```
!pip install keras keras-hub --upgrade -q

━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 0.0/1.4 MB ? eta -:--:--
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 1.4/1.4 MB 43.2 MB/s eta
0:00:01 ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 1.4/1.4 MB 28.9 MB/s
eta 0:00:00
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 0.0/947.9 kB ? eta -:--:--
━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 947.9/947.9 kB 56.4 MB/s eta
0:00:00
ERROR: pip's dependency resolver does not currently take into account
all the packages that are installed. This behaviour is the source of
the following dependency conflicts.
keras-nlp 0.21.1 requires keras-hub==0.21.1, but you have keras-hub
0.22.2 which is incompatible.

import os
os.environ["KERAS_BACKEND"] = "jax" # Or "tensorflow" or "torch"

import keras
from keras import layers
import keras_hub
from keras.utils import image_dataset_from_directory
import numpy as np
import matplotlib.pyplot as plt
import pathlib
import shutil
import zipfile
import pandas as pd
import random
import tensorflow as tf

zip_file_path = "/content/cats_vs_dogs_small.zip"

if os.path.exists(zip_file_path):
    print(f"Found {zip_file_path}, now extracting...")
    with zipfile.ZipFile(zip_file_path, "r") as zip_ref:
        zip_ref.extractall("/content/")
    print(" Data extracted successfully.")
else:
    print(f" '{zip_file_path}' not found. Please upload the zipped
folder first.")
    raise FileNotFoundError(f"'{zip_file_path}' not found.")

# Define the base directory path after unzipping
base_dir = pathlib.Path("/content/cats_vs_dogs_small")
source_train_dir = base_dir / "train"
source_val_dir = base_dir / "validation"
source_test_dir = base_dir / "test"
```

```
if base_dir.exists():
    num_train = len(list(source_train_dir.glob("*/*.jpg")))
    num_val = len(list(source_val_dir.glob("*/*.jpg")))
    num_test = len(list(source_test_dir.glob("*/*.jpg")))
    print(f"\nData verification successful!")
    print(f"  Total original training images found:   {num_train}")
    print(f"  Total original validation images found: {num_val}")
    print(f"  Total original test images found:       {num_test}")
else:
    print(f" Base directory not found at {base_dir}")
    raise FileNotFoundError("Base directory not found after
unzipping.")
```

```
Found /content/cats_vs_dogs_small.zip, now extracting...
 Data extracted successfully.
```

```
Data verification successful!
  Total original training images found:   2000
  Total original validation images found: 1000
  Total original test images found:       1000
```

```
def create_experimental_training_set(source_dir, dest_dir,
train_size_per_class):

    if dest_dir.exists():
        shutil.rmtree(dest_dir)
    os.makedirs(dest_dir)

    for category in ("cats", "dogs"):
        os.makedirs(dest_dir / category, exist_ok=True)
        fnames = [f for f in os.listdir(source_dir / category) if
f.endswith('.jpg')]
        random.shuffle(fnames)

        num_to_copy = min(train_size_per_class, len(fnames))
        for i in range(num_to_copy):
            src = source_dir / category / fnames[i]
            dst = dest_dir / category / fnames[i]
            shutil.copyfile(src, dst)
    print(f"Created experimental training set with {num_to_copy}
images per class.")

def create_experimental_validation_set(source_dir, dest_dir,
val_size_per_class):

    if dest_dir.exists():
        shutil.rmtree(dest_dir)
    os.makedirs(dest_dir)

    for category in ("cats", "dogs"):
        os.makedirs(dest_dir / category, exist_ok=True)
        fnames = [f for f in os.listdir(source_dir / category) if
f.endswith('.jpg')]
        random.shuffle(fnames)

        num_to_copy = min(val_size_per_class, len(fnames))
        for i in range(num_to_copy):
            src = source_dir / category / fnames[i]
            dst = dest_dir / category / fnames[i]
            shutil.copyfile(src, dst)
    print(f"Created experimental validation set with {num_to_copy}
images per class.")

def create_experimental_test_set(source_dir, dest_dir,
test_size_per_class):

    if dest_dir.exists():
        shutil.rmtree(dest_dir)
    os.makedirs(dest_dir)

    for category in ("cats", "dogs"):
        os.makedirs(dest_dir / category, exist_ok=True)
        fnames = [f for f in os.listdir(source_dir / category) if
f.endswith('.jpg')]
        random.shuffle(fnames)

        num_to_copy = min(test_size_per_class, len(fnames))
        for i in range(num_to_copy):
            src = source_dir / category / fnames[i]
            dst = dest_dir / category / fnames[i]
            shutil.copyfile(src, dst)
    print(f"Created experimental test set with {num_to_copy} images
per class.")


data_augmentation_layer = keras.Sequential(
    [
        layers.RandomFlip("horizontal"),
        layers.RandomRotation(0.1),
        layers.RandomZoom(0.2),
    ],
    name="data_augmentation"
)

def build_scratch_model(input_shape=(180, 180, 3), dropout_rate=0.25):
    inputs = keras.Input(shape=input_shape)
    # Augmentation as a layer
    x = data_augmentation_layer(inputs)
    # Rescaling
    x = layers.Rescaling(1.0 / 255)(x)
    # Rest of the model
    x = layers.Conv2D(32, 3, activation="relu")(x); x =
layers.MaxPooling2D(2)(x)
    x = layers.Conv2D(64, 3, activation="relu")(x); x =
layers.MaxPooling2D(2)(x)
    x = layers.Conv2D(128, 3, activation="relu")(x); x =
layers.MaxPooling2D(2)(x)
    x = layers.Conv2D(256, 3, activation="relu")(x); x =
layers.MaxPooling2D(2)(x)
    x = layers.Conv2D(512, 3, activation="relu")(x); x =
layers.GlobalAveragePooling2D()(x)
    x = layers.Dropout(dropout_rate)(x)
    outputs = layers.Dense(1, activation="sigmoid")(x)
    model = keras.Model(inputs=inputs, outputs=outputs)
    model.compile(loss="binary_crossentropy", optimizer="adam",
metrics=["accuracy"])
    return model

def build_pretrained_xception_model(trainable_base=False,
dropout_rate=0.25, input_shape=(180, 180, 3)):

    try:

        conv_base =
keras_hub.models.Backbone.from_preset("xception_41_imagenet",
trainable=trainable_base, name="xception_backbone")
        preprocessor =
keras_hub.layers.ImageConverter.from_preset("xception_41_imagenet",
image_size=(180, 180))

        inputs = keras.Input(shape=input_shape)
        # Apply augmentation first
        x = data_augmentation_layer(inputs)

        x = preprocessor(x)

        x = conv_base(x)
        # Add classification head
        x = layers.GlobalAveragePooling2D()(x)
        x = layers.Dense(256, activation="relu")(x)
        x = layers.Dropout(dropout_rate)(x)
        outputs = layers.Dense(1, activation="sigmoid")(x)
        model = keras.Model(inputs, outputs)


        optimizer = keras.optimizers.Adam()
        model.compile(loss="binary_crossentropy", optimizer=optimizer,
metrics=["accuracy"])
        return model, conv_base # Return conv_base for fine-tuning
access
```

```python
    except Exception as e:
        print(f"Error building pretrained Xception model: {e}")

        raise

def train_and_evaluate(model, train_dataset, val_dataset,
test_dataset, model_name, epochs=50):
    callbacks = [
        keras.callbacks.ModelCheckpoint(f"{model_name}.keras",
save_best_only=True, monitor="val_loss", verbose=0),
        keras.callbacks.EarlyStopping(monitor="val_loss", patience=10,
restore_best_weights=True, verbose=1) # Verbose early stopping
    ]
    print(f"Starting training for {model_name}...")
    history = model.fit(
        train_dataset,
        epochs=epochs,
        validation_data=val_dataset,
        callbacks=callbacks,
        verbose=1
    )
    print(f"Training finished for {model_name}. Loading best
model...")

    try:
        best_model = keras.models.load_model(f"{model_name}.keras")
        print("Best model loaded successfully.")
    except Exception as e:
        print(f"Could not load the best model from {model_name}.keras.
Using the model state from the end of training. Error: {e}")
        best_model = model

    print(f"Evaluating {model_name} on test data...")
    test_loss, test_acc = best_model.evaluate(test_dataset, verbose=0)
    print(f"Evaluation complete for {model_name}.")
    return {"history": history.history, "test_loss": test_loss,
"test_accuracy": test_acc}

def plot_training_history(history, title):
    if not history:
        print(f"No history data to plot for {title}")
        return
    acc = history.get("accuracy", [])
    val_acc = history.get("val_accuracy", [])
    loss = history.get("loss", [])
    val_loss = history.get("val_loss", [])

    if not acc or not val_acc or not loss or not val_loss:
        print(f"History data is incomplete for {title}. Cannot plot.")
        # print(f"Available keys: {history.keys()}") # Debugging line
        return

    epochs = range(1, len(acc) + 1)
    fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(14, 5))
    ax1.plot(epochs, acc, 'r--', label='Training accuracy');
ax1.plot(epochs, val_acc, 'b-', label='Validation accuracy')
    ax1.set_title(f'{title} - Accuracy'); ax1.legend()
    ax1.grid(True, alpha=0.3)
    ax2.plot(epochs, loss, 'r--', label='Training loss');
ax2.plot(epochs, val_loss, 'b-', label='Validation loss')
    ax2.set_title(f'{title} - Loss'); ax2.legend()
    ax2.grid(True, alpha=0.3)
    plt.tight_layout()
    plt.show()



batch_size = 32
image_size = (180, 180)


val_set_size_per_class = 250
test_set_size_per_class = 250

experimental_val_dir =
pathlib.Path(f"experimental_validation_{val_set_size_per_class*2}")
experimental_test_dir =
pathlib.Path(f"experimental_test_{test_set_size_per_class*2}")


print("Creating smaller validation and test sets as required by
instructions...")
create_experimental_validation_set(source_val_dir,
experimental_val_dir, val_set_size_per_class)
create_experimental_test_set(source_test_dir, experimental_test_dir,
test_set_size_per_class)


print("\nLoading fixed smaller validation and test datasets...")
validation_dataset = image_dataset_from_directory(
    experimental_val_dir,
    image_size=image_size,
    batch_size=batch_size
).cache().prefetch(buffer_size=tf.data.AUTOTUNE)

test_dataset = image_dataset_from_directory(
    experimental_test_dir,
    image_size=image_size,
    batch_size=batch_size
).cache().prefetch(buffer_size=tf.data.AUTOTUNE)

print(f"\nFixed smaller validation set loaded:
{tf.data.experimental.cardinality(validation_dataset)*batch_size}
images")
print(f"Fixed smaller test set loaded:
{tf.data.experimental.cardinality(test_dataset)*batch_size} images")
print("Fixed smaller validation and test datasets ready.")

Creating smaller validation and test sets as required by
instructions...
Created experimental validation set with 250 images per class.
Created experimental test set with 250 images per class.

Loading fixed smaller validation and test datasets...
Found 500 files belonging to 2 classes.
Found 500 files belonging to 2 classes.

Fixed smaller validation set loaded: 512 images
Fixed smaller test set loaded: 512 images
Fixed smaller validation and test datasets ready.

scratch_results = []
experimental_train_sizes = [500, 750, 1000] # 1000, 1500, 2000 total
training images



for train_size in experimental_train_sizes:
    print(f"\n{'='*20} Starting Scratch Training with {train_size*2}
samples {'='*20}")
    print(f"Training from scratch with an experimental set of
{train_size} samples per class")

    experimental_train_dir =
pathlib.Path(f"experimental_train_{train_size}")

    create_experimental_training_set(source_train_dir,
experimental_train_dir, train_size) #


    train_dataset = image_dataset_from_directory(
        experimental_train_dir,
        image_size=image_size,
        batch_size=batch_size
    )


    model_scratch = build_scratch_model(input_shape=(180, 180, 3)) #
    model_scratch.summary()
    prefetched_train_dataset =
train_dataset.cache().prefetch(buffer_size=tf.data.AUTOTUNE)


    results_scratch = train_and_evaluate(
        model=model_scratch,
        train_dataset=prefetched_train_dataset,
        val_dataset=validation_dataset,
        test_dataset=test_dataset,
        model_name=f"scratch_train_{train_size}",
        epochs=100
    )


    plot_training_history(results_scratch["history"], f"From Scratch -
{train_size*2} Training Samples")
    scratch_results.append({
        "train_size": train_size * 2,
        "val_accuracy":
max(results_scratch["history"].get("val_accuracy", [0])),
        "test_accuracy": results_scratch["test_accuracy"]
    })
    print(f"\nFinal Results (Scratch, Train Size {train_size*2}): Test
Accuracy = {results_scratch['test_accuracy']:.4f}")
```

```
==================== Starting Scratch Training with 1000 samples
====================
Training from scratch with an experimental set of 500 samples per
class
Created experimental training set with 500 images per class.
