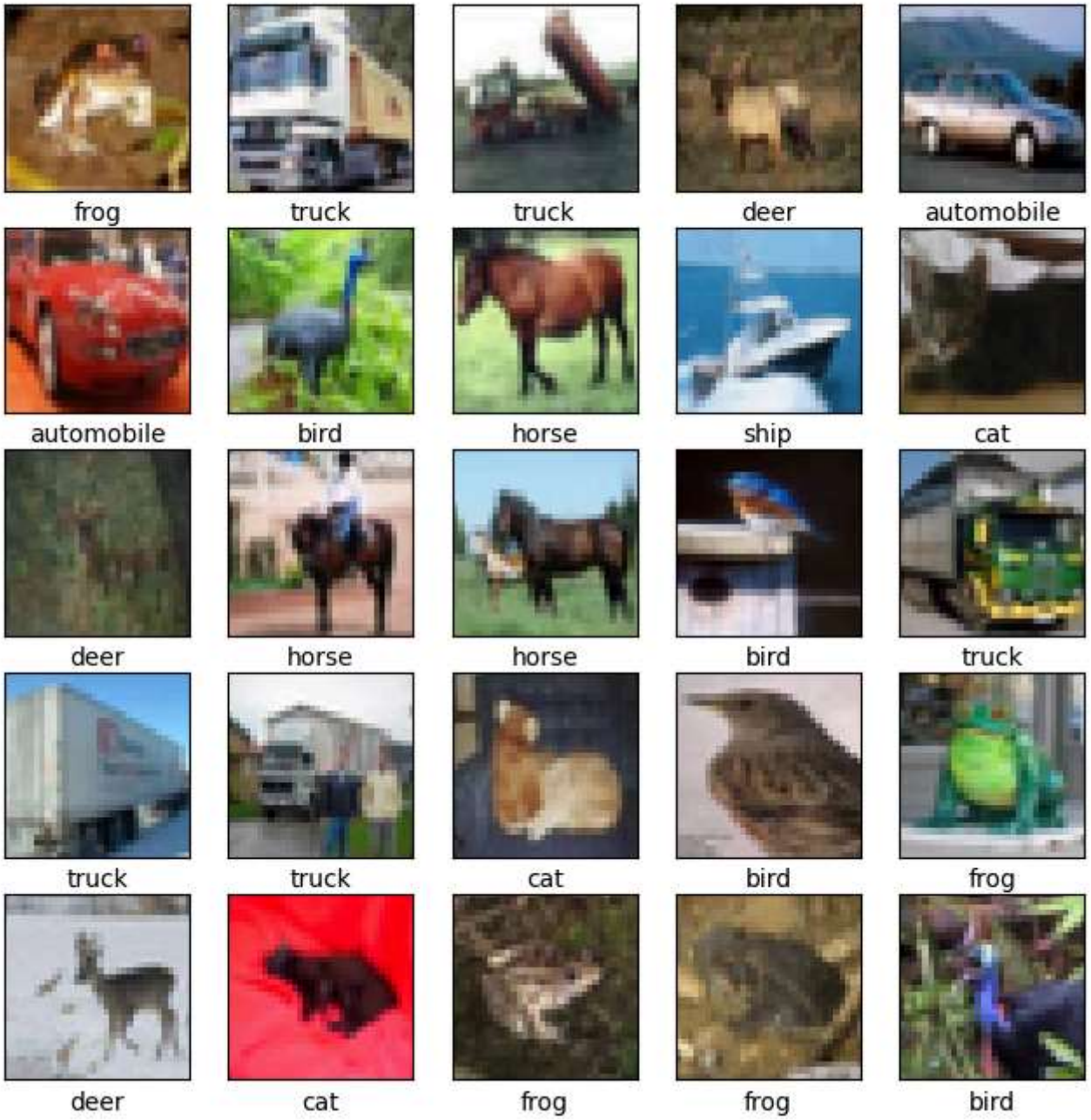
In [1]:
```
import tensorflow as tf
from tensorflow.keras import layers, models
from tensorflow.keras.datasets import cifar10
import matplotlib.pyplot as plt

# Load dataset
(x_train, y_train), (x_test, y_test) = cifar10.load_data()

# Normalize pixel values
x_train, x_test = x_train / 255.0, x_test / 255.0
```

In [2]:
```
class_names = ['airplane', 'automobile', 'bird', 'cat', 'deer',
               'dog', 'frog', 'horse', 'ship', 'truck']

plt.figure(figsize=(8,8))
for i in range(25):
    plt.subplot(5,5,i+1)
    plt.xticks([])
    plt.yticks([])
    plt.grid(False)
    plt.imshow(x_train[i])
    # The CIFAR labels happen to be arrays,
    #which is why we need the extra index
    plt.xlabel(class_names[y_train[i][0]])
plt.show()
```



