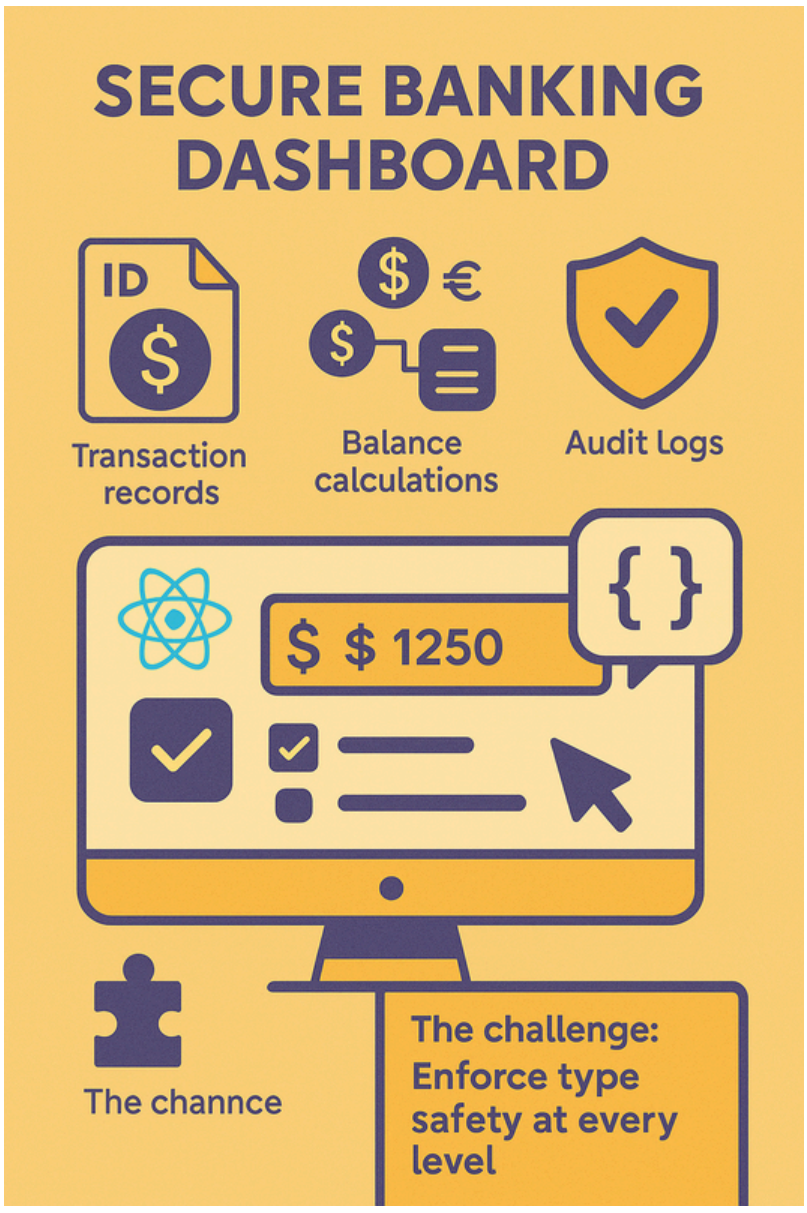
1. Problem Statement

Case Study: Secure Banking Dashboard

A financial institution is building a React dashboard to handle high-stakes transactions:

- Transaction records must have strictly typed properties (ID, amount, currency, timestamp).
- Balance calculations must prevent type mismatches (e.g., adding USD to EUR).
- Audit logs require immutable state with strict type checks to prevent tampering.
- A single type error could lead to financial discrepancies or regulatory violations.



The challenge:
How do you enforce **type safety at every level**—props, state, events, and API responses—while maintaining React's flexibility and developer productivity?

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2. Learning Objectives

By the end of this tutorial, you will:

- Define **type-safe props** using interfaces and type aliases.
- Implement **strictly typed state** in functional and class components.
- Handle complex state scenarios with `useState`, `useReducer`, and generics.
- Type class components with lifecycle methods and inherited props.

- Avoid common pitfalls like `any` types and implicit type coercion.

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3. Concept Introduction with Analogy

Analogy: The Bank's Type-Safe Vault System

Imagine a bank vault where:

- **Props** are deposit slips: They must specify exact currency, amount, and account numbers.
- **State** is the ledger: Every entry is validated against strict schemas before being recorded.
- **Class Components** are vault managers: They follow strict protocols (lifecycles) to handle transactions.
- **Functional Components** are tellers: Quick and efficient, but bound by the same type rules.

TypeScript in React is this vault system: It ensures every "transaction" (data flow) is validated against a precise contract.

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4. Technical Deep Dive

A. Props: Contracts for Component Input

1. Interfaces vs. Type Aliases

```tsx
// Interface: Extensible via declaration merging
interface TransactionProps {
  id: string;
  amount: number;
  currency: 'USD' | 'EUR' | 'GBP';
}

// Type Alias: Fixed structure, supports unions
type PaymentMethod = 'credit' | 'debit';
type PaymentProps = {
  method: PaymentMethod;
  fee: number;
};
```

- **Use interfaces** for public APIs (extendable).
- **Use type aliases** for unions/utilities.

2. Optional vs. Required Props

```tsx
interface UserProfileProps {
  name: string;
  age?: number; // Optional
}
```

- `age?: number` vs. `age: number | undefined` : The former allows omission.