Found 1000 files belonging to 2 classes.

Model: "functional_1"

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━
━━━━━┓
┃ Layer (type)                     ┃ Output Shape           ┃
Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━
━━━━━┩
│ input_layer (InputLayer)         │ (None, 180, 180, 3)    │
0 │
├──────────────────────────────────┼────────────────────────┼──────────
─────┤
│ data_augmentation (Sequential)   │ (None, 180, 180, 3)    │
0 │
├──────────────────────────────────┼────────────────────────┼──────────
─────┤
│ rescaling (Rescaling)            │ (None, 180, 180, 3)    │
```

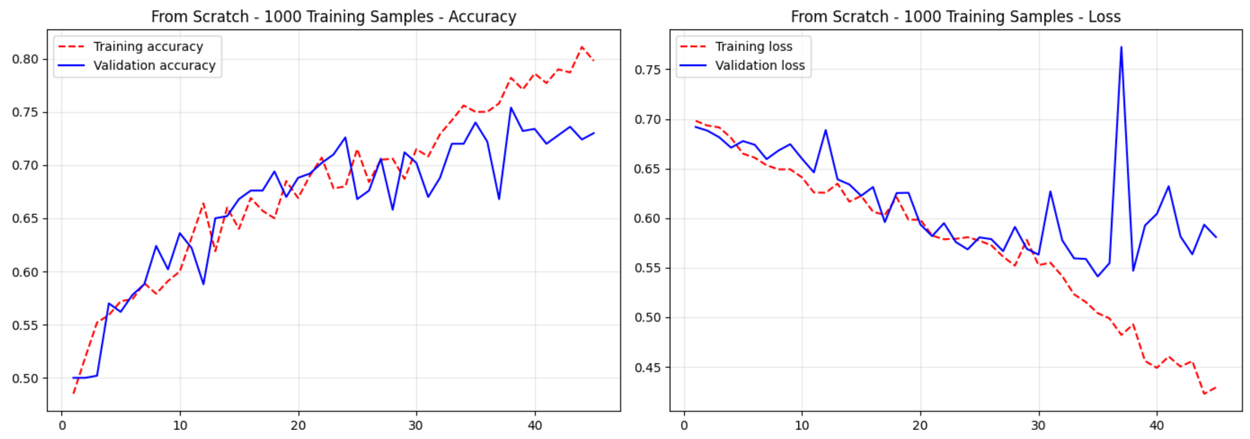
```
0 │
├──────────────────────────────────┼─────────────────────────┼──────────
───────┤
│ conv2d (Conv2D)                  │ (None, 178, 178, 32)    │
896 │
├──────────────────────────────────┼─────────────────────────┼──────────
───────┤
│ max_pooling2d (MaxPooling2D)     │ (None, 89, 89, 32)      │
0 │
├──────────────────────────────────┼─────────────────────────┼──────────
───────┤
│ conv2d_1 (Conv2D)                │ (None, 87, 87, 64)      │
18,496 │
├──────────────────────────────────┼─────────────────────────┼──────────
───────┤
│ max_pooling2d_1 (MaxPooling2D)   │ (None, 43, 43, 64)      │
0 │
├──────────────────────────────────┼─────────────────────────┼──────────
───────┤
│ conv2d_2 (Conv2D)                │ (None, 41, 41, 128)     │
73,856 │
├──────────────────────────────────┼─────────────────────────┼──────────
───────┤
│ max_pooling2d_2 (MaxPooling2D)   │ (None, 20, 20, 128)     │
0 │
├──────────────────────────────────┼─────────────────────────┼──────────
───────┤
│ conv2d_3 (Conv2D)                │ (None, 18, 18, 256)     │
295,168 │
├──────────────────────────────────┼─────────────────────────┼──────────
───────┤
│ max_pooling2d_3 (MaxPooling2D)   │ (None, 9, 9, 256)       │
0 │
├──────────────────────────────────┼─────────────────────────┼──────────
───────┤
│ conv2d_4 (Conv2D)                │ (None, 7, 7, 512)       │
1,180,160 │
├──────────────────────────────────┼─────────────────────────┼──────────
───────┤
│ global_average_pooling2d         │ (None, 512)             │
0 │
│ (GlobalAveragePooling2D)         │                         │
│
├──────────────────────────────────┼─────────────────────────┼──────────
───────┤
│ dropout (Dropout)                │ (None, 512)             │
0 │
├──────────────────────────────────┼─────────────────────────┼──────────
───────┤
```

```
│ dense (Dense)                   │ (None, 1)                 │
513 │
└─────────────────────────────────┴───────────────────────────┴────────────
──────┘

 Total params: 1,569,089 (5.99 MB)

 Trainable params: 1,569,089 (5.99 MB)

 Non-trainable params: 0 (0.00 B)

Starting training for scratch_train_500...
Epoch 1/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 45s 775ms/step - accuracy: 0.4850 - loss:
0.6981 - val_accuracy: 0.5000 - val_loss: 0.6919
Epoch 2/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 316ms/step - accuracy: 0.5190 - loss:
0.6933 - val_accuracy: 0.5000 - val_loss: 0.6881
Epoch 3/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 12s 349ms/step - accuracy: 0.5520 - loss:
0.6914 - val_accuracy: 0.5020 - val_loss: 0.6814
Epoch 4/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 324ms/step - accuracy: 0.5590 - loss:
0.6808 - val_accuracy: 0.5700 - val_loss: 0.6710
Epoch 5/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 9s 292ms/step - accuracy: 0.5720 - loss:
0.6650 - val_accuracy: 0.5620 - val_loss: 0.6776
Epoch 6/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 11s 324ms/step - accuracy: 0.5740 - loss:
0.6609 - val_accuracy: 0.5780 - val_loss: 0.6739
Epoch 7/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 326ms/step - accuracy: 0.5890 - loss:
0.6533 - val_accuracy: 0.5880 - val_loss: 0.6594
Epoch 8/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 323ms/step - accuracy: 0.5790 - loss:
0.6491 - val_accuracy: 0.6240 - val_loss: 0.6680
Epoch 9/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 326ms/step - accuracy: 0.5910 - loss:
0.6492 - val_accuracy: 0.6020 - val_loss: 0.6745
Epoch 10/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 20s 324ms/step - accuracy: 0.6000 - loss:
0.6410 - val_accuracy: 0.6360 - val_loss: 0.6597
Epoch 11/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 21s 322ms/step - accuracy: 0.6320 - loss:
0.6258 - val_accuracy: 0.6220 - val_loss: 0.6460
Epoch 12/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 20s 327ms/step - accuracy: 0.6640 - loss:
0.6256 - val_accuracy: 0.5880 - val_loss: 0.6888
Epoch 13/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 21s 333ms/step - accuracy: 0.6190 - loss:
```

```
0.6347 - val_accuracy: 0.6500 - val_loss: 0.6390
Epoch 14/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 327ms/step - accuracy: 0.6600 - loss:
0.6166 - val_accuracy: 0.6520 - val_loss: 0.6339
Epoch 15/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 11s 333ms/step - accuracy: 0.6400 - loss:
0.6224 - val_accuracy: 0.6680 - val_loss: 0.6225
Epoch 16/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 308ms/step - accuracy: 0.6690 - loss:
0.6064 - val_accuracy: 0.6760 - val_loss: 0.6313
Epoch 17/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 329ms/step - accuracy: 0.6570 - loss:
0.6031 - val_accuracy: 0.6760 - val_loss: 0.5959
Epoch 18/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 324ms/step - accuracy: 0.6500 - loss:
0.6210 - val_accuracy: 0.6940 - val_loss: 0.6253
Epoch 19/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 324ms/step - accuracy: 0.6850 - loss:
0.5983 - val_accuracy: 0.6700 - val_loss: 0.6255
Epoch 20/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 327ms/step - accuracy: 0.6690 - loss:
0.5985 - val_accuracy: 0.6880 - val_loss: 0.5937
Epoch 21/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 329ms/step - accuracy: 0.6900 - loss:
0.5824 - val_accuracy: 0.6920 - val_loss: 0.5818
Epoch 22/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 302ms/step - accuracy: 0.7070 - loss:
0.5786 - val_accuracy: 0.7020 - val_loss: 0.5949
Epoch 23/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 324ms/step - accuracy: 0.6780 - loss:
0.5791 - val_accuracy: 0.7100 - val_loss: 0.5759
Epoch 24/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 20s 327ms/step - accuracy: 0.6800 - loss:
0.5807 - val_accuracy: 0.7260 - val_loss: 0.5684
Epoch 25/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 327ms/step - accuracy: 0.7150 - loss:
0.5772 - val_accuracy: 0.6680 - val_loss: 0.5806
Epoch 26/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 326ms/step - accuracy: 0.6840 - loss:
0.5725 - val_accuracy: 0.6760 - val_loss: 0.5788
Epoch 27/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 328ms/step - accuracy: 0.7050 - loss:
0.5611 - val_accuracy: 0.7060 - val_loss: 0.5667
Epoch 28/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 20s 316ms/step - accuracy: 0.7060 - loss:
0.5521 - val_accuracy: 0.6580 - val_loss: 0.5911
Epoch 29/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 328ms/step - accuracy: 0.6870 - loss:
0.5781 - val_accuracy: 0.7120 - val_loss: 0.5691
```

```
Epoch 30/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 11s 330ms/step - accuracy: 0.7150 - loss:
0.5525 - val_accuracy: 0.7020 - val_loss: 0.5631
Epoch 31/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 326ms/step - accuracy: 0.7080 - loss:
0.5551 - val_accuracy: 0.6700 - val_loss: 0.6269
Epoch 32/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 21s 330ms/step - accuracy: 0.7290 - loss:
0.5415 - val_accuracy: 0.6880 - val_loss: 0.5776
Epoch 33/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 325ms/step - accuracy: 0.7420 - loss:
0.5231 - val_accuracy: 0.7200 - val_loss: 0.5594
Epoch 34/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 319ms/step - accuracy: 0.7560 - loss:
0.5153 - val_accuracy: 0.7200 - val_loss: 0.5588
Epoch 35/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 11s 331ms/step - accuracy: 0.7500 - loss:
0.5042 - val_accuracy: 0.7400 - val_loss: 0.5411
Epoch 36/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 20s 327ms/step - accuracy: 0.7500 - loss:
0.4988 - val_accuracy: 0.7220 - val_loss: 0.5547
Epoch 37/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 21s 331ms/step - accuracy: 0.7580 - loss:
0.4822 - val_accuracy: 0.6680 - val_loss: 0.7725
Epoch 38/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 11s 334ms/step - accuracy: 0.7820 - loss:
0.4928 - val_accuracy: 0.7540 - val_loss: 0.5469
Epoch 39/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 302ms/step - accuracy: 0.7710 - loss:
0.4560 - val_accuracy: 0.7320 - val_loss: 0.5926
Epoch 40/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 11s 322ms/step - accuracy: 0.7860 - loss:
0.4490 - val_accuracy: 0.7340 - val_loss: 0.6043
Epoch 41/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 326ms/step - accuracy: 0.7770 - loss:
0.4605 - val_accuracy: 0.7200 - val_loss: 0.6321
Epoch 42/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 324ms/step - accuracy: 0.7900 - loss:
0.4503 - val_accuracy: 0.7280 - val_loss: 0.5814
Epoch 43/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 323ms/step - accuracy: 0.7870 - loss:
0.4559 - val_accuracy: 0.7360 - val_loss: 0.5635
Epoch 44/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 10s 321ms/step - accuracy: 0.8110 - loss:
0.4229 - val_accuracy: 0.7240 - val_loss: 0.5933
Epoch 45/100
32/32 ━━━━━━━━━━━━━━━━━━━━ 11s 334ms/step - accuracy: 0.7980 - loss:
0.4293 - val_accuracy: 0.7300 - val_loss: 0.5808
Epoch 45: early stopping
```

```
Restoring model weights from the end of the best epoch: 35.
Training finished for scratch_train_500. Loading best model...
Best model loaded successfully.
Evaluating scratch_train_500 on test data...
Evaluation complete for scratch_train_500.
```



```

Final Results (Scratch, Train Size 1000): Test Accuracy = 0.7180

==================== Starting Scratch Training with 1500 samples
====================
Training from scratch with an experimental set of 750 samples per
class
Created experimental training set with 750 images per class.
Found 1500 files belonging to 2 classes.