In [3]:
```
from tensorflow.keras.preprocessing.image import ImageDataGenerator
```

```
datagen = ImageDataGenerator(
    rotation_range=15,
    width_shift_range=0.1,
    height_shift_range=0.1,
    horizontal_flip=True,
)
datagen.fit(x_train)
```

In [4]:
```
model = models.Sequential([
    layers.Conv2D(32, (3,3), padding='same', activation='relu', input_shape=(32,32,3)),
    layers.BatchNormalization(),
    layers.Conv2D(32, (3,3), activation='relu'),
    layers.BatchNormalization(),
    layers.MaxPooling2D(pool_size=(2,2)),
    layers.Dropout(0.25),

    layers.Conv2D(64, (3,3), padding='same', activation='relu'),
    layers.BatchNormalization(),
    layers.Conv2D(64, (3,3), activation='relu'),
    layers.BatchNormalization(),
    layers.MaxPooling2D(pool_size=(2,2)),
    layers.Dropout(0.35),

    layers.Flatten(),
    layers.Dense(128, activation='relu'),
    layers.BatchNormalization(),
    layers.Dropout(0.5),
    layers.Dense(10, activation='softmax')
])
```

```
c:\Users\KAUSHIK\AppData\Local\Programs\Python\Python312\Lib\site-packages\keras\src\layers\convolutional\base_conv.py:113: UserWarning: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

In [5]:
```
model.summary()
```

Model: "sequential"

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 32, 32, 32)	896
batch_normalization (BatchNormalization)	(None, 32, 32, 32)	128
conv2d_1 (Conv2D)	(None, 30, 30, 32)	9,248
batch_normalization_1 (BatchNormalization)	(None, 30, 30, 32)	128
max_pooling2d (MaxPooling2D)	(None, 15, 15, 32)	0
dropout (Dropout)	(None, 15, 15, 32)	0
conv2d_2 (Conv2D)	(None, 15, 15, 64)	18,496
batch_normalization_2 (BatchNormalization)	(None, 15, 15, 64)	256
conv2d_3 (Conv2D)	(None, 13, 13, 64)	36,928
batch_normalization_3 (BatchNormalization)	(None, 13, 13, 64)	256
max_pooling2d_1 (MaxPooling2D)	(None, 6, 6, 64)	0
dropout_1 (Dropout)	(None, 6, 6, 64)	0
flatten (Flatten)	(None, 2304)	0
dense (Dense)	(None, 128)	295,040
batch_normalization_4 (BatchNormalization)	(None, 128)	512
dropout_2 (Dropout)	(None, 128)	0
dense_1 (Dense)	(None, 10)	1,290

Total params: 363,178 (1.39 MB)

Trainable params: *362,538 (1.38 MB)*

Non-trainable params: *640 (2.50 KB)*

In [6]:
```
model.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])
```

In [7]:
```
from tensorflow.keras.callbacks import EarlyStopping, ReduceLROnPlateau