3. Default Props

```tsx
// Functional Component
const Greeting: React.FC<{ message?: string }> = ({ message = 'Hello' }) => (
  <h1>{message}</h1>
);
```

```tsx
// Class Component
class Greeting extends React.Component<{ message?: string }> {
  static defaultProps = { message: 'Hello' };
  render() { return <h1>{this.props.message}</h1>; }
}
```

B. State: Typing Component Internal Data

1. `useState` with Type Inference

```tsx
const [balance, setBalance] = useState<number>(0); // Explicit
const [currency, setCurrency] = useState('USD');    // Inferred as string
```

2. Complex State with `useReducer`

```tsx
type TransactionAction =
  | { type: 'deposit'; amount: number }
  | { type: 'withdraw'; amount: number };

interface TransactionState {
  balance: number;
  history: Array<{ type: string; amount: number }>;
}

const reducer = (state: TransactionState, action: TransactionAction): TransactionState => {
  switch (action.type) {
    case 'deposit': return { ...state, balance: state.balance + action.amount };
    case 'withdraw': return { ...state, balance: state.balance - action.amount };
    default: return state;
  }
};
```

3. Immutable State Patterns

```tsx
// Use Readonly/ReadonlyArray to prevent mutations
interface AccountState {
  readonly transactions: ReadonlyArray<Transaction>;
}
```

C. Functional Components: Advanced Typing

```tsx
**1.  `React.FC`  vs. Explicit Return Types**

// Implicit return type (avoid unless simple)
const DepositButton: React.FC<{ onClick: () => void }> = ({ onClick }) => (
  <button onClick={onClick}>Deposit</button>
);

// Explicit return type (better for complex logic)
const WithdrawButton = ({ onClick }: { onClick: () => void }): JSX.Element => {
  return <button onClick={onClick}>Withdraw</button>;
};
```

2. Generics in Functional Components

```tsx
type CurrencyConverterProps<T extends string> = {
  currencies: T[];
  onConvert: (amount: number, from: T, to: T) => number;
};

const CurrencyConverter = <T extends string>({
  currencies,
  onConvert
}: CurrencyConverterProps<T>) => (
```

```
  // Component logic
);
```

D. Class Components: Full Type System Integration

1. Props and State Type Parameters

```
interface AccountProps {
  accountId: string;
}

interface AccountState {
  balance: number;
  isLocked: boolean;
}

class AccountManager extends React.Component<AccountProps, AccountState> {
  state: AccountState = { balance: 0, isLocked: false };
  // Lifecycle methods with type context
}
```

2. Typing Lifecycle Methods

```
componentDidUpdate(prevProps: AccountProps, prevState: AccountState) {
  if (this.props.accountId !== prevProps.accountId) {
    // Fetch new account data
  }
}
```

5. Step-by-Step Data Modeling & Code Walkthrough

A. Transaction List Component (Functional)

```
interface Transaction {
  id: string;
  amount: number;
  currency: 'USD' | 'EUR';
  date: Date;
}

interface TransactionListProps {
  transactions: Transaction[];
  onSelect: (id: string) => void;
}

const TransactionList: React.FC<TransactionListProps> = ({
  transactions,
  onSelect
}) => (
  <ul>
    {transactions.map(tx => (
      <li key={tx.id} onClick={() => onSelect(tx.id)}>
        {tx.amount} {tx.currency} - {tx.date.toLocaleDateString()}
      </li>
    ))}
  </ul>
);
```

B. Transaction Form (Class Component)

```
interface TransactionFormState {
  amount: string;
  currency: 'USD' | 'EUR';
}
```

```tsx
interface TransactionFormProps {
  onSubmit: (amount: number, currency: 'USD' | 'EUR') => void;
}

class TransactionForm extends React.Component<TransactionFormProps, TransactionFormState> {
  state: TransactionFormState = { amount: '', currency: 'USD' };

  handleSubmit = (e: React.FormEvent) => {
    e.preventDefault();
    this.props.onSubmit(Number(this.state.amount), this.state.currency);
  };

  render() {
    return (
      <form onSubmit={this.handleSubmit}>
        <input
          type="number"
          value={this.state.amount}
          onChange={e => this.setState({ amount: e.target.value })}
        />
        <select
          value={this.state.currency}
          onChange={e => this.setState({ currency: e.target.value as 'USD' | 'EUR' })}
        >
          <option value="USD">USD</option>
          <option value="EUR">EUR</option>
        </select>
        <button type="submit">Submit</button>
      </form>
    );
  }
}
```

6. Interactive Challenge / Mini-Project

Your Task:
Build a `BudgetTracker` component that:

- Tracks income and expenses in different currencies.
- Shows net balance in a selected currency.
- Uses `useReducer` for state management.
- Implements type-safe props for currency conversion rates.

Requirements:

1. Define interfaces for `IncomeEntry` and `ExpenseEntry`.
2. Create a reducer with `addIncome` and `addExpense` actions.
3. Prevent negative balances through type-safe checks.

7. Common Pitfalls & Best Practices

Pitfall	Best Practice
Using `any` for props/state	Always define explicit types
Optional props without defaults	Use `Required<T>` or `defaultProps`

Pitfall	Best Practice
Mutating state directly	Use read-only types and immutable updates
Ignoring type inference	Let TypeScript infer when possible
Complex unions without validation	Use `Zod` or `Yup` for runtime validation

8. Optional: Programmer's Workflow Checklist

- Define interfaces/types before writing components.
- Validate props with PropTypes or runtime checks.
- Use `Readonly<T>` for state immutability.
- Test type boundaries (e.g., max currency values).
- Audit type definitions with `tsc --noEmit`.