Model: "functional_5"

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━
━━━━━┓
┃ Layer (type)                     ┃ Output Shape           ┃
Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━
━━━━━┩
│ input_layer_2 (InputLayer)       │ (None, 180, 180, 3)    │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ data_augmentation (Sequential)   │ (None, 180, 180, 3)    │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ rescaling_1 (Rescaling)          │ (None, 180, 180, 3)    │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
```

```
│ conv2d_5 (Conv2D)               │ (None, 178, 178, 32)   │
896 │
├─────────────────────────────────┼────────────────────────┼───────
──────┤
│ max_pooling2d_4 (MaxPooling2D)  │ (None, 89, 89, 32)     │
0 │
├─────────────────────────────────┼────────────────────────┼───────
──────┤
│ conv2d_6 (Conv2D)               │ (None, 87, 87, 64)     │
18,496 │
├─────────────────────────────────┼────────────────────────┼───────
──────┤
│ max_pooling2d_5 (MaxPooling2D)  │ (None, 43, 43, 64)     │
0 │
├─────────────────────────────────┼────────────────────────┼───────
──────┤
│ conv2d_7 (Conv2D)               │ (None, 41, 41, 128)    │
73,856 │
├─────────────────────────────────┼────────────────────────┼───────
──────┤
│ max_pooling2d_6 (MaxPooling2D)  │ (None, 20, 20, 128)    │
0 │
├─────────────────────────────────┼────────────────────────┼───────
──────┤
│ conv2d_8 (Conv2D)               │ (None, 18, 18, 256)    │
295,168 │
├─────────────────────────────────┼────────────────────────┼───────
──────┤
│ max_pooling2d_7 (MaxPooling2D)  │ (None, 9, 9, 256)      │
0 │
├─────────────────────────────────┼────────────────────────┼───────
──────┤
│ conv2d_9 (Conv2D)               │ (None, 7, 7, 512)      │
1,180,160 │
├─────────────────────────────────┼────────────────────────┼───────
──────┤
│ global_average_pooling2d_1      │ (None, 512)            │
0 │
│ (GlobalAveragePooling2D)        │                        │
│
├─────────────────────────────────┼────────────────────────┼───────
──────┤
│ dropout_1 (Dropout)             │ (None, 512)            │
0 │
├─────────────────────────────────┼────────────────────────┼───────
──────┤
│ dense_1 (Dense)                 │ (None, 1)              │
513 │
```

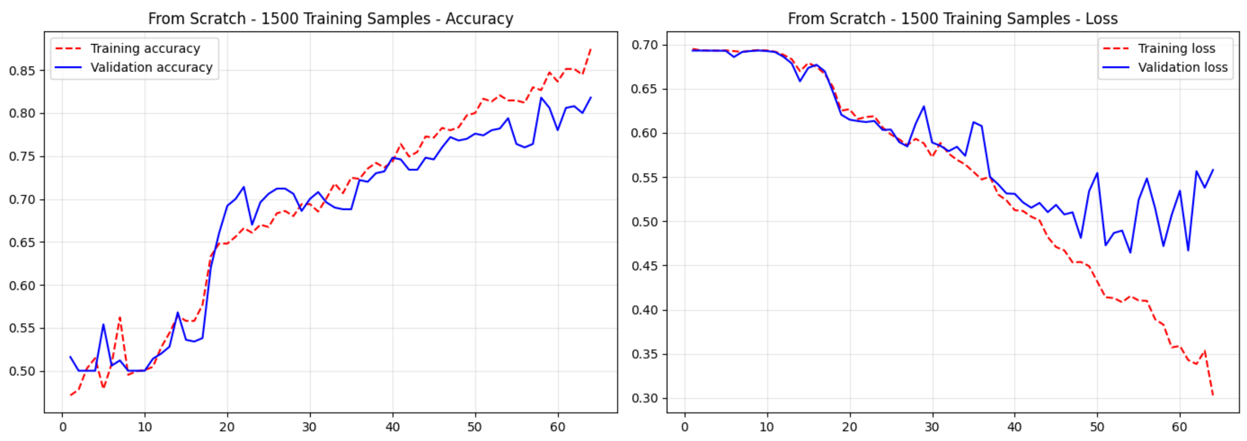
```
└──────────────────────────────────┴─────────────────────────┴──────────
─────┘

 Total params: 1,569,089 (5.99 MB)

 Trainable params: 1,569,089 (5.99 MB)

 Non-trainable params: 0 (0.00 B)

Starting training for scratch_train_750...
Epoch 1/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 27s 583ms/step - accuracy: 0.4713 - loss:
0.6950 - val_accuracy: 0.5160 - val_loss: 0.6931
Epoch 2/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 313ms/step - accuracy: 0.4780 - loss:
0.6934 - val_accuracy: 0.5000 - val_loss: 0.6931
Epoch 3/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 323ms/step - accuracy: 0.5027 - loss:
0.6933 - val_accuracy: 0.5000 - val_loss: 0.6930
Epoch 4/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 337ms/step - accuracy: 0.5147 - loss:
0.6931 - val_accuracy: 0.5000 - val_loss: 0.6930
Epoch 5/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 324ms/step - accuracy: 0.4787 - loss:
0.6933 - val_accuracy: 0.5540 - val_loss: 0.6929
Epoch 6/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 333ms/step - accuracy: 0.5080 - loss:
0.6925 - val_accuracy: 0.5060 - val_loss: 0.6858
Epoch 7/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 343ms/step - accuracy: 0.5620 - loss:
0.6916 - val_accuracy: 0.5120 - val_loss: 0.6916
Epoch 8/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 321ms/step - accuracy: 0.4953 - loss:
0.6931 - val_accuracy: 0.5000 - val_loss: 0.6925
Epoch 9/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 332ms/step - accuracy: 0.4993 - loss:
0.6937 - val_accuracy: 0.5000 - val_loss: 0.6932
Epoch 10/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 324ms/step - accuracy: 0.5007 - loss:
0.6932 - val_accuracy: 0.5000 - val_loss: 0.6926
Epoch 11/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 335ms/step - accuracy: 0.5047 - loss:
0.6919 - val_accuracy: 0.5140 - val_loss: 0.6914
Epoch 12/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 320ms/step - accuracy: 0.5273 - loss:
0.6883 - val_accuracy: 0.5200 - val_loss: 0.6861
Epoch 13/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 320ms/step - accuracy: 0.5440 - loss:
0.6833 - val_accuracy: 0.5280 - val_loss: 0.6786
Epoch 14/100
```

```
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 320ms/step - accuracy: 0.5640 - loss:
0.6698 - val_accuracy: 0.5680 - val_loss: 0.6584
Epoch 15/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 335ms/step - accuracy: 0.5580 - loss:
0.6790 - val_accuracy: 0.5360 - val_loss: 0.6735
Epoch 16/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 319ms/step - accuracy: 0.5580 - loss:
0.6749 - val_accuracy: 0.5340 - val_loss: 0.6770
Epoch 17/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 319ms/step - accuracy: 0.5767 - loss:
0.6666 - val_accuracy: 0.5380 - val_loss: 0.6696
Epoch 18/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 317ms/step - accuracy: 0.6333 - loss:
0.6519 - val_accuracy: 0.6200 - val_loss: 0.6460
Epoch 19/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 335ms/step - accuracy: 0.6480 - loss:
0.6252 - val_accuracy: 0.6600 - val_loss: 0.6206
Epoch 20/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 320ms/step - accuracy: 0.6480 - loss:
0.6267 - val_accuracy: 0.6920 - val_loss: 0.6149
Epoch 21/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 318ms/step - accuracy: 0.6560 - loss:
0.6155 - val_accuracy: 0.7000 - val_loss: 0.6134
Epoch 22/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 328ms/step - accuracy: 0.6660 - loss:
0.6180 - val_accuracy: 0.7140 - val_loss: 0.6122
Epoch 23/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 344ms/step - accuracy: 0.6607 - loss:
0.6189 - val_accuracy: 0.6700 - val_loss: 0.6135
Epoch 24/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 321ms/step - accuracy: 0.6700 - loss:
0.6061 - val_accuracy: 0.6960 - val_loss: 0.6034
Epoch 25/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 314ms/step - accuracy: 0.6673 - loss:
0.5982 - val_accuracy: 0.7060 - val_loss: 0.6037
Epoch 26/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 320ms/step - accuracy: 0.6833 - loss:
0.5927 - val_accuracy: 0.7120 - val_loss: 0.5897
Epoch 27/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 21s 325ms/step - accuracy: 0.6860 - loss:
0.5862 - val_accuracy: 0.7120 - val_loss: 0.5846
Epoch 28/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 319ms/step - accuracy: 0.6800 - loss:
0.5933 - val_accuracy: 0.7060 - val_loss: 0.6102
Epoch 29/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 336ms/step - accuracy: 0.6940 - loss:
0.5882 - val_accuracy: 0.6860 - val_loss: 0.6300
Epoch 30/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 319ms/step - accuracy: 0.6940 - loss:
```

```
0.5725 - val_accuracy: 0.7000 - val_loss: 0.5891
Epoch 31/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 315ms/step - accuracy: 0.6853 - loss:
0.5886 - val_accuracy: 0.7080 - val_loss: 0.5854
Epoch 32/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 21s 323ms/step - accuracy: 0.7007 - loss:
0.5765 - val_accuracy: 0.6960 - val_loss: 0.5793
Epoch 33/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 316ms/step - accuracy: 0.7180 - loss:
0.5695 - val_accuracy: 0.6900 - val_loss: 0.5843
Epoch 34/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 320ms/step - accuracy: 0.7067 - loss:
0.5643 - val_accuracy: 0.6880 - val_loss: 0.5740
Epoch 35/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 332ms/step - accuracy: 0.7247 - loss:
0.5559 - val_accuracy: 0.6880 - val_loss: 0.6121
Epoch 36/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 316ms/step - accuracy: 0.7233 - loss:
0.5472 - val_accuracy: 0.7220 - val_loss: 0.6077
Epoch 37/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 319ms/step - accuracy: 0.7353 - loss:
0.5505 - val_accuracy: 0.7200 - val_loss: 0.5503
Epoch 38/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 320ms/step - accuracy: 0.7420 - loss:
0.5302 - val_accuracy: 0.7300 - val_loss: 0.5417
Epoch 39/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 342ms/step - accuracy: 0.7367 - loss:
0.5236 - val_accuracy: 0.7320 - val_loss: 0.5314
Epoch 40/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 20s 334ms/step - accuracy: 0.7433 - loss:
0.5125 - val_accuracy: 0.7480 - val_loss: 0.5310
Epoch 41/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 342ms/step - accuracy: 0.7640 - loss:
0.5116 - val_accuracy: 0.7460 - val_loss: 0.5213
Epoch 42/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 334ms/step - accuracy: 0.7493 - loss:
0.5052 - val_accuracy: 0.7340 - val_loss: 0.5152
Epoch 43/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 319ms/step - accuracy: 0.7547 - loss:
0.5010 - val_accuracy: 0.7340 - val_loss: 0.5207
Epoch 44/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 322ms/step - accuracy: 0.7727 - loss:
0.4821 - val_accuracy: 0.7480 - val_loss: 0.5103
Epoch 45/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 334ms/step - accuracy: 0.7713 - loss:
0.4708 - val_accuracy: 0.7460 - val_loss: 0.5185
Epoch 46/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 20s 324ms/step - accuracy: 0.7827 - loss:
0.4670 - val_accuracy: 0.7600 - val_loss: 0.5077
```

```
Epoch 47/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 346ms/step - accuracy: 0.7800 - loss:
0.4534 - val_accuracy: 0.7720 - val_loss: 0.5101
Epoch 48/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 323ms/step - accuracy: 0.7833 - loss:
0.4539 - val_accuracy: 0.7680 - val_loss: 0.4811
Epoch 49/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 319ms/step - accuracy: 0.7973 - loss:
0.4492 - val_accuracy: 0.7700 - val_loss: 0.5340
Epoch 50/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 320ms/step - accuracy: 0.8000 - loss:
0.4315 - val_accuracy: 0.7760 - val_loss: 0.5547
Epoch 51/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 339ms/step - accuracy: 0.8167 - loss:
0.4139 - val_accuracy: 0.7740 - val_loss: 0.4727
Epoch 52/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 319ms/step - accuracy: 0.8133 - loss:
0.4130 - val_accuracy: 0.7800 - val_loss: 0.4867
Epoch 53/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 320ms/step - accuracy: 0.8207 - loss:
0.4083 - val_accuracy: 0.7820 - val_loss: 0.4894
Epoch 54/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 322ms/step - accuracy: 0.8147 - loss:
0.4153 - val_accuracy: 0.7940 - val_loss: 0.4644
Epoch 55/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 337ms/step - accuracy: 0.8147 - loss:
0.4103 - val_accuracy: 0.7640 - val_loss: 0.5241
Epoch 56/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 318ms/step - accuracy: 0.8120 - loss:
0.4099 - val_accuracy: 0.7600 - val_loss: 0.5485
Epoch 57/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 21s 338ms/step - accuracy: 0.8300 - loss:
0.3890 - val_accuracy: 0.7640 - val_loss: 0.5146
Epoch 58/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 321ms/step - accuracy: 0.8267 - loss:
0.3829 - val_accuracy: 0.8180 - val_loss: 0.4718
Epoch 59/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 317ms/step - accuracy: 0.8473 - loss:
0.3572 - val_accuracy: 0.8060 - val_loss: 0.5072
Epoch 60/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 21s 321ms/step - accuracy: 0.8367 - loss:
0.3588 - val_accuracy: 0.7800 - val_loss: 0.5345
Epoch 61/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 322ms/step - accuracy: 0.8513 - loss:
0.3429 - val_accuracy: 0.8060 - val_loss: 0.4669
Epoch 62/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 320ms/step - accuracy: 0.8513 - loss:
0.3384 - val_accuracy: 0.8080 - val_loss: 0.5566
Epoch 63/100
```

```
47/47 ━━━━━━━━━━━━━━━━━━━━ 16s 343ms/step - accuracy: 0.8447 - loss:
0.3535 - val_accuracy: 0.8000 - val_loss: 0.5379
Epoch 64/100
47/47 ━━━━━━━━━━━━━━━━━━━━ 15s 318ms/step - accuracy: 0.8747 - loss:
0.3029 - val_accuracy: 0.8180 - val_loss: 0.5580
Epoch 64: early stopping
Restoring model weights from the end of the best epoch: 54.