early_stop = EarlyStopping(patience=10, restore_best_weights=True)
lr_reduce = ReduceLROnPlateau(monitor='val_accuracy', factor=0.5, patience=3)
```

In [8]:
```
layers.BatchNormalization()
```

Out[8]:
```
<BatchNormalization name=batch_normalization_5, built=False>
```

In [25]:
```
# Further reduce batch size to lower memory usage
history = model.fit(datagen.flow(x_train, y_train, batch_size=25),
                    epochs=10,
                    validation_data=(x_test, y_test),
                    callbacks=[early_stop, lr_reduce])
```

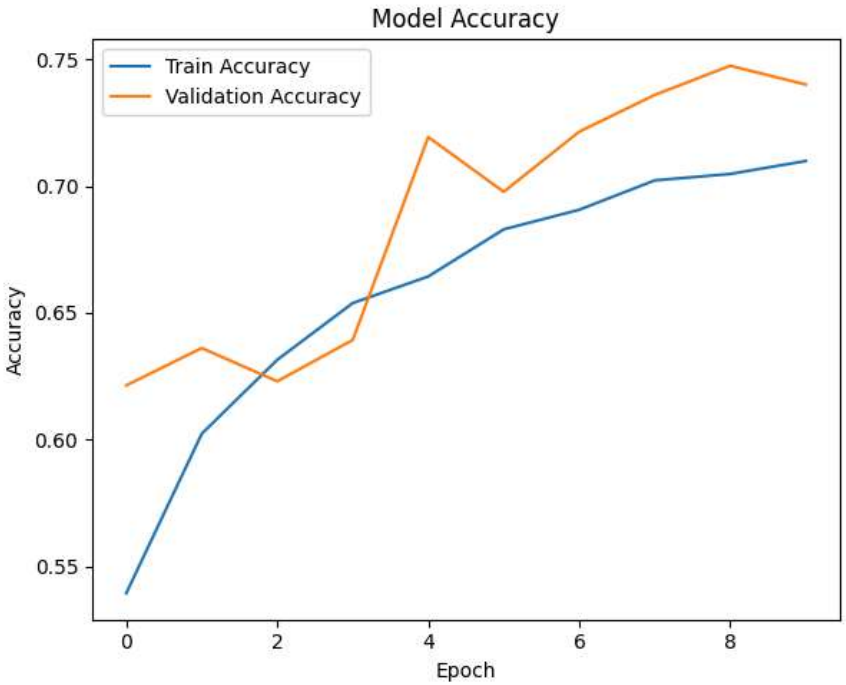
```
Epoch 1/10
2000/2000 ━━━━━━━━━━━━━━━━━━━━ 118s 59ms/step - accuracy: 0.5185 - loss: 1.3498 - val_accuracy: 0.6214 - val_loss: 1.
0810 - learning_rate: 0.0010
Epoch 2/10
2000/2000 ━━━━━━━━━━━━━━━━━━━━ 121s 60ms/step - accuracy: 0.5909 - loss: 1.1645 - val_accuracy: 0.6361 - val_loss: 1.
0489 - learning_rate: 0.0010
Epoch 3/10
2000/2000 ━━━━━━━━━━━━━━━━━━━━ 119s 60ms/step - accuracy: 0.6285 - loss: 1.0660 - val_accuracy: 0.6230 - val_loss: 1.
1251 - learning_rate: 0.0010
Epoch 4/10
2000/2000 ━━━━━━━━━━━━━━━━━━━━ 120s 60ms/step - accuracy: 0.6534 - loss: 1.0002 - val_accuracy: 0.6393 - val_loss: 1.
0786 - learning_rate: 0.0010
Epoch 5/10
2000/2000 ━━━━━━━━━━━━━━━━━━━━ 120s 60ms/step - accuracy: 0.6587 - loss: 0.9648 - val_accuracy: 0.7193 - val_loss: 0.
8217 - learning_rate: 0.0010
Epoch 6/10
2000/2000 ━━━━━━━━━━━━━━━━━━━━ 120s 60ms/step - accuracy: 0.6827 - loss: 0.9241 - val_accuracy: 0.6977 - val_loss: 0.
8868 - learning_rate: 0.0010
Epoch 7/10
2000/2000 ━━━━━━━━━━━━━━━━━━━━ 122s 61ms/step - accuracy: 0.6918 - loss: 0.8932 - val_accuracy: 0.7214 - val_loss: 0.
7926 - learning_rate: 0.0010
Epoch 8/10
2000/2000 ━━━━━━━━━━━━━━━━━━━━ 123s 61ms/step - accuracy: 0.6965 - loss: 0.8825 - val_accuracy: 0.7359 - val_loss: 0.
7511 - learning_rate: 0.0010
Epoch 9/10
2000/2000 ━━━━━━━━━━━━━━━━━━━━ 124s 62ms/step - accuracy: 0.7044 - loss: 0.8589 - val_accuracy: 0.7474 - val_loss: 0.
7361 - learning_rate: 0.0010
Epoch 10/10
2000/2000 ━━━━━━━━━━━━━━━━━━━━ 127s 64ms/step - accuracy: 0.7133 - loss: 0.8386 - val_accuracy: 0.7400 - val_loss: 0.
7468 - learning_rate: 0.0010
```

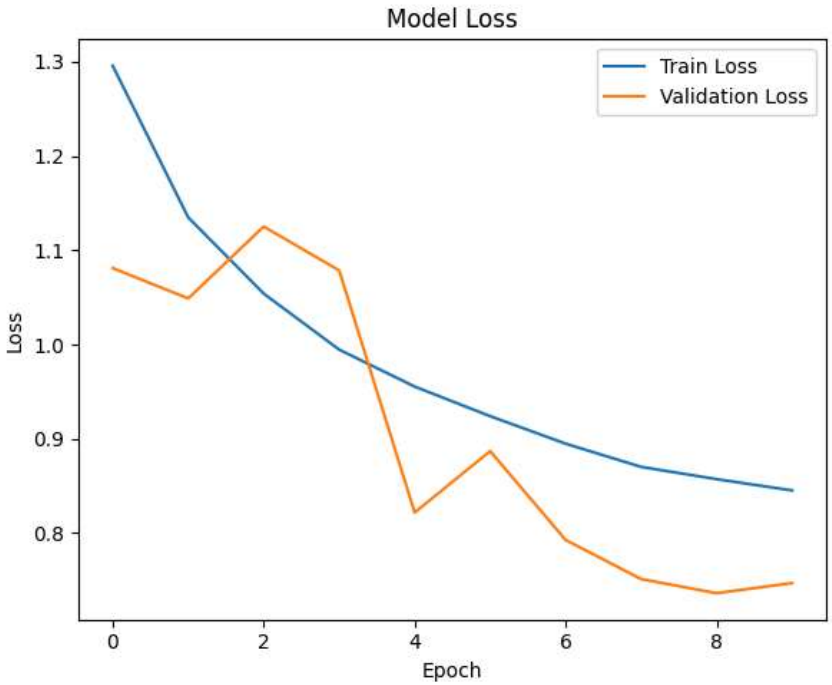
In [26]:
```python
test_loss, test_acc = model.evaluate(x_test, y_test, verbose=2)
print("Test Accuracy:", test_acc)
```