Training finished for scratch_train_750. Loading best model...
Best model loaded successfully.
Evaluating scratch_train_750 on test data...
Evaluation complete for scratch_train_750.
```



```

Final Results (Scratch, Train Size 1500): Test Accuracy = 0.7660

==================== Starting Scratch Training with 2000 samples
====================
Training from scratch with an experimental set of 1000 samples per
class
Created experimental training set with 1000 images per class.
Found 2000 files belonging to 2 classes.

Model: "functional_9"

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━
━━━━━┓
┃ Layer (type)                     ┃ Output Shape           ┃
Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━
━━━━━┩
│ input_layer_3 (InputLayer)       │ (None, 180, 180, 3)    │
0 │
├──────────────────────────────────┼────────────────────────┼──────────
─────┤
│ data_augmentation (Sequential)   │ (None, 180, 180, 3)    │
0 │
```

```
├─────────────────────────────────┼────────────────────────┼───────────
──────┤
│ rescaling_2 (Rescaling)         │ (None, 180, 180, 3)    │
0 │
├─────────────────────────────────┼────────────────────────┼───────────
──────┤
│ conv2d_10 (Conv2D)              │ (None, 178, 178, 32)   │
896 │
├─────────────────────────────────┼────────────────────────┼───────────
──────┤
│ max_pooling2d_8 (MaxPooling2D)  │ (None, 89, 89, 32)     │
0 │
├─────────────────────────────────┼────────────────────────┼───────────
──────┤
│ conv2d_11 (Conv2D)              │ (None, 87, 87, 64)     │
18,496 │
├─────────────────────────────────┼────────────────────────┼───────────
──────┤
│ max_pooling2d_9 (MaxPooling2D)  │ (None, 43, 43, 64)     │
0 │
├─────────────────────────────────┼────────────────────────┼───────────
──────┤
│ conv2d_12 (Conv2D)              │ (None, 41, 41, 128)    │
73,856 │
├─────────────────────────────────┼────────────────────────┼───────────
──────┤
│ max_pooling2d_10 (MaxPooling2D) │ (None, 20, 20, 128)    │
0 │
├─────────────────────────────────┼────────────────────────┼───────────
──────┤
│ conv2d_13 (Conv2D)              │ (None, 18, 18, 256)    │
295,168 │
├─────────────────────────────────┼────────────────────────┼───────────
──────┤
│ max_pooling2d_11 (MaxPooling2D) │ (None, 9, 9, 256)      │
0 │
├─────────────────────────────────┼────────────────────────┼───────────
──────┤
│ conv2d_14 (Conv2D)              │ (None, 7, 7, 512)      │
1,180,160 │
├─────────────────────────────────┼────────────────────────┼───────────
──────┤
│ global_average_pooling2d_2      │ (None, 512)            │
0 │
│ (GlobalAveragePooling2D)        │                        │
│
├─────────────────────────────────┼────────────────────────┼───────────
──────┤
│ dropout_2 (Dropout)             │ (None, 512)            │
```

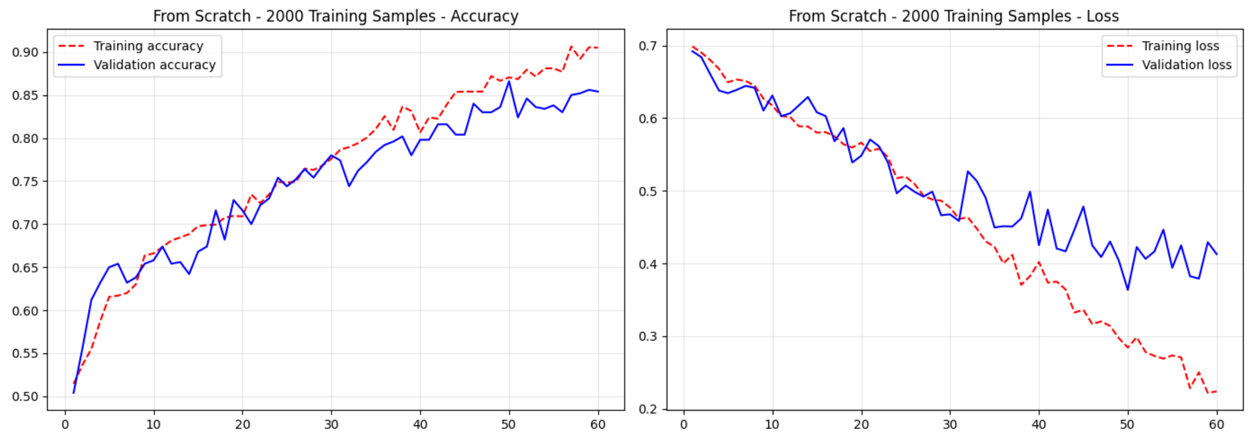
```
0 │
├─────────────────────────────────┼────────────────────────┼───────
──────┤
│ dense_2 (Dense)                 │ (None, 1)              │
513 │
└─────────────────────────────────┴────────────────────────┴───────
──────┘

 Total params: 1,569,089 (5.99 MB)

 Trainable params: 1,569,089 (5.99 MB)

 Non-trainable params: 0 (0.00 B)

Starting training for scratch_train_1000...
Epoch 1/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 32s 515ms/step - accuracy: 0.5145 - loss:
0.6988 - val_accuracy: 0.5040 - val_loss: 0.6920
Epoch 2/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 310ms/step - accuracy: 0.5365 - loss:
0.6903 - val_accuracy: 0.5560 - val_loss: 0.6841
Epoch 3/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 21s 321ms/step - accuracy: 0.5550 - loss:
0.6800 - val_accuracy: 0.6120 - val_loss: 0.6607
Epoch 4/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 325ms/step - accuracy: 0.5875 - loss:
0.6678 - val_accuracy: 0.6320 - val_loss: 0.6379
Epoch 5/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 312ms/step - accuracy: 0.6155 - loss:
0.6494 - val_accuracy: 0.6500 - val_loss: 0.6344
Epoch 6/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 324ms/step - accuracy: 0.6170 - loss:
0.6532 - val_accuracy: 0.6540 - val_loss: 0.6390
Epoch 7/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 21s 330ms/step - accuracy: 0.6200 - loss:
0.6512 - val_accuracy: 0.6320 - val_loss: 0.6444
Epoch 8/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 320ms/step - accuracy: 0.6300 - loss:
0.6448 - val_accuracy: 0.6380 - val_loss: 0.6418
Epoch 9/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 22s 335ms/step - accuracy: 0.6635 - loss:
0.6269 - val_accuracy: 0.6540 - val_loss: 0.6104
Epoch 10/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 21s 334ms/step - accuracy: 0.6660 - loss:
0.6173 - val_accuracy: 0.6580 - val_loss: 0.6311
Epoch 11/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 21s 336ms/step - accuracy: 0.6735 - loss:
0.6029 - val_accuracy: 0.6740 - val_loss: 0.6027
Epoch 12/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 313ms/step - accuracy: 0.6810 - loss:
```

```
0.6016 - val_accuracy: 0.6540 - val_loss: 0.6066
Epoch 13/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 320ms/step - accuracy: 0.6845 - loss:
0.5887 - val_accuracy: 0.6560 - val_loss: 0.6177
Epoch 14/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 322ms/step - accuracy: 0.6885 - loss:
0.5885 - val_accuracy: 0.6420 - val_loss: 0.6291
Epoch 15/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 313ms/step - accuracy: 0.6975 - loss:
0.5801 - val_accuracy: 0.6680 - val_loss: 0.6081
Epoch 16/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 323ms/step - accuracy: 0.6990 - loss:
0.5807 - val_accuracy: 0.6740 - val_loss: 0.6028
Epoch 17/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 317ms/step - accuracy: 0.6995 - loss:
0.5750 - val_accuracy: 0.7160 - val_loss: 0.5682
Epoch 18/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 318ms/step - accuracy: 0.7075 - loss:
0.5641 - val_accuracy: 0.6820 - val_loss: 0.5863
Epoch 19/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 323ms/step - accuracy: 0.7095 - loss:
0.5595 - val_accuracy: 0.7280 - val_loss: 0.5390
Epoch 20/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 313ms/step - accuracy: 0.7090 - loss:
0.5662 - val_accuracy: 0.7160 - val_loss: 0.5482
Epoch 21/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 321ms/step - accuracy: 0.7345 - loss:
0.5547 - val_accuracy: 0.7000 - val_loss: 0.5705
Epoch 22/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 21s 328ms/step - accuracy: 0.7245 - loss:
0.5580 - val_accuracy: 0.7220 - val_loss: 0.5612
Epoch 23/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 323ms/step - accuracy: 0.7345 - loss:
0.5465 - val_accuracy: 0.7300 - val_loss: 0.5393
Epoch 24/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 21s 324ms/step - accuracy: 0.7490 - loss:
0.5174 - val_accuracy: 0.7540 - val_loss: 0.4965
Epoch 25/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 21s 328ms/step - accuracy: 0.7485 - loss:
0.5195 - val_accuracy: 0.7440 - val_loss: 0.5073
Epoch 26/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 318ms/step - accuracy: 0.7490 - loss:
0.5095 - val_accuracy: 0.7520 - val_loss: 0.4986
Epoch 27/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 320ms/step - accuracy: 0.7645 - loss:
0.4932 - val_accuracy: 0.7640 - val_loss: 0.4920
Epoch 28/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 326ms/step - accuracy: 0.7630 - loss:
0.4880 - val_accuracy: 0.7540 - val_loss: 0.4988
```

```
Epoch 29/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 40s 317ms/step - accuracy: 0.7680 - loss:
0.4863 - val_accuracy: 0.7680 - val_loss: 0.4663
Epoch 30/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 21s 327ms/step - accuracy: 0.7760 - loss:
0.4769 - val_accuracy: 0.7800 - val_loss: 0.4676
Epoch 31/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 324ms/step - accuracy: 0.7865 - loss:
0.4613 - val_accuracy: 0.7740 - val_loss: 0.4584
Epoch 32/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 312ms/step - accuracy: 0.7895 - loss:
0.4634 - val_accuracy: 0.7440 - val_loss: 0.5267
Epoch 33/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 323ms/step - accuracy: 0.7940 - loss:
0.4480 - val_accuracy: 0.7620 - val_loss: 0.5134
Epoch 34/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 322ms/step - accuracy: 0.8005 - loss:
0.4304 - val_accuracy: 0.7720 - val_loss: 0.4905
Epoch 35/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 315ms/step - accuracy: 0.8105 - loss:
0.4228 - val_accuracy: 0.7840 - val_loss: 0.4495
Epoch 36/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 21s 322ms/step - accuracy: 0.8255 - loss:
0.4001 - val_accuracy: 0.7920 - val_loss: 0.4512
Epoch 37/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 21s 325ms/step - accuracy: 0.8095 - loss:
0.4117 - val_accuracy: 0.7960 - val_loss: 0.4508
Epoch 38/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 19s 309ms/step - accuracy: 0.8365 - loss:
0.3705 - val_accuracy: 0.8020 - val_loss: 0.4619
Epoch 39/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 322ms/step - accuracy: 0.8315 - loss:
0.3825 - val_accuracy: 0.7800 - val_loss: 0.4988
Epoch 40/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 323ms/step - accuracy: 0.8065 - loss:
0.4019 - val_accuracy: 0.7980 - val_loss: 0.4250
Epoch 41/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 315ms/step - accuracy: 0.8240 - loss:
0.3736 - val_accuracy: 0.7980 - val_loss: 0.4740
Epoch 42/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 324ms/step - accuracy: 0.8225 - loss:
0.3749 - val_accuracy: 0.8160 - val_loss: 0.4205
Epoch 43/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 323ms/step - accuracy: 0.8390 - loss:
0.3641 - val_accuracy: 0.8160 - val_loss: 0.4166
Epoch 44/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 19s 309ms/step - accuracy: 0.8535 - loss:
0.3324 - val_accuracy: 0.8040 - val_loss: 0.4467
Epoch 45/100
```

```
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 323ms/step - accuracy: 0.8540 - loss:
0.3361 - val_accuracy: 0.8040 - val_loss: 0.4783
Epoch 46/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 21s 324ms/step - accuracy: 0.8540 - loss:
0.3165 - val_accuracy: 0.8400 - val_loss: 0.4248
Epoch 47/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 314ms/step - accuracy: 0.8540 - loss:
0.3202 - val_accuracy: 0.8300 - val_loss: 0.4088
Epoch 48/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 21s 320ms/step - accuracy: 0.8720 - loss:
0.3140 - val_accuracy: 0.8300 - val_loss: 0.4301
Epoch 49/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 324ms/step - accuracy: 0.8665 - loss:
0.2969 - val_accuracy: 0.8360 - val_loss: 0.4035
Epoch 50/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 312ms/step - accuracy: 0.8705 - loss:
0.2842 - val_accuracy: 0.8660 - val_loss: 0.3634
Epoch 51/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 21s 322ms/step - accuracy: 0.8685 - loss:
0.2983 - val_accuracy: 0.8240 - val_loss: 0.4226
Epoch 52/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 21s 323ms/step - accuracy: 0.8795 - loss:
0.2780 - val_accuracy: 0.8460 - val_loss: 0.4063
Epoch 53/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 19s 310ms/step - accuracy: 0.8715 - loss:
0.2726 - val_accuracy: 0.8360 - val_loss: 0.4165
Epoch 54/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 319ms/step - accuracy: 0.8810 - loss:
0.2690 - val_accuracy: 0.8340 - val_loss: 0.4465
Epoch 55/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 21s 329ms/step - accuracy: 0.8810 - loss:
0.2733 - val_accuracy: 0.8380 - val_loss: 0.3940
Epoch 56/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 317ms/step - accuracy: 0.8770 - loss:
0.2707 - val_accuracy: 0.8300 - val_loss: 0.4248
Epoch 57/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 21s 321ms/step - accuracy: 0.9065 - loss:
0.2283 - val_accuracy: 0.8500 - val_loss: 0.3823
Epoch 58/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 317ms/step - accuracy: 0.8920 - loss:
0.2501 - val_accuracy: 0.8520 - val_loss: 0.3791
Epoch 59/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 309ms/step - accuracy: 0.9055 - loss:
0.2218 - val_accuracy: 0.8560 - val_loss: 0.4292
Epoch 60/100
63/63 ━━━━━━━━━━━━━━━━━━━━ 20s 319ms/step - accuracy: 0.9050 - loss:
0.2239 - val_accuracy: 0.8540 - val_loss: 0.4128
Epoch 60: early stopping
Restoring model weights from the end of the best epoch: 50.
```

```
Training finished for scratch_train_1000. Loading best model...
Best model loaded successfully.
Evaluating scratch_train_1000 on test data...
Evaluation complete for scratch_train_1000.
```



```
Final Results (Scratch, Train Size 2000): Test Accuracy = 0.8460

pretrained_results = []


for train_size in experimental_train_sizes:
  print(f"\n Starting Pretrained Xception with {train_size*2} samples
")
  print(f"Using pretrained Xception model with an experimental set of
{train_size} samples per class")

  experimental_train_dir =
pathlib.Path(f"experimental_train_{train_size}")

  if not experimental_train_dir.exists():
        print(f"ERROR: Experimental training set for size
{train_size} not found. Run Part 1 first.")
        continue


  train_dataset = image_dataset_from_directory(
        experimental_train_dir,
        image_size=image_size,
        batch_size=batch_size
    )


  print("\nBuilding model for Phase 1 (Frozen Base)...")

  model_frozen, conv_base_frozen =
build_pretrained_xception_model(trainable_base=False)
  model_frozen.summary()


  print("\nPhase 1: Training with frozen base...")

  prefetched_train_dataset =
train_dataset.cache().prefetch(buffer_size=tf.data.AUTOTUNE)


  results_frozen = train_and_evaluate(
        model=model_frozen,
        train_dataset=prefetched_train_dataset,
        val_dataset=validation_dataset,
        test_dataset=test_dataset,
        model_name=f"pretrained_frozen_xception_train_{train_size}",
        epochs=30
    )
  print(f"Phase 1 (Frozen Xception) Test Accuracy:
{results_frozen['test_accuracy']:.4f}")


  print("\nPhase 2: Fine-tuning Xception...")

  try:

        model_finetune = keras.models.load_model(
            f"pretrained_frozen_xception_train_{train_size}.keras"

            )
        print("Best frozen model loaded successfully for fine-
tuning.")
  except Exception as e:
        print(f"Could not load the best frozen model from
{f'pretrained_frozen_xception_train_{train_size}'}.keras. Skipping
fine-tuning for this size. Error: {e}")
        continue


  try:
        conv_base_finetune =
model_finetune.get_layer("xception_backbone")
        conv_base_finetune.trainable = True
        print(f"Xception backbone '{conv_base_finetune.name}'
unfrozen.")


        for layer in conv_base_finetune.layers:
           if isinstance(layer, layers.BatchNormalization):
               layer.trainable = False
        print("Batch normalization layers within the backbone frozen
for fine-tuning.")

  except ValueError:
        print("Could not find the 'xception_backbone' layer. Check
model structure. Skipping fine-tuning.")
        continue



  model_finetune.compile(
        loss="binary_crossentropy",
        optimizer=keras.optimizers.Adam(learning_rate=1e-5),
        metrics=["accuracy"]
    )
  print("Model recompiled for fine-tuning with low learning rate.")
  model_finetune.summary()

    # Fine-tune the model
  results_finetuned = train_and_evaluate(
        model=model_finetune,
        train_dataset=prefetched_train_dataset,
        val_dataset=validation_dataset,
        test_dataset=test_dataset,

model_name=f"pretrained_finetuned_xception_train_{train_size}",
        epochs=30
    )


  plot_training_history(
        results_finetuned["history"],
        f"Pretrained Xception (Fine-tuned) - {train_size*2} Samples"
    ) #

  pretrained_results.append({
        "train_size": train_size * 2,
        "val_accuracy":
max(results_finetuned["history"].get("val_accuracy", [0])),
        "test_accuracy": results_finetuned["test_accuracy"]
    })
  print(f"\nFinal Results (Fine-tuned Xception, Train Size
{train_size*2}): Test Accuracy =
{results_finetuned['test_accuracy']:.4f}")


 Starting Pretrained Xception with 1000 samples
Using pretrained Xception model with an experimental set of 500
samples per class
Found 1000 files belonging to 2 classes.

Building model for Phase 1 (Frozen Base)...
```

```
Model: "functional_13"

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━
━━━━━┓
┃ Layer (type)                     ┃ Output Shape            ┃
Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━
━━━━━┩
│ input_layer_5 (InputLayer)       │ (None, 180, 180, 3)     │
0 │
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ data_augmentation (Sequential)   │ (None, 180, 180, 3)     │
0 │
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ image_converter                  │ (None, 180, 180, 3)     │
0 │
│ (ImageConverter)                 │                         │
│
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ xception_backbone                │ (None, 6, 6, 2048)      │
20,861,480 │
│ (XceptionBackbone)               │                         │
│
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ global_average_pooling2d_3       │ (None, 2048)            │
0 │
│ (GlobalAveragePooling2D)         │                         │
│
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ dense_3 (Dense)                  │ (None, 256)             │
524,544 │
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ dropout_3 (Dropout)              │ (None, 256)             │
0 │
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ dense_4 (Dense)                  │ (None, 1)               │
257 │
└──────────────────────────────────┴─────────────────────────┴──────────
─────┘

 Total params: 21,386,281 (81.58 MB)

 Trainable params: 21,331,753 (81.37 MB)
 Non-trainable params: 54,528 (213.00 KB)


Phase 1: Training with frozen base...
Starting training for pretrained_frozen_xception_train_500...
Epoch 1/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 187s 4s/step - accuracy: 0.8580 - loss:
0.3240 - val_accuracy: 0.9260 - val_loss: 0.9085
Epoch 2/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 82s 3s/step - accuracy: 0.9360 - loss:
0.1573 - val_accuracy: 0.7900 - val_loss: 2.3162
Epoch 3/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 80s 3s/step - accuracy: 0.9240 - loss:
0.2302 - val_accuracy: 0.7460 - val_loss: 3.8728
Epoch 4/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 90s 3s/step - accuracy: 0.9420 - loss:
0.1630 - val_accuracy: 0.9020 - val_loss: 0.7400
Epoch 5/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 83s 3s/step - accuracy: 0.9530 - loss:
0.1396 - val_accuracy: 0.9060 - val_loss: 0.5448
Epoch 6/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 82s 3s/step - accuracy: 0.9500 - loss:
0.1156 - val_accuracy: 0.8460 - val_loss: 1.4128
Epoch 7/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 81s 3s/step - accuracy: 0.9680 - loss:
0.1158 - val_accuracy: 0.9100 - val_loss: 0.5735
Epoch 8/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 88s 3s/step - accuracy: 0.9760 - loss:
0.0932 - val_accuracy: 0.9260 - val_loss: 0.3436
Epoch 9/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 82s 3s/step - accuracy: 0.9840 - loss:
0.0510 - val_accuracy: 0.9320 - val_loss: 0.3744
Epoch 10/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 81s 3s/step - accuracy: 0.9690 - loss:
0.0877 - val_accuracy: 0.7560 - val_loss: 2.4329
Epoch 11/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 82s 3s/step - accuracy: 0.9640 - loss:
0.1051 - val_accuracy: 0.9100 - val_loss: 0.3605
Epoch 12/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 81s 3s/step - accuracy: 0.9760 - loss:
0.0770 - val_accuracy: 0.8660 - val_loss: 0.5219
Epoch 13/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 82s 3s/step - accuracy: 0.9760 - loss:
0.0588 - val_accuracy: 0.9120 - val_loss: 0.3823
Epoch 14/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 89s 3s/step - accuracy: 0.9790 - loss:
0.0580 - val_accuracy: 0.9420 - val_loss: 0.2497
Epoch 15/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 81s 3s/step - accuracy: 0.9810 - loss:
0.0507 - val_accuracy: 0.7780 - val_loss: 1.5789
```

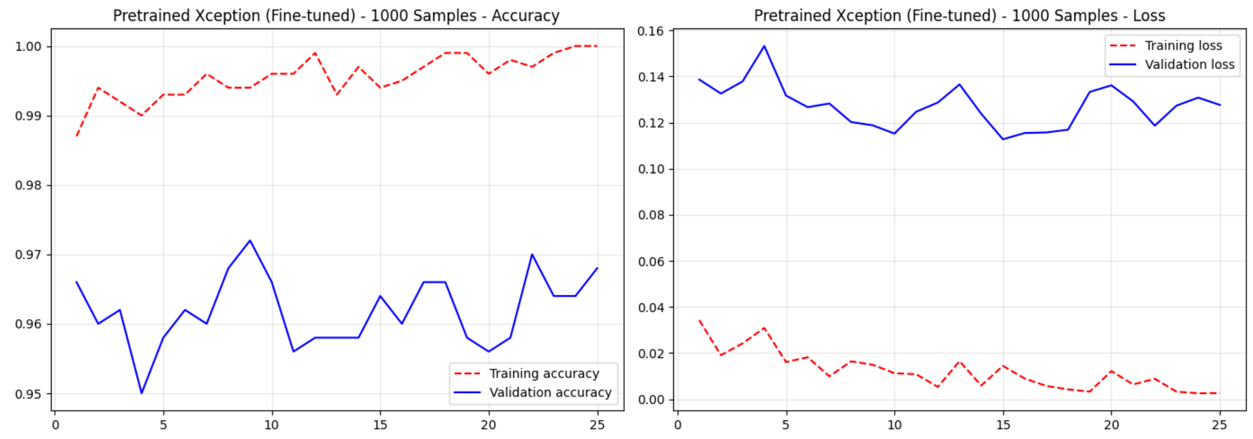
```
Epoch 16/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 83s 3s/step - accuracy: 0.9880 - loss:
0.0475 - val_accuracy: 0.9200 - val_loss: 0.5141
Epoch 17/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 81s 3s/step - accuracy: 0.9880 - loss:
0.0333 - val_accuracy: 0.8640 - val_loss: 0.6853
Epoch 18/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 82s 3s/step - accuracy: 0.9730 - loss:
0.0727 - val_accuracy: 0.6900 - val_loss: 1.5271
Epoch 19/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 90s 3s/step - accuracy: 0.9830 - loss:
0.0598 - val_accuracy: 0.9240 - val_loss: 0.2331
Epoch 20/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 93s 3s/step - accuracy: 0.9920 - loss:
0.0271 - val_accuracy: 0.9520 - val_loss: 0.1644
Epoch 21/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 131s 3s/step - accuracy: 0.9810 - loss:
0.0581 - val_accuracy: 0.9400 - val_loss: 0.2257
Epoch 22/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 141s 3s/step - accuracy: 0.9930 - loss:
0.0295 - val_accuracy: 0.9380 - val_loss: 0.2817
Epoch 23/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 83s 3s/step - accuracy: 0.9880 - loss:
0.0359 - val_accuracy: 0.8660 - val_loss: 0.9514
Epoch 24/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 141s 3s/step - accuracy: 0.9670 - loss:
0.0996 - val_accuracy: 0.8680 - val_loss: 0.5151
Epoch 25/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 95s 3s/step - accuracy: 0.9870 - loss:
0.0317 - val_accuracy: 0.9560 - val_loss: 0.1506
Epoch 26/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 81s 3s/step - accuracy: 0.9940 - loss:
0.0161 - val_accuracy: 0.9360 - val_loss: 0.2694
Epoch 27/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 81s 3s/step - accuracy: 0.9600 - loss:
0.1167 - val_accuracy: 0.7720 - val_loss: 0.9381
Epoch 28/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 82s 3s/step - accuracy: 0.9690 - loss:
0.0814 - val_accuracy: 0.9160 - val_loss: 0.2760
Epoch 29/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 81s 3s/step - accuracy: 0.9910 - loss:
0.0285 - val_accuracy: 0.9620 - val_loss: 0.1509
Epoch 30/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 80s 3s/step - accuracy: 0.9890 - loss:
0.0226 - val_accuracy: 0.9200 - val_loss: 0.2772
Restoring model weights from the end of the best epoch: 25.