```
313/313 - 4s - 12ms/step - accuracy: 0.7474 - loss: 0.7361
Test Accuracy: 0.7473999857902527
Test Accuracy: 0.7473999857902527
```

In [27]:
```python
import matplotlib.pyplot as plt

# Check if 'history' is defined
if 'history' not in locals():
```

```
        raise NameError("The variable 'history' is not defined. Please run the cell where model.fit() is called.")

# Plot training & validation accuracy and loss values
plt.figure(figsize=(12, 5))

plt.subplot(1, 2, 1)
plt.plot(history.history['accuracy'], label='Train Accuracy')
plt.plot(history.history['val_accuracy'], label='Validation Accuracy')
plt.title('Model Accuracy')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.legend()

plt.subplot(1, 2, 2)
plt.plot(history.history['loss'], label='Train Loss')
plt.plot(history.history['val_loss'], label='Validation Loss')
plt.title('Model Loss')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.legend()

plt.tight_layout()
plt.show()
```





In [36]:
```python
# Make predictions
predictions = model.predict(x_test)
# Display predictions for the first 5 test images
for i in range(67,80):
    plt.imshow(x_test[i])
    plt.title(f"Predicted: {class_names[predictions[i].argmax()]}, Actual: {class_names[y_test[i][0]]}")
    plt.axis('off')
    plt.show()
# Save the model
model.save('cifar10_model.h5')
# Load the model (if needed)
# loaded_model = models.load_model('cifar10_model.h5')
# loaded_model.summary()
# Make predictions with the loaded model
```