Training finished for pretrained_frozen_xception_train_500. Loading
best model...
Best model loaded successfully.
```

```
Evaluating pretrained_frozen_xception_train_500 on test data...
Evaluation complete for pretrained_frozen_xception_train_500.
Phase 1 (Frozen Xception) Test Accuracy: 0.9200

Phase 2: Fine-tuning Xception...
Best frozen model loaded successfully for fine-tuning.
Xception backbone 'xception_backbone' unfrozen.
Batch normalization layers within the backbone frozen for fine-tuning.
Model recompiled for fine-tuning with low learning rate.

Model: "functional_13"

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━
━━━━━┓
┃ Layer (type)                    ┃ Output Shape           ┃
Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━
━━━━━┩
│ input_layer_5 (InputLayer)      │ (None, 180, 180, 3)    │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ data_augmentation (Sequential)  │ (None, 180, 180, 3)    │
0 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ image_converter                 │ (None, 180, 180, 3)    │
0 │
│ (ImageConverter)                │                        │
│
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ xception_backbone               │ (None, 6, 6, 2048)     │
20,861,480 │
│ (XceptionBackbone)              │                        │
│
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ global_average_pooling2d_3      │ (None, 2048)           │
0 │
│ (GlobalAveragePooling2D)        │                        │
│
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ dense_3 (Dense)                 │ (None, 256)            │
524,544 │
├─────────────────────────────────┼────────────────────────┼──────────
─────┤
│ dropout_3 (Dropout)             │ (None, 256)            │
0 │
```

```
├──────────────────────────────────┼─────────────────────────┼───────────
─────┤
│ dense_4 (Dense)                  │ (None, 1)               │
257 │
└──────────────────────────────────┴─────────────────────────┴───────────
─────┘

 Total params: 21,386,281 (81.58 MB)

 Trainable params: 21,277,225 (81.17 MB)

 Non-trainable params: 109,056 (426.00 KB)

Starting training for pretrained_finetuned_xception_train_500...
Epoch 1/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 58s 2s/step - accuracy: 0.9870 - loss:
0.0343 - val_accuracy: 0.9660 - val_loss: 0.1387
Epoch 2/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 89s 3s/step - accuracy: 0.9940 - loss:
0.0191 - val_accuracy: 0.9600 - val_loss: 0.1326
Epoch 3/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 49s 2s/step - accuracy: 0.9920 - loss:
0.0242 - val_accuracy: 0.9620 - val_loss: 0.1379
Epoch 4/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 48s 2s/step - accuracy: 0.9900 - loss:
0.0309 - val_accuracy: 0.9500 - val_loss: 0.1532
Epoch 5/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 54s 2s/step - accuracy: 0.9930 - loss:
0.0161 - val_accuracy: 0.9580 - val_loss: 0.1317
Epoch 6/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 84s 3s/step - accuracy: 0.9930 - loss:
0.0182 - val_accuracy: 0.9620 - val_loss: 0.1267
Epoch 7/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 48s 2s/step - accuracy: 0.9960 - loss:
0.0099 - val_accuracy: 0.9600 - val_loss: 0.1283
Epoch 8/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 61s 2s/step - accuracy: 0.9940 - loss:
0.0164 - val_accuracy: 0.9680 - val_loss: 0.1202
Epoch 9/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 77s 2s/step - accuracy: 0.9940 - loss:
0.0150 - val_accuracy: 0.9720 - val_loss: 0.1188
Epoch 10/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 60s 2s/step - accuracy: 0.9960 - loss:
0.0113 - val_accuracy: 0.9660 - val_loss: 0.1152
Epoch 11/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 47s 1s/step - accuracy: 0.9960 - loss:
0.0109 - val_accuracy: 0.9560 - val_loss: 0.1247
Epoch 12/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 48s 1s/step - accuracy: 0.9990 - loss:
0.0053 - val_accuracy: 0.9580 - val_loss: 0.1287
```

```
Epoch 13/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 48s 1s/step - accuracy: 0.9930 - loss:
0.0165 - val_accuracy: 0.9580 - val_loss: 0.1366
Epoch 14/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 48s 1s/step - accuracy: 0.9970 - loss:
0.0059 - val_accuracy: 0.9580 - val_loss: 0.1238
Epoch 15/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 79s 3s/step - accuracy: 0.9940 - loss:
0.0145 - val_accuracy: 0.9640 - val_loss: 0.1128
Epoch 16/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 50s 1s/step - accuracy: 0.9950 - loss:
0.0090 - val_accuracy: 0.9600 - val_loss: 0.1155
Epoch 17/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 47s 1s/step - accuracy: 0.9970 - loss:
0.0058 - val_accuracy: 0.9660 - val_loss: 0.1157
Epoch 18/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 48s 2s/step - accuracy: 0.9990 - loss:
0.0043 - val_accuracy: 0.9660 - val_loss: 0.1169
Epoch 19/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 81s 1s/step - accuracy: 0.9990 - loss:
0.0033 - val_accuracy: 0.9580 - val_loss: 0.1333
Epoch 20/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 82s 1s/step - accuracy: 0.9960 - loss:
0.0122 - val_accuracy: 0.9560 - val_loss: 0.1362
Epoch 21/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 48s 2s/step - accuracy: 0.9980 - loss:
0.0064 - val_accuracy: 0.9580 - val_loss: 0.1292
Epoch 22/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 48s 1s/step - accuracy: 0.9970 - loss:
0.0089 - val_accuracy: 0.9700 - val_loss: 0.1187
Epoch 23/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 48s 1s/step - accuracy: 0.9990 - loss:
0.0033 - val_accuracy: 0.9640 - val_loss: 0.1274
Epoch 24/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 83s 2s/step - accuracy: 1.0000 - loss:
0.0026 - val_accuracy: 0.9640 - val_loss: 0.1308
Epoch 25/30
32/32 ━━━━━━━━━━━━━━━━━━━━ 47s 1s/step - accuracy: 1.0000 - loss:
0.0027 - val_accuracy: 0.9680 - val_loss: 0.1277
Epoch 25: early stopping
Restoring model weights from the end of the best epoch: 15.
Training finished for pretrained_finetuned_xception_train_500. Loading
best model...

/usr/local/lib/python3.12/dist-packages/keras/src/saving/
saving_lib.py:797: UserWarning: Skipping variable loading for
optimizer 'adam', because it has 318 variables whereas the saved
optimizer has 158 variables.
  saveable.load_own_variables(weights_store.get(inner_path))
```

```
Best model loaded successfully.
Evaluating pretrained_finetuned_xception_train_500 on test data...
Evaluation complete for pretrained_finetuned_xception_train_500.
```



```

Final Results (Fine-tuned Xception, Train Size 1000): Test Accuracy =
0.9500

 Starting Pretrained Xception with 1500 samples
Using pretrained Xception model with an experimental set of 750
samples per class
Found 1500 files belonging to 2 classes.

Building model for Phase 1 (Frozen Base)...

Model: "functional_23"

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━
━━━━━┓
┃ Layer (type)                     ┃ Output Shape           ┃
Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━
━━━━━┩
│ input_layer_10 (InputLayer)      │ (None, 180, 180, 3)    │
0 │
├──────────────────────────────────┼────────────────────────┼──────────
─────┤
│ data_augmentation (Sequential)   │ (None, 180, 180, 3)    │
0 │
├──────────────────────────────────┼────────────────────────┼──────────
─────┤
│ image_converter                  │ (None, 180, 180, 3)    │
0 │
│ (ImageConverter)                 │                        │
│
├──────────────────────────────────┼────────────────────────┼──────────
```

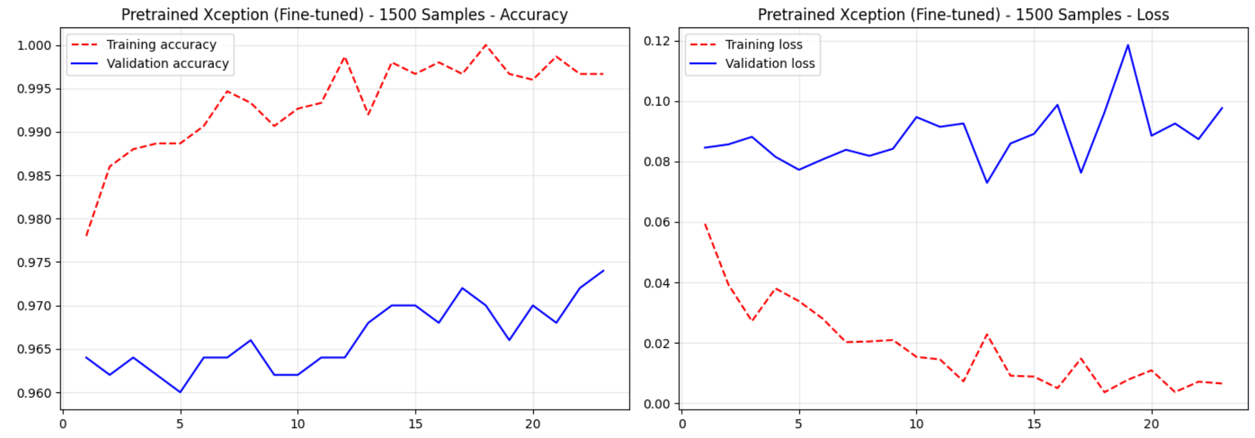
```
──────┤
│ xception_backbone                 │ (None, 6, 6, 2048)       │
20,861,480 │
│ (XceptionBackbone)                │                          │
│
├───────────────────────────────────┼──────────────────────────┼──────────
──────┤
│ global_average_pooling2d_4        │ (None, 2048)             │
0 │
│ (GlobalAveragePooling2D)          │                          │
│
├───────────────────────────────────┼──────────────────────────┼──────────
──────┤
│ dense_5 (Dense)                   │ (None, 256)              │
524,544 │
├───────────────────────────────────┼──────────────────────────┼──────────
──────┤
│ dropout_4 (Dropout)               │ (None, 256)              │
0 │
├───────────────────────────────────┼──────────────────────────┼──────────
──────┤
│ dense_6 (Dense)                   │ (None, 1)                │
257 │
└───────────────────────────────────┴──────────────────────────┴──────────
──────┘

 Total params: 21,386,281 (81.58 MB)

 Trainable params: 21,331,753 (81.37 MB)

 Non-trainable params: 54,528 (213.00 KB)


Phase 1: Training with frozen base...
Starting training for pretrained_frozen_xception_train_750...
Epoch 1/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 173s 4s/step - accuracy: 0.8920 - loss:
0.2637 - val_accuracy: 0.8960 - val_loss: 1.2999
Epoch 2/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 155s 3s/step - accuracy: 0.9307 - loss:
0.1826 - val_accuracy: 0.9080 - val_loss: 0.7356
Epoch 3/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 127s 3s/step - accuracy: 0.9487 - loss:
0.1678 - val_accuracy: 0.9220 - val_loss: 0.4001
Epoch 4/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 120s 3s/step - accuracy: 0.9593 - loss:
0.1302 - val_accuracy: 0.9040 - val_loss: 0.7902
Epoch 5/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 130s 3s/step - accuracy: 0.9707 - loss:
0.0903 - val_accuracy: 0.9640 - val_loss: 0.1033
```

```
Epoch 6/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 118s 3s/step - accuracy: 0.9693 - loss:
0.0870 - val_accuracy: 0.9420 - val_loss: 0.5019
Epoch 7/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 143s 3s/step - accuracy: 0.9773 - loss:
0.0726 - val_accuracy: 0.9460 - val_loss: 0.2237
Epoch 8/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 142s 3s/step - accuracy: 0.9727 - loss:
0.0675 - val_accuracy: 0.8700 - val_loss: 0.5568
Epoch 9/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 121s 3s/step - accuracy: 0.9760 - loss:
0.0594 - val_accuracy: 0.9560 - val_loss: 0.1364
Epoch 10/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 119s 3s/step - accuracy: 0.9853 - loss:
0.0467 - val_accuracy: 0.9420 - val_loss: 0.1789
Epoch 11/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 119s 3s/step - accuracy: 0.9767 - loss:
0.0844 - val_accuracy: 0.8100 - val_loss: 1.1753
Epoch 12/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 118s 3s/step - accuracy: 0.9820 - loss:
0.0527 - val_accuracy: 0.8420 - val_loss: 0.5309
Epoch 13/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 142s 2s/step - accuracy: 0.9680 - loss:
0.1091 - val_accuracy: 0.5300 - val_loss: 6.5201
Epoch 14/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 118s 3s/step - accuracy: 0.9680 - loss:
0.0919 - val_accuracy: 0.9540 - val_loss: 0.2174
Epoch 15/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 118s 3s/step - accuracy: 0.9833 - loss:
0.0550 - val_accuracy: 0.9380 - val_loss: 0.3647
Epoch 15: early stopping
Restoring model weights from the end of the best epoch: 5.
Training finished for pretrained_frozen_xception_train_750. Loading
best model...
Best model loaded successfully.
Evaluating pretrained_frozen_xception_train_750 on test data...
Evaluation complete for pretrained_frozen_xception_train_750.
Phase 1 (Frozen Xception) Test Accuracy: 0.9720

Phase 2: Fine-tuning Xception...
Best frozen model loaded successfully for fine-tuning.
Xception backbone 'xception_backbone' unfrozen.
Batch normalization layers within the backbone frozen for fine-tuning.
Model recompiled for fine-tuning with low learning rate.

Model: "functional_23"

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━
━━━━━┓
┃ Layer (type)                     ┃ Output Shape           ┃
```

```
Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━
━━━━━┩
│ input_layer_10 (InputLayer)      │ (None, 180, 180, 3)     │
0 │
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ data_augmentation (Sequential)   │ (None, 180, 180, 3)     │
0 │
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ image_converter                  │ (None, 180, 180, 3)     │
0 │
│ (ImageConverter)                 │                         │
│
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ xception_backbone                │ (None, 6, 6, 2048)      │
20,861,480 │
│ (XceptionBackbone)               │                         │
│
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ global_average_pooling2d_4       │ (None, 2048)            │
0 │
│ (GlobalAveragePooling2D)         │                         │
│
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ dense_5 (Dense)                  │ (None, 256)             │
524,544 │
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ dropout_4 (Dropout)              │ (None, 256)             │
0 │
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ dense_6 (Dense)                  │ (None, 1)               │
257 │
└──────────────────────────────────┴─────────────────────────┴──────────
─────┘

 Total params: 21,386,281 (81.58 MB)

 Trainable params: 21,277,225 (81.17 MB)

 Non-trainable params: 109,056 (426.00 KB)

Starting training for pretrained_finetuned_xception_train_750...
Epoch 1/30
```

```
47/47 ━━━━━━━━━━━━━━━━━━━━ 77s 2s/step - accuracy: 0.9780 - loss:
0.0594 - val_accuracy: 0.9640 - val_loss: 0.0846
Epoch 2/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 73s 1s/step - accuracy: 0.9860 - loss:
0.0393 - val_accuracy: 0.9620 - val_loss: 0.0856
Epoch 3/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 69s 1s/step - accuracy: 0.9880 - loss:
0.0272 - val_accuracy: 0.9640 - val_loss: 0.0881
Epoch 4/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 115s 2s/step - accuracy: 0.9887 - loss:
0.0380 - val_accuracy: 0.9620 - val_loss: 0.0815
Epoch 5/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 82s 2s/step - accuracy: 0.9887 - loss:
0.0338 - val_accuracy: 0.9600 - val_loss: 0.0772
Epoch 6/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 69s 1s/step - accuracy: 0.9907 - loss:
0.0281 - val_accuracy: 0.9640 - val_loss: 0.0806
Epoch 7/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 69s 1s/step - accuracy: 0.9947 - loss:
0.0202 - val_accuracy: 0.9640 - val_loss: 0.0839
Epoch 8/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 82s 1s/step - accuracy: 0.9933 - loss:
0.0205 - val_accuracy: 0.9660 - val_loss: 0.0818
Epoch 9/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 68s 1s/step - accuracy: 0.9907 - loss:
0.0209 - val_accuracy: 0.9620 - val_loss: 0.0842
Epoch 10/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 69s 1s/step - accuracy: 0.9927 - loss:
0.0154 - val_accuracy: 0.9620 - val_loss: 0.0947
Epoch 11/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 69s 1s/step - accuracy: 0.9933 - loss:
0.0145 - val_accuracy: 0.9640 - val_loss: 0.0914
Epoch 12/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 68s 1s/step - accuracy: 0.9987 - loss:
0.0073 - val_accuracy: 0.9640 - val_loss: 0.0926
Epoch 13/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 98s 2s/step - accuracy: 0.9920 - loss:
0.0228 - val_accuracy: 0.9680 - val_loss: 0.0729
Epoch 14/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 69s 1s/step - accuracy: 0.9980 - loss:
0.0091 - val_accuracy: 0.9700 - val_loss: 0.0859
Epoch 15/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 82s 1s/step - accuracy: 0.9967 - loss:
0.0088 - val_accuracy: 0.9700 - val_loss: 0.0891
Epoch 16/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 69s 1s/step - accuracy: 0.9980 - loss:
0.0050 - val_accuracy: 0.9680 - val_loss: 0.0987
Epoch 17/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 82s 1s/step - accuracy: 0.9967 - loss:
```

```
0.0148 - val_accuracy: 0.9720 - val_loss: 0.0763
Epoch 18/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 68s 1s/step - accuracy: 1.0000 - loss:
0.0037 - val_accuracy: 0.9700 - val_loss: 0.0963
Epoch 19/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 69s 1s/step - accuracy: 0.9967 - loss:
0.0078 - val_accuracy: 0.9660 - val_loss: 0.1185
Epoch 20/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 69s 1s/step - accuracy: 0.9960 - loss:
0.0109 - val_accuracy: 0.9700 - val_loss: 0.0885
Epoch 21/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 69s 1s/step - accuracy: 0.9987 - loss:
0.0037 - val_accuracy: 0.9680 - val_loss: 0.0926
Epoch 22/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 69s 1s/step - accuracy: 0.9967 - loss:
0.0071 - val_accuracy: 0.9720 - val_loss: 0.0874
Epoch 23/30
47/47 ━━━━━━━━━━━━━━━━━━━━ 69s 1s/step - accuracy: 0.9967 - loss:
0.0066 - val_accuracy: 0.9740 - val_loss: 0.0977
Epoch 23: early stopping
Restoring model weights from the end of the best epoch: 13.
Training finished for pretrained_finetuned_xception_train_750. Loading
best model...
Best model loaded successfully.
Evaluating pretrained_finetuned_xception_train_750 on test data...
Evaluation complete for pretrained_finetuned_xception_train_750.
```



```
Final Results (Fine-tuned Xception, Train Size 1500): Test Accuracy =
0.9700

 Starting Pretrained Xception with 2000 samples
Using pretrained Xception model with an experimental set of 1000
samples per class
Found 2000 files belonging to 2 classes.
```

```
Building model for Phase 1 (Frozen Base)...

Model: "functional_33"

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━
━━━━━┓
┃ Layer (type)                     ┃ Output Shape            ┃
Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━
━━━━━┩
│ input_layer_15 (InputLayer)      │ (None, 180, 180, 3)     │
0 │
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ data_augmentation (Sequential)   │ (None, 180, 180, 3)     │
0 │
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ image_converter                  │ (None, 180, 180, 3)     │
0 │
│ (ImageConverter)                 │                         │
│
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ xception_backbone                │ (None, 6, 6, 2048)      │
20,861,480 │
│ (XceptionBackbone)               │                         │
│
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ global_average_pooling2d_5       │ (None, 2048)            │
0 │
│ (GlobalAveragePooling2D)         │                         │
│
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ dense_7 (Dense)                  │ (None, 256)             │
524,544 │
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ dropout_5 (Dropout)              │ (None, 256)             │
0 │
├──────────────────────────────────┼─────────────────────────┼──────────
─────┤
│ dense_8 (Dense)                  │ (None, 1)               │
257 │
└──────────────────────────────────┴─────────────────────────┴──────────
─────┘
```

```
 Total params: 21,386,281 (81.58 MB)

 Trainable params: 21,331,753 (81.37 MB)

 Non-trainable params: 54,528 (213.00 KB)


Phase 1: Training with frozen base...
Starting training for pretrained_frozen_xception_train_1000...
Epoch 1/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 205s 3s/step - accuracy: 0.8795 - loss:
0.2961 - val_accuracy: 0.6740 - val_loss: 4.8891
Epoch 2/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 171s 3s/step - accuracy: 0.9250 - loss:
0.2140 - val_accuracy: 0.8500 - val_loss: 1.7193
Epoch 3/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 223s 3s/step - accuracy: 0.9425 - loss:
0.1644 - val_accuracy: 0.9360 - val_loss: 0.2293
Epoch 4/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 160s 3s/step - accuracy: 0.9645 - loss:
0.0986 - val_accuracy: 0.8660 - val_loss: 0.8030
Epoch 5/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 207s 3s/step - accuracy: 0.9685 - loss:
0.0923 - val_accuracy: 0.9400 - val_loss: 0.2803
Epoch 6/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 159s 3s/step - accuracy: 0.9665 - loss:
0.0988 - val_accuracy: 0.9460 - val_loss: 0.2851
Epoch 7/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 164s 3s/step - accuracy: 0.9760 - loss:
0.0655 - val_accuracy: 0.9440 - val_loss: 0.3207
Epoch 8/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 195s 3s/step - accuracy: 0.9675 - loss:
0.0794 - val_accuracy: 0.9400 - val_loss: 0.2275
Epoch 9/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 178s 3s/step - accuracy: 0.9780 - loss:
0.0773 - val_accuracy: 0.9560 - val_loss: 0.1614
Epoch 10/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 177s 3s/step - accuracy: 0.9695 - loss:
0.0716 - val_accuracy: 0.9660 - val_loss: 0.1231
Epoch 11/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 166s 3s/step - accuracy: 0.9825 - loss:
0.0508 - val_accuracy: 0.9580 - val_loss: 0.1388
Epoch 12/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 201s 3s/step - accuracy: 0.9835 - loss:
0.0503 - val_accuracy: 0.9640 - val_loss: 0.1543
Epoch 13/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 166s 3s/step - accuracy: 0.9855 - loss:
0.0385 - val_accuracy: 0.9620 - val_loss: 0.2313
Epoch 14/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 165s 3s/step - accuracy: 0.9730 - loss:
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0.0729 - val_accuracy: 0.8920 - val_loss: 0.6263
Epoch 15/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 236s 3s/step - accuracy: 0.9800 - loss:
0.0654 - val_accuracy: 0.9660 - val_loss: 0.0997
Epoch 16/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 164s 3s/step - accuracy: 0.9910 - loss:
0.0391 - val_accuracy: 0.9620 - val_loss: 0.1069
Epoch 17/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 163s 3s/step - accuracy: 0.9865 - loss:
0.0362 - val_accuracy: 0.9540 - val_loss: 0.1516
Epoch 18/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 163s 3s/step - accuracy: 0.9815 - loss:
0.0602 - val_accuracy: 0.9680 - val_loss: 0.1236
Epoch 19/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 203s 3s/step - accuracy: 0.9850 - loss:
0.0401 - val_accuracy: 0.9580 - val_loss: 0.1033
Epoch 20/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 164s 3s/step - accuracy: 0.9895 - loss:
0.0369 - val_accuracy: 0.9220 - val_loss: 0.3902
Epoch 21/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 161s 3s/step - accuracy: 0.9905 - loss:
0.0348 - val_accuracy: 0.9520 - val_loss: 0.1986
Epoch 22/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 159s 3s/step - accuracy: 0.9890 - loss:
0.0259 - val_accuracy: 0.9220 - val_loss: 0.3595
Epoch 23/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 161s 3s/step - accuracy: 0.9910 - loss:
0.0297 - val_accuracy: 0.8940 - val_loss: 0.5220
Epoch 24/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 161s 3s/step - accuracy: 0.9860 - loss:
0.0427 - val_accuracy: 0.8120 - val_loss: 1.2303
Epoch 25/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 160s 3s/step - accuracy: 0.9855 - loss:
0.0502 - val_accuracy: 0.9500 - val_loss: 0.1928
Epoch 25: early stopping
Restoring model weights from the end of the best epoch: 15.
Training finished for pretrained_frozen_xception_train_1000. Loading
best model...
Best model loaded successfully.
Evaluating pretrained_frozen_xception_train_1000 on test data...
Evaluation complete for pretrained_frozen_xception_train_1000.
Phase 1 (Frozen Xception) Test Accuracy: 0.9600

Phase 2: Fine-tuning Xception...
Best frozen model loaded successfully for fine-tuning.
Xception backbone 'xception_backbone' unfrozen.
Batch normalization layers within the backbone frozen for fine-tuning.
Model recompiled for fine-tuning with low learning rate.