```
313/313 ━━━━━━━━━━━━━━━━━━━━ 4s 13ms/step
```

Predicted: bird, Actual: bird

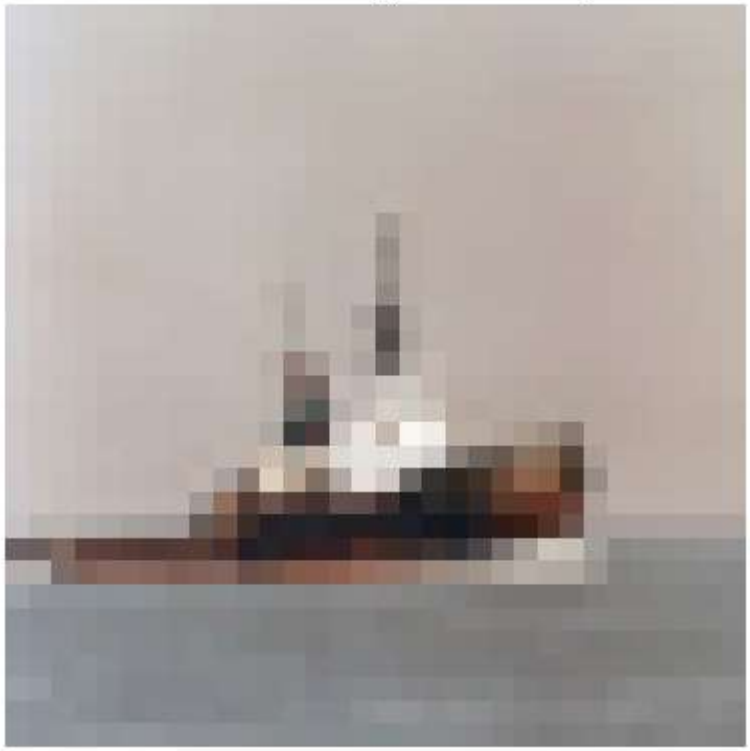
Predicted: cat, Actual: cat

Predicted: horse, Actual: horse


Predicted: bird, Actual: bird

Predicted: frog, Actual: frog

Predicted: ship, Actual: ship

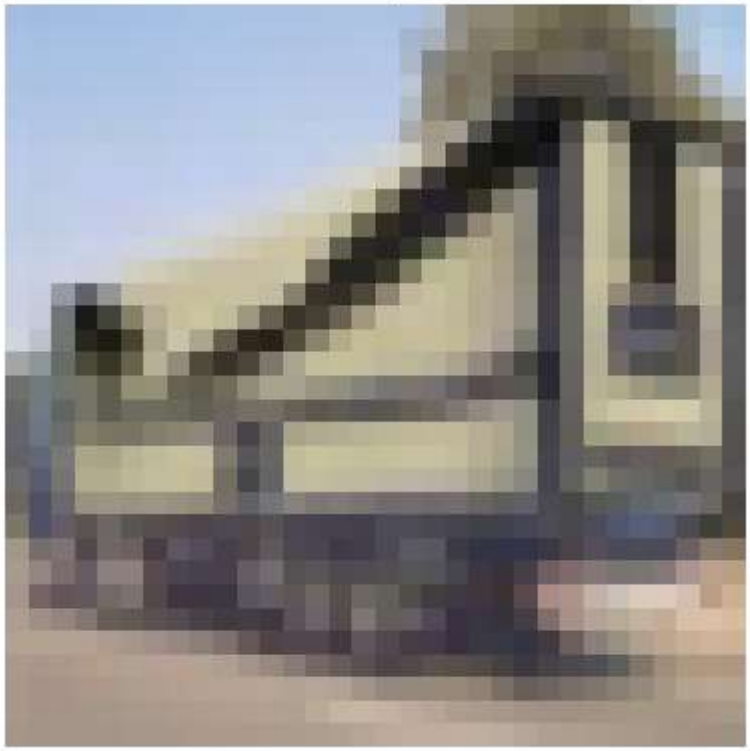


Predicted: ship, Actual: ship

Predicted: airplane, Actual: airplane

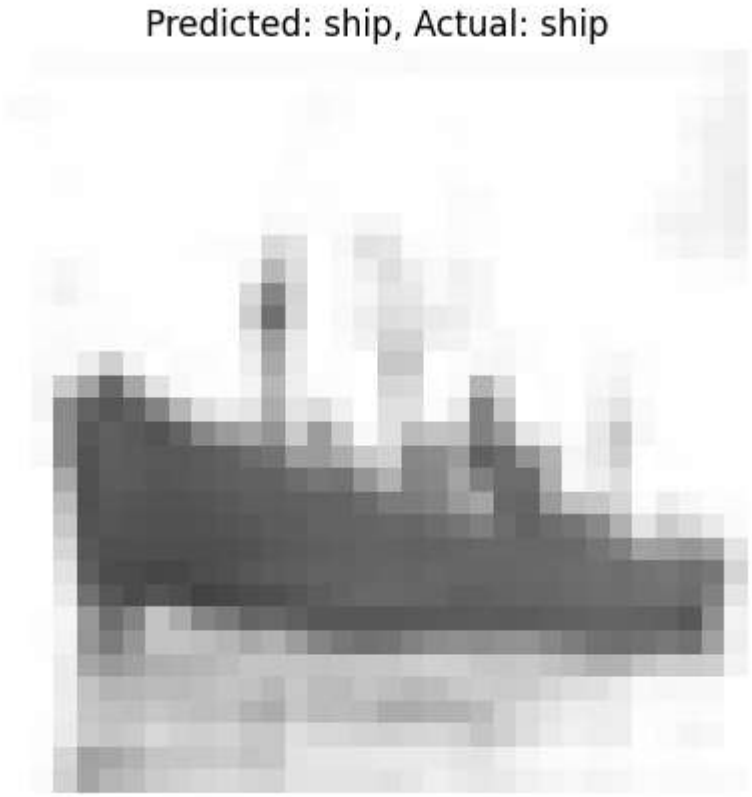
Predicted: bird, Actual: bird

Predicted: truck, Actual: truck



Predicted: cat, Actual: cat


Predicted: cat, Actual: cat




```
WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or `keras.saving.save_model(model)`. This file format is considered legacy. We recommend using instead the native Keras format, e.g. `model.save('my_model.keras')` or `keras.saving.save_model(model, 'my_model.keras')`.
```