Model: "functional_33"
```
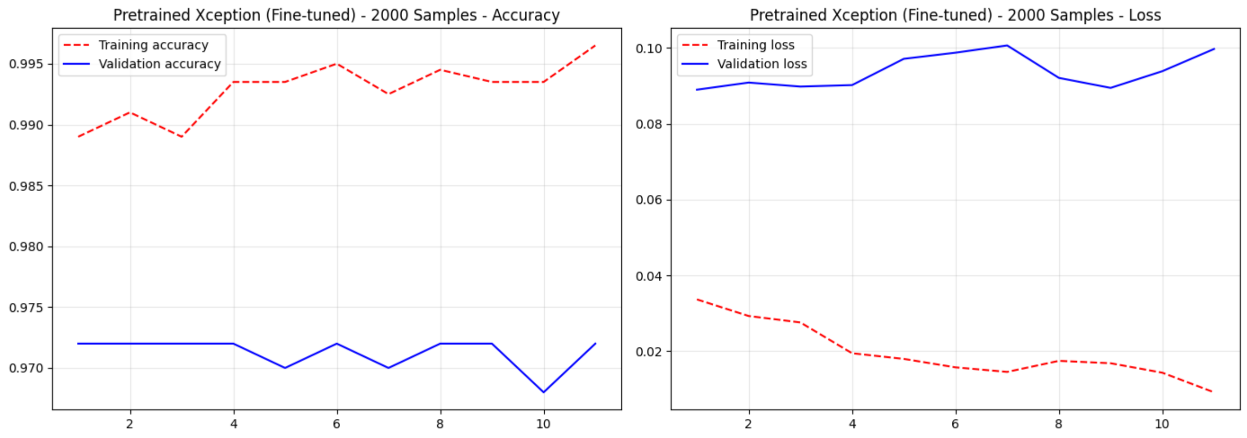

```
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━
━━━━━┓
┃ Layer (type)                     ┃ Output Shape           ┃
Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━
━━━━━┩
│ input_layer_15 (InputLayer)      │ (None, 180, 180, 3)    │
0 │
├──────────────────────────────────┼────────────────────────┼──────────
─────┤
│ data_augmentation (Sequential)   │ (None, 180, 180, 3)    │
0 │
├──────────────────────────────────┼────────────────────────┼──────────
─────┤
│ image_converter                  │ (None, 180, 180, 3)    │
0 │
│ (ImageConverter)                 │                        │
│
├──────────────────────────────────┼────────────────────────┼──────────
─────┤
│ xception_backbone                │ (None, 6, 6, 2048)     │
20,861,480 │
│ (XceptionBackbone)               │                        │
│
├──────────────────────────────────┼────────────────────────┼──────────
─────┤
│ global_average_pooling2d_5       │ (None, 2048)           │
0 │
│ (GlobalAveragePooling2D)         │                        │
│
├──────────────────────────────────┼────────────────────────┼──────────
─────┤
│ dense_7 (Dense)                  │ (None, 256)            │
524,544 │
├──────────────────────────────────┼────────────────────────┼──────────
─────┤
│ dropout_5 (Dropout)              │ (None, 256)            │
0 │
├──────────────────────────────────┼────────────────────────┼──────────
─────┤
│ dense_8 (Dense)                  │ (None, 1)              │
257 │
└──────────────────────────────────┴────────────────────────┴──────────
─────┘

 Total params: 21,386,281 (81.58 MB)

 Trainable params: 21,277,225 (81.17 MB)

 Non-trainable params: 109,056 (426.00 KB)
```

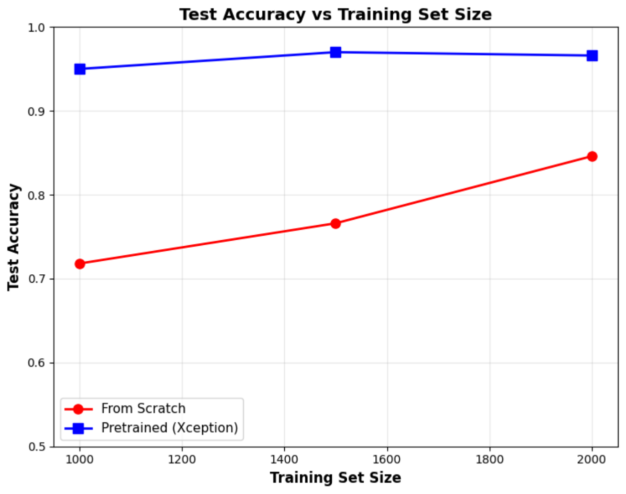
```
Starting training for pretrained_finetuned_xception_train_1000...
Epoch 1/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 104s 2s/step - accuracy: 0.9890 - loss:
0.0337 - val_accuracy: 0.9720 - val_loss: 0.0890
Epoch 2/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 94s 2s/step - accuracy: 0.9910 - loss:
0.0293 - val_accuracy: 0.9720 - val_loss: 0.0909
Epoch 3/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 95s 2s/step - accuracy: 0.9890 - loss:
0.0276 - val_accuracy: 0.9720 - val_loss: 0.0898
Epoch 4/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 94s 1s/step - accuracy: 0.9935 - loss:
0.0195 - val_accuracy: 0.9720 - val_loss: 0.0902
Epoch 5/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 94s 1s/step - accuracy: 0.9935 - loss:
0.0180 - val_accuracy: 0.9700 - val_loss: 0.0971
Epoch 6/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 94s 1s/step - accuracy: 0.9950 - loss:
0.0157 - val_accuracy: 0.9720 - val_loss: 0.0987
Epoch 7/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 94s 1s/step - accuracy: 0.9925 - loss:
0.0145 - val_accuracy: 0.9700 - val_loss: 0.1006
Epoch 8/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 92s 1s/step - accuracy: 0.9945 - loss:
0.0174 - val_accuracy: 0.9720 - val_loss: 0.0921
Epoch 9/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 93s 1s/step - accuracy: 0.9935 - loss:
0.0168 - val_accuracy: 0.9720 - val_loss: 0.0895
Epoch 10/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 93s 1s/step - accuracy: 0.9935 - loss:
0.0143 - val_accuracy: 0.9680 - val_loss: 0.0939
Epoch 11/30
63/63 ━━━━━━━━━━━━━━━━━━━━ 93s 1s/step - accuracy: 0.9965 - loss:
0.0092 - val_accuracy: 0.9720 - val_loss: 0.0997
Epoch 11: early stopping
Restoring model weights from the end of the best epoch: 1.
Training finished for pretrained_finetuned_xception_train_1000.
Loading best model...
Best model loaded successfully.
Evaluating pretrained_finetuned_xception_train_1000 on test data...
Evaluation complete for pretrained_finetuned_xception_train_1000.
```

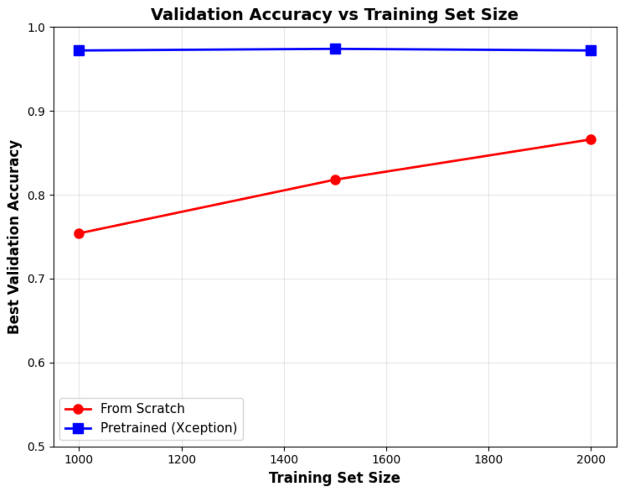


```
Final Results (Fine-tuned Xception, Train Size 2000): Test Accuracy =
0.9660

if 'scratch_results' not in locals() or not scratch_results:
    print("\nScratch results not found. Please run Part 1.")
    df_scratch = pd.DataFrame(columns=['train_size', 'val_accuracy',
'test_accuracy'])
else:
    df_scratch = pd.DataFrame(scratch_results)

if 'pretrained_results' not in locals() or not pretrained_results:
     print("Pretrained results not found. Please run Part 2.")
     df_pretrained = pd.DataFrame(columns=['train_size',
'val_accuracy', 'test_accuracy'])
else:
    df_pretrained = pd.DataFrame(pretrained_results)


print("\n  Scratch Results ")
print(df_scratch.to_string(index=False))

print("\nPretrained Model  Results ")
print(df_pretrained.to_string(index=False))


fig, axes = plt.subplots(1, 2, figsize=(15, 6))

# Plot 1: Test Accuracy vs Training Size
axes[0].plot(df_scratch['train_size'], df_scratch['test_accuracy'],
             'o-', label='From Scratch', linewidth=2, markersize=8,
color='red')
axes[0].plot(df_pretrained['train_size'],
df_pretrained['test_accuracy'],
             's-', label='Pretrained (Xception)', linewidth=2,
markersize=8, color='blue')
axes[0].set_xlabel('Training Set Size', fontsize=12,
fontweight='bold')
axes[0].set_ylabel('Test Accuracy', fontsize=12, fontweight='bold')
axes[0].set_title('Test Accuracy vs Training Set Size', fontsize=14,
fontweight='bold')
axes[0].legend(fontsize=11)
axes[0].grid(True, alpha=0.3)
axes[0].set_ylim([0.5, 1.0]) # Set y-axis from 50% to 100%

# Plot 2: Validation Accuracy vs Training Size
axes[1].plot(df_scratch['train_size'], df_scratch['val_accuracy'],
             'o-', label='From Scratch', linewidth=2, markersize=8,
color='red')
axes[1].plot(df_pretrained['train_size'],
df_pretrained['val_accuracy'],
             's-', label='Pretrained (Xception)', linewidth=2,
markersize=8, color='blue')
axes[1].set_xlabel('Training Set Size', fontsize=12,
fontweight='bold')
axes[1].set_ylabel('Best Validation Accuracy', fontsize=12,
fontweight='bold')
axes[1].set_title('Validation Accuracy vs Training Set Size',
fontsize=14, fontweight='bold')
axes[1].legend(fontsize=11)
axes[1].grid(True, alpha=0.3)
axes[1].set_ylim([0.5, 1.0])

plt.tight_layout()
plt.savefig('comparison_results_xception_500valtest.png', dpi=300)
plt.show()


comparison_df = pd.merge(
    df_scratch[['train_size',
'test_accuracy']].rename(columns={'test_accuracy': 'Scratch Test
Acc'}),
    df_pretrained[['train_size',
'test_accuracy']].rename(columns={'test_accuracy': 'Pretrained Test
Acc'}),
    on='train_size',
    how='outer'
)
comparison_df['Improvement'] = (comparison_df['Pretrained Test Acc'] -
comparison_df['Scratch Test Acc'])

print("\n--- Comparison Table (Test Accuracy) ---")
print(comparison_df.round(4).to_string(index=False)) #


best_scratch_acc = 0
best_scratch_size = 'N/A'
```

```
if not df_scratch.empty:
    best_scratch_idx = df_scratch['test_accuracy'].idxmax()
    best_scratch_acc = df_scratch.loc[best_scratch_idx,
'test_accuracy']
    best_scratch_size = df_scratch.loc[best_scratch_idx, 'train_size']

best_pretrained_acc = 0
best_pretrained_size = 'N/A'
if not df_pretrained.empty:
    best_pretrained_idx = df_pretrained['test_accuracy'].idxmax()
    best_pretrained_acc = df_pretrained.loc[best_pretrained_idx,
'test_accuracy']
    best_pretrained_size = df_pretrained.loc[best_pretrained_idx,
'train_size']



print("KEY FINDINGS / CONCLUSIONS (Based on this experiment)")

print(f"\nBest performance for training from scratch (among sizes
tested):")
print(f"  Training Size: {best_scratch_size}")
print(f"  Test Accuracy: {best_scratch_acc:.4f}")

print(f"\nBest performance for pretrained model (Xception, among sizes
tested):")
print(f"  Training Size: {best_pretrained_size}")
print(f"  Test Accuracy: {best_pretrained_acc:.4f}")
```

```
  Scratch Results
 train_size  val_accuracy  test_accuracy
       1000         0.754          0.718
       1500         0.818          0.766
       2000         0.866          0.846

Pretrained Model  Results
 train_size  val_accuracy  test_accuracy
       1000         0.972          0.950
       1500         0.974          0.970
       2000         0.972          0.966
```





```
--- Comparison Table (Test Accuracy) ---
 train_size  Scratch Test Acc  Pretrained Test Acc  Improvement
       1000             0.718                0.950        0.232
       1500             0.766                0.970        0.204
       2000             0.846                0.966        0.120
KEY FINDINGS / CONCLUSIONS (Based on this experiment)

Best performance for training from scratch (among sizes tested):
  Training Size: 2000
  Test Accuracy: 0.8460

Best performance for pretrained model (Xception, among sizes tested):
  Training Size: 1500
  Test Accuracy: 0.9700